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EXPLORING THE MEANING OF PRACTICING CLASSROOM INQUIRY FROM
THE PERSPECTIVES OF NATIONAL BOARD CERTIFIED SCIENCE TEACHERS

By

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To my beloved children, Emre and Merve.
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TABLE OF CONTENTS

LIST OF TABLES.....	X
LIST OF FIGURES	XI
ABSTRACT	XII
CHAPTER 1.....	1
INTRODUCTION TO RESEARCH TOPIC	1
NATIONAL BOARD FOR PROFESSIONAL TEACHING STANDARDS.....	1
SCIENTIFICALLY LITERATE SOCIETY AND INQUIRY SCIENCE	3
NBPTS AND INQUIRY	6
PROBLEM STATEMENT	7
PURPOSE AND SIGNIFICANCE OF THE STUDY	10
RESEARCH QUESTIONS.....	10
SUMMARY	11
CHAPTER 2.....	13
LITERATURE REVIEW.....	13
INTRODUCTION.....	13
TEACHING AS A PROFESSION	13
TEACHER QUALITY AND PERFORMANCE ASSESSMENT.....	15
NEW GENERATION OF TEACHER CERTIFICATION	19
STANDARDS FOR ACCOMPLISHED SCIENCE TEACHERS.....	22
A CRITICAL LOOK	24
NBC AS PROFESSIONAL DEVELOPMENT ACTIVITY	27
<i>Research Studies on Teacher Learning from NBC.....</i>	<i>28</i>
SCIENCE AS A WAY OF KNOWING	31
SCIENTIFIC LITERACY	33
INQUIRY AS DOING AND TEACHING SCIENCE.....	35
<i>Inquiry as Doing Science.....</i>	<i>36</i>
<i>Inquiry as Teaching Science.....</i>	<i>39</i>
<i>Levels of Inquiry Teaching.....</i>	<i>42</i>
<i>Personal Definition of Classroom Inquiry.....</i>	<i>45</i>
A QUEST FOR QUESTIONING IN INQUIRY	45
TEACHERS AND INQUIRY SCIENCE TEACHING	46
<i>Challenges of Teachers with Inquiry Science Teaching.....</i>	<i>49</i>
<i>Need for More Research on Teachers' Conceptions and Enactment of Inquiry.....</i>	<i>51</i>
SUMMARY	52
CHAPTER 3.....	54
RESEARCH PERSPECTIVE	54
INTRODUCTION.....	54
THE INTEGRAL VISION	55
MEANINGFUL CONSTRUCTIONS.....	57
<i>Understanding Meaningful Constructions.....</i>	<i>60</i>

HERMENEUTIC DIALECTIC CIRCLE	62
NATURALISTIC (CONSTRUCTIVIST) INQUIRY	67
RESEARCH SETTINGS AND DATA COLLECTION METHODS	71
<i>Classroom Observations, In-Depth Interviews, and Document Analyses</i>	73
ANALYSIS OF QUALITATIVE DATA.....	79
QUALITY CRITERIA.....	82
<i>Credibility</i>	83
<i>Transferability</i>	86
<i>Dependability</i>	86
<i>Confirmability</i>	86
<i>Fairness</i>	87
<i>Ontological Authenticity</i>	87
<i>Educative Authenticity</i>	88
RESEARCH ETHICS	88
CHAPTER 4.....	89
ENTERING INTO THE CONTEXT OF NBCSTs.....	89
INTRODUCTION.....	89
PERSONAL AND CONTEXTUAL INFORMATION ABOUT JENNIFER	89
<i>Jennifer's Classroom Context</i>	91
<i>Becoming a NBCST</i>	92
<i>Views on Teaching and Learning Science</i>	93
PERSONAL AND CONTEXTUAL INFORMATION ABOUT PATRICIA.....	96
<i>Patricia's Classroom Context</i>	97
<i>Becoming a NBCST</i>	98
<i>Views on Teaching and Learning Science</i>	99
PERSONAL AND CONTEXTUAL INFORMATION ABOUT MARTHA	102
<i>Martha's Classroom Context</i>	103
<i>Becoming a NBCST</i>	104
<i>Views on Teaching and Learning Science</i>	105
PERSONAL AND CONTEXTUAL INFORMATION ABOUT MARY	107
<i>Mary's Classroom Context</i>	108
<i>Becoming a NBCST</i>	109
<i>Views on Teaching and Learning Science</i>	111
COMPARATIVE OVERVIEW	113
CHAPTER 5.....	115
NBC AS PROFESSIONAL DEVELOPMENT EXPERIENCE	115
INTRODUCTION.....	115
AFFIRMATIONAL ROLE OF NBC IN PROFESSIONAL DEVELOPMENT OF TEACHERS	116
<i>Jennifer</i>	118
<i>Patricia</i>	122
<i>Martha</i>	124
<i>Mary</i>	128
<i>Comparative Overview</i>	134
LEARNING EXPERIENCES FROM NBC ASSESSMENT PROCESS	139
<i>Jennifer</i>	140
<i>Patricia</i>	143
<i>Martha</i>	145
<i>Mary</i>	146
<i>Comparative Overview</i>	148

CHAPTER 6.....	152
IMAGES OF CLASSROOM INQUIRY REPRESENTED IN THE MINDS OF NBCSTs.....	152
INTRODUCTION.....	152
INQUIRY PRACTICED BY SCIENTISTS AND BY STUDENTS.....	153
<i>Scientific Inquiry</i>	155
Jennifer	155
Patricia	157
Martha	158
Mary.....	160
Summary	161
<i>Classroom Inquiry</i>	162
Jennifer	163
Patricia	164
Martha	165
Mary.....	166
<i>Comparative Overview</i>	166
SCIENTIFIC METHOD AND CLASSROOM INQUIRY	170
Jennifer	171
Patricia	173
Martha	174
Mary.....	176
<i>Comparative Overview</i>	177
STUDENT INQUIRY IN CLASSROOM.....	180
Jennifer	181
Patricia	182
Martha	184
Mary.....	186
<i>Comparative Overview</i>	188
CONFIRMATORY SCIENCE VERSUS INQUIRY SCIENCE.....	189
Jennifer	190
Patricia	192
Martha	195
Mary.....	197
<i>Comparative Overview</i>	199
CHAPTER 7.....	203
INTENTIONS AND CHALLENGES OF NBCSTs WITH PRACTICING INQUIRY	203
INTRODUCTION.....	203
EDUCATIONAL GOALS WITH PRACTICING INQUIRY	203
<i>Teachers' Intentions with Practicing Inquiry</i>	206
Jennifer	206
Patricia	208
Martha	210
Mary.....	212
Summary	213
<i>Educating Scientifically Literate Students</i>	214
Jennifer	216
Patricia	217
Martha	219
Mary.....	220
<i>Comparative Overview</i>	221

CHALLENGES WITH ENACTING INQUIRY	224
<i>Jennifer</i>	226
<i>Patricia</i>	228
<i>Martha</i>	231
<i>Mary</i>	233
<i>Comparative Overview</i>	235
CHAPTER 8.....	240
INQUIRY-ORIENTED TEACHING PRACTICES OF NBCSTs	240
INTRODUCTION.....	240
INQUIRY TEACHING IN ACTION.....	241
<i>Jennifer</i>	242
<i>Patricia</i>	247
<i>Martha</i>	251
<i>Mary</i>	255
<i>Comparative Overview</i>	258
STIR ANALYSIS OF INQUIRY TEACHING PRACTICES OF NBCSTs.....	265
CHAPTER 9.....	271
DISCUSSION, CONCLUSIONS AND IMPLICATIONS.....	271
INTRODUCTION.....	271
THE ROLE OF NBC IN PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS.....	272
INQUIRY CONCEPTIONS OF THE TEACHERS.....	277
<i>Inquiry Conceptions Driven by Scientific Rationales</i>	278
<i>Inquiry Conceptions Driven by Constructivist Rationales</i>	289
EDUCATIONAL GOALS WITH CLASSROOM INQUIRY.....	294
CHALLENGES PRESENTED BY CLASSROOM INQUIRY	298
IMPLICATIONS OF THE STUDY	301
LIMITATIONS OF THE STUDY	304
APPENDIX A	306
APPENDIX B	309
APPENDIX C	313
APPENDIX D	315
APPENDIX E	320
REFERENCES.....	322
BIOGRAPHICAL SKETCH	345

LIST OF TABLES

TABLE 1 DATA SOURCES AND CORRESPONDING RESEARCH QUESTIONS.....	73
TABLE 2 EARLY ADOLESCENCE SCIENCE PORTFOLIO (PATRICIA, MARTHA, AND MARY).....	78
TABLE 3 ADOLESCENCE AND YOUNG ADULTHOOD SCIENCE PORTFOLIO (JENNIFER)	78
TABLE 4 INFORMATION ABOUT JENNIFER'S HIGH SCHOOL	91
TABLE 5 INFORMATION ABOUT PATRICIA'S MIDDLE SCHOOL.....	97
TABLE 6 INFORMATION ABOUT MARTHA'S AND MARY'S MIDDLE SCHOOL	103
TABLE 7 AT FIRST GLANCE: NBC AS A PROFESSIONAL DEVELOPMENT EXPERIENCE	117
TABLE 8 AT FIRST GLANCE: LEARNING EXPERIENCES FROM NBC.....	140
TABLE 9 AT FIRST GLANCE: INQUIRY IN SCIENCE AND IN CLASSROOM	154
TABLE 10 IMMEDIATE TEACHER RESPONSES.....	168
TABLE 11 AT FIRST GLANCE: VIEWS OF SCIENTIFIC METHOD	171
TABLE 12 AT FIRST GLANCE: CONCEPTIONS OF STUDENT INQUIRY.....	180
TABLE 13 AT FIRST GLANCE: PERSPECTIVES ON CONFIRMATORY AND INQUIRY SCIENCE	190
TABLE 14 AT FIRST GLANCE: INTENTIONS WITH INQUIRY AND DESCRIPTION OF SCIENTIFIC LITERACY	205
TABLE 15 AT FIRST GLANCE: HURDLES WITH PRACTICING INQUIRY	226
TABLE 16 STIR ANALYSES OF CLASSROOM INQUIRY.....	265

LIST OF FIGURES

FIGURE 1 GENERAL DISPLAY OF RESEARCH PERSPECTIVE.....	55
FIGURE 2 THE INTEGRAL VISION-FOUR QUADRANT MODEL (KEN WILBER)	56
FIGURE 3 THE HERMENEUTIC DIALECTIC CIRCLE (GUBA & LINCOLN, 1989)	65
FIGURE 4 THE FLOW OF NATURALISTIC INQUIRY (LINCOLN & GUBA, 1985).....	68
FIGURE 5 SAMPLE VIEW OF DATA CODING PROCESS	80
FIGURE 6 REPRESENTATIVE TERMS OF CLASSROOM INQUIRY	214
FIGURE 7 INQUIRY TEACHING PERFORMANCES OF NBCSTs	260
FIGURE 8 EXPANDED VIEW OF CLASSROOM INQUIRY.....	288
FIGURE 9 ALTERNATIVE MODES OF TEACHING SCIENCE	294

ABSTRACT

Inquiry has been one of the most prominent terms of the contemporary science education reform movement (Buck, Latta, & Leslie-Pelecky, 2007; Colburn, 2006; Settlage, 2007). Practicing classroom inquiry has maintained its central position in science education for several decades because science education reform documents promote classroom inquiry as the potential savior of science education from its current problems. Likewise, having the capabilities of teaching science through inquiry has been considered by National Board for Professional Teaching Standards [NBPTS] as one of the essential elements of being an accomplished science teacher. Successful completion of National Board Certification [NBC] assessment process involves presenting a clear evidence of enacting inquiry with students. Despite the high-profile of the word inquiry in the reform documents, the same is not true in schools (Crawford, 2007). Most of the science teachers do not embrace this type of approach in their everyday teaching practices of science (Johnson, 2006; Luera, Moyer, & Everett, 2005; Smolleck, Zembal-Saul, & Yoder, 2006; Trumbull, Scarano, & Bonney, 2006). And the specific meanings attributed to inquiry by science teachers do not necessarily match with the original intentions of science education reform documents (Matson & Parsons, 2006; Wheeler, 2000; Windschitl, 2003). Unveiling the various meanings held by science teachers is important in developing better strategies for the future success of science education reform efforts (Jones & Eick, 2007; Keys & Bryan, 2001). Due to the potential influences of National Board Certified Science Teachers [NBCSTs] on inexperienced science teachers as their mentors, examining inquiry conceptions of NBCSTs is called for. How do these accomplished practitioners understand and enact inquiry?

The purpose of this dissertation research study was twofold. First, it investigated the role of NBC performance assessment process on the professional development of science teachers. Second, it examined the meaning of practicing classroom inquiry for National Board Certified Science Teachers [NBCSTs]. Based on the specific cases of four NBCSTs, this naturalistic inquiry study was conducted to answer to those questions

with the involvement of the following qualitative data sources: classroom observations, in-depth teacher interviews, and document analyses of teacher portfolios.

The specific cases in this study indicated that undergoing the performance assessment process of NBC played an affirmational role for National Board Certified Science Teachers [NBCSTs] in their professional development. Their successful completion of the portfolio assessment process created a sharpened confidence into their existing notions and ways of teaching science. In the study, not all teachers were equally open to science education reform ideas. This meant that NBC experience strengthened the conventional notions of teaching science held by some teachers rather than generating a higher affiliation with the reform ideas. The teacher cases presented in this study denoted that teachers' conceptions of classroom inquiry were driven both by scientific and constructivist rationales. However, NBCSTs failed to create broader operational definitions of classroom inquiry. They tended to reduce the meaning of classroom inquiry into empirical investigations of students. The conventional representation of the scientific method as a stepwise linear process influenced teachers' understandings and practices of classroom inquiry. NBCSTs used inquiry in their classrooms to introduce their students to the cognitive processes and the actions of practicing scientists but not necessarily to teach scientific principles. Their reluctance to teach scientific principles through inquiry developed in parallel to their tendency of associating classroom inquiry with the highest levels of student autonomy. Participant teachers' particular understandings of scientific literacy produced a tension between embracing inquiry more in their teaching practices of science and educating scientifically literate students. The teachers in the study attributed the hurdles that kept them from using more inquiry with their students to external factors. In the final chapter of the dissertation study, these findings were discussed in connection with the education literature.

CHAPTER 1

INTRODUCTION TO RESEARCH TOPIC

National Board for Professional Teaching Standards

Educational reform is not an unfamiliar concept for Americans. Throughout the last century, reform movements have emerged periodically in order to improve students' academic performances (Pool, Ellett, Schiavone, & Carey-Lewis, 2001). Many efforts focused primarily on altering school characteristics with an expectation of better student achievement (Hallinan & Khmelkov, 2001), but with little success (National Commission on Teaching and America's Future [NCTAF], 1997). Relying on a growing body of educational research that underlines the critical importance of the quality of teachers on student learning, in the mid-80s reform agendas shifted from improving schools to enhancing teacher quality (Hallinan & Khmelkov, 2001). While many variables contribute to student success, teacher quality and quality of teaching are commonly agreed upon as the most important factors (Committee on Science and Mathematics Teacher Preparation, 2001; Darling-Hammond, 1999c; Haycock, 1998; Goldhaber & Anthony, 2003; NCTAF, 1996, 1997; Pool et al., 2001; Sanders & Rivers, 1996). The National Commission on Teaching and America's Future (1996) phrased this reality as "what teachers know and do is the most important influence on what students learn" (p.6).

Particularly for the last two decades, educational initiatives periodically call public attention to American educational system's failure to educate world class students. In 1983, the publication of *A Nation at Risk: The Imperative for Educational Reform* by National Commission on Excellence in Education alerted the nation about the worsening status of American educational system and triggered standards-based reform efforts in order to improve student success. In 1986, two national reports, *A Nation Prepared: Teachers for the 21st Century* by Carnegie Task Force on Teaching as

a Profession and *Tomorrow's Teachers* by Holmes Group, argued for the necessity of transforming teaching into a profession of well-educated teachers and creating a career ladder for teachers that distinguishes and rewards accomplished teaching (Hallinan & Khmelkov, 2001; Johnson, 1987). In order to improve the professional status of teaching, Carnegie Task Force on Teaching as a Profession (1986) called for the establishment of a National Board for Professional Teaching Standards by modeling other professions like medicine, architecture, law, accounting etc. whose professional standards boards already serve to create standards to increase the professional quality of their members (Darling-Hammond, 2001). The following year led to the birth of National Board for Professional Teaching Standards [NBPTS] with a mission to “establish high and rigorous standards for what accomplished teachers should know and be able to do, and to develop and operate a national, voluntary system to assess and certify teachers who meet these standards” (NBPTS, 1989, p.1).

Whereas few people can argue about the critical role of quality teachers on student learning, there exists very little consensus on how to define and to measure teacher quality (Delandshere & Petrosky, 2004; Goldhaber & Anthony, 2003; National Center for Education Statistics [NCES], 1999). Latest standards-based teacher education reform movements like Interstate New Teacher Assessment and Support Consortium [INTASC] and National Board for Professional Teaching Standards [NBPTS] revealed their version of teacher quality by creating their respective teaching standards for beginner and experienced teachers. These clarify the qualifications of quality teachers at entry and advanced level (Delandshere & Arens, 2001). In order to get licensed and certified, beginner and experienced teachers' written portfolios, which reflect their teaching performances, are evaluated based on how aligned their teaching practices are with these standards (Burroughs, Schwartz & Hendricks-Lee, 2000). Together with National Council for Accreditation of Teacher Education [NCATE], these standards for teacher education accreditation (NCATE), initial licensing (INTASC) and advanced certification (NBPTS) constitute a “three-legged stool” (NCTAF, 1996, p.29) which maintains “quality assurance” (Darling-Hammond, 2001, p.13) in the teaching profession. In this research study, my focus will be on the last leg of stool, which is National Board for Professional Teaching Standards [NBPTS].

Scientifically Literate Society and Inquiry Science

For the last two decades, like the education field in general, science education is undergoing a process of change (Radford, 1998; van Driel, Beijaard, & Verloop, 2001). With a major influence of the publication of *A Nation at Risk: The Imperative for Educational Reform*, latest reform efforts in science education center on scientific literacy (Bianchini & Kelly, 2003; Buxton, 2001; Parsons, Matson, & Quintanar, 2002). In the document of *A Nation at Risk* (1983), the following statement by Paul Hurd alarmed the education community for the failure of the American education system in preparing students with the knowledge of scientific ideas and the capabilities of using scientific reasoning processes: “We are raising a new generation of Americans that is scientifically and technologically illiterate” (Indicators of the Risk, ¶ 1). The goal of educating scientifically literate citizens is crucially important for the better functioning of the democratic system because the future of the society relies heavily on its members who have the abilities to make informed decisions on critical societal issues. However, achieving that goal requires alternative teaching methods in science because conventional teaching methods do not seem to produce satisfactory results in student learning (National Commission on Mathematics and Science Teaching for the 21st Century, 2000). Even talented students exposed to good science instruction learn less than what we can imagine (Nelson, 1999). Far from assisting, traditional methods of science instruction even “impede progress toward science literacy” (American Association for the Advancement of Science [AAAS], 1990). Science instruction, in most of the American schools, stresses “the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understandings in context, recitation over argument, reading in lieu of doing” (AAAS, 1990). Traditional science instruction “overburden[s] students with the mastery of facts and technical terminology at the expense of having them actively doing science” (NBPTS, 2003b, p.2). Hence, traditional science instruction fails to introduce the students to essence of the scientific knowledge and tenets of the scientific method of investigation. According to National Commission on Mathematics and Science Teaching for the 21st Century (2000), “students’ grasp of science as a process of discovery...is often formulaic, fragile, or absent altogether” (p.10). Kennedy (1998) stated, “If students

learn only through lectures, even if the lectures are as clear and compelling as Feynman's, they might erroneously perceive science as a subject that is finished and undisputed rather than in process and contentious" (p.258). However, National Research Council [NRC] (1996) explicitly emphasized the importance of students' "understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture" (p.2).

Most science teachers are no different than students when it comes to their learning in science. Likewise, most of their learning experiences are based on scientific facts imposed by an external source. They experience science in their undergraduate classes as "a rigid body of facts, theories, and rules to be memorized and practiced, rather than a way of knowing about natural phenomena" (van Driel et al., 2001, p. 138). In most science classes, teacher candidates are taught "what science knows" (p.24) but they are not usually introduced to "what science is really all about" (Johnston, 2000, p.24). Hence, most science teachers as products of the traditional education system are not accustomed to ways of learning based on their own reasoning and conclusions. They, in turn, teach in the way they were taught (McDermott, Shaffer, & Constantinou, 2000; Pinar, Reynolds, Slattery, & Taubman, 2000).

For the last two decades, our understanding of how people learn has improved considerably (Northwest Regional Educational Laboratory [NWREL], 1997, 1999). With new understandings of how learning takes place, constructivist teaching methods have flourished as alternative to traditional methods of teaching. In that respect, national organizations like AAAS (1993) and NRC (1996) promote inquiry-based instruction as "the central strategy for teaching science" (NRC, 1996, p.31) through a slogan "learning science is something that students do, not something that is done to them" (NRC, 1996, p.20). These two national organizations envision a scientifically literate society, and learning science through inquiry constitutes the essence of achieving that vision (AAAS, 1993; Britner & Finson, 2005; NRC, 1996). According to these organizations, understanding the essence of scientific inquiry occupies the central element of scientific literacy. It is intuitive that one needs to experience the process of scientific investigation in order to be able to learn the essence of scientific inquiry (McDermott et al., 2000).

Chapman (2000) expressed the necessity of students' own engagement with science activities through the following analogy:

Learning science is like losing weight. You can hire a coach to instruct you, you can read books about it, and you can get lots of free advice on how to do it, but in the end you must do it. To learn science, students must do science. (p.98)

By engaging in authentic science inquiries, without knowing the learning outcomes beforehand, students are expected to choose their own questions to inquire, design their own investigations, collect their own evidence, and reach their own conclusions, which clearly opposes very traditional images of science instruction (Horizon Research, 2003).

However, despite many efforts and good intentions, inquiry science is still not a widespread method of science teaching in most of the American classrooms (Crawford, 2007; Horizon Research, 2003; Polman & Pea, 2001; Smolleck, Zembal-Saul, & Yoder, 2006; Tobin, Tippins, & Gallard, 1994). Science teachers do not seem to incorporate this type of teaching in their practices. Even if they adopt the general tenets of the reform documents, most of them "tend to incorporate standards-based ideas piecemeal, often using some reform strategies and activities but not doing so consistently or coherently" (Horizon Research, 2003, p.104). One might find several reasons in the literature for why this is the case. It is a widely accepted fact that teachers resist fundamental changes in their beliefs of their teaching philosophies (Horizon Research, 2003; Polman & Pea, 2001). However, teaching by inquiry requires teachers to adopt a new way of thinking in their teaching which is quite different from what they are used to (Bodzin & Beerer, 2003; Levitt, 2001; van Driel et al., 2001). In addition, inquiry science invites unpredictability of what is next into teaching because the learning process is mostly shaped by students (Keys & Kennedy, 1999). Inadequate education, prior commitments, parent involvement, lack of understanding of inquiry etc. might further be listed as a few of the reasons that teachers do not use inquiry (Anderson, 2002; Barrow, 2006; Furtak, 2006). It is imperative for science education community to understand the dynamics of teachers' ideas and practices in science inquiry in order to be able to foster the implementation of this type of science teaching in a more widespread sense.

NBPTS and Inquiry

Quality teachers with exceptional teaching practices make the biggest difference in student learning (NCTAF, 1996; Wenglinsky, 2000). NBPTS emphasizes classroom inquiry by considering it one of the most effective methods of science instruction. According to NBPTS (2003b), accomplished science “teachers organize their classrooms around frequent, open-ended investigations of natural phenomena in which students initiate the pursuit of knowledge” (p.40). Science teachers, who pursue the portfolio assessment process of NBC, are expected to present clear evidence of their practice of inquiry with their students. They present their enactment of inquiry with a videotape and written reflections on their inquiry teaching practices. Successful completion of NBC assessment process indicates that those teachers have the professional capabilities of using inquiry teaching strategies with their students. Investigating the perspectives of experienced teachers with the capabilities of implementing inquiry promises a big potential for the future success of science education reform efforts because inquiry is one of the central dynamics of science education reform. National Board Certified Science Teachers [NBCSTs] might play crucial roles in bringing the ideals of science education reform into reality. NBPTS (2006) expects science teachers with advanced teaching certificates to mentor more inexperienced teachers in their schools. Although passing the performance assessment of NBC might be considered as an indication of the capabilities of quality science teaching, having these capabilities does not explain by itself the specific meanings attributed to practicing classroom inquiry by NBCSTs. Especially if we consider the possible influences of those experienced science teachers on their novice colleagues as their mentors, scrutinizing NBCSTs’ notions and practices of classroom inquiry becomes more crucial. NBCSTs’ understanding of and intentions with practicing inquiry in connection to the ideas promoted in science education reform documents require a closer examination by science education community. This dissertation study aims to uncover the inquiry conceptions of those experienced science teachers.

Problem Statement

With all the money¹ and the efforts spent on NBC, this new generation of teacher assessment is gaining more recognition by larger education community (Darling-Hammond, 2001). Aside from being a teacher assessment procedure to distinguish accomplished teachers with exceptional teaching practices, NBPTS (2003a) described the certification process as “a challenging but deeply rewarding experience that provides rich professional development benefits and expanded opportunities for teacher leadership” (p.5). Even teachers who fail the assessment process of National Board Certification [NBC] agree on the value of their learning from their certification experiences (Vandevoort, Amrein-Beardsley, & Berliner, 2004). Some of the studies that focused on teachers’ perspectives with NBC confirm this. For example, according to a survey research study conducted by NBPTS (2001a), 96% of the teachers rated the certification process as an excellent (39%), very good (36%) and good (21%) professional development experience. Of the respondent teachers, 92% agreed that NBC process made them a better teacher. According to another survey research by NBPTS (2001b), 80% of teachers found NBC process better than any other professional development experiences and 91% responded that it affected their teaching positively. In another survey study, 78% of teachers conducted by the Center for the Future of Teaching and Learning (2002) responded that the certification experience strengthened their teaching. However, the expressions that teachers used in most of these studies in order to identify their learning experiences do not go beyond some broad statements like “I learned so much through hours of analyzing and reflecting” (NBPTS, 2001a, p.4), “The certification process...directly affected the way I think about my teaching” (NBPTS, 2001b, p.4), “I grew significantly as a teacher” (NBPTS, 2001a, p.5). Becoming “more reflective about one’s teaching” seems to be a common theme arising from teachers’ comments on their experiences with the certification process.

While these insights emphasize the value of the certification experience, they essentially tell us very little in terms of our understanding of teachers’ learning (Lustick, 2002). Although “there is substantial testimony that teachers learn a great deal by

¹ By September 2006, federal funds of \$159 million (34 percent) and non-federal funds of \$278 million (66 percent) were released for NBC project.

participating in these assessments, we do not know exactly what kind of learning takes place, under what circumstances, and how it can be harnessed to the cause of sustained professional development and widespread improvements in teaching” (Darling-Hammond, 1999a, pp. 36–37). However, the literature seems to be insufficient in presenting the place of NBC in the professional development of teachers. It would be a necessary step to explore more deeply NBCSTs’ perceptions of their learning experiences with NBC. Some scholars (e.g. Goldhaber, Perry, & Anthony, 2003; Keiffer-Barone, Mulvaney, Hillman, & Parker, 1999) implied the necessity for more research studies that examine teachers’ learning experiences with NBC by pointing out relatively few numbers of studies conducted on this area. With science teachers specifically, there is less likelihood of finding a study that investigates their NBC learning experiences. Most of the existing studies inquired into teacher learning in a more general sense by focusing on teachers who completed NBC in any subject area. Few, if any, studies looked at teacher learning with respect to subject-specific focus. For example, because science teachers specifically need to present clear evidence of inquiry-based science in their practices, their engagement with inquiry science teaching is unique. Thus, studies which focus on specific subjects might help us better understand teachers’ subject-specific learning experiences with the certification process. Furthermore, the relatively few studies conducted on the impact of NBC are criticized for being biased due to having a connection with NBPTS (Goldhaber et al., 2003). Therefore, NBPTS encourages independent researchers to study the topic because they need more evaluative evidence, particularly from independent sources.

While teaching by inquiry is a very desirable goal to achieve for science education community, researchers agree that embracing and performing such teaching is a complex process (Crawford, 2000; Flick, 2000; Fradd & Lee, 1999; Keys & Bryan, 2001; Minstrell & van Zee, 2000). Because inquiry is a broadly defined concept in science education (Brown, Abell, Demir, & Schmidt, 2006; Windschitl, 2003), actual classroom implementation of inquiry is mostly shaped by teachers’ own understanding of the inquiry process. Although NRC (1996, 2000) furnished several examples of inquiry-oriented science instruction, these examples do not offer systematic directions for teachers to follow in order to teach science through inquiry (Abd-el-Khalick, 2004;

Anderson, 2002; Bodzin & Beerer, 2003; Keys & Bryan, 2001; Windschitl, 2004). In a sense, teachers are left to translate their own understandings of inquiry to satisfy the specific needs of their local classroom situations. Keys and Kennedy (1999) expressed:

These types of broad definitions of inquiry provide little guidance for the actual planning, teaching, and evaluation of inquiry in the science classroom. In particular, they lack any description of teacher beliefs, thinking, decision making, action, or reflection during the planning and teaching of inquiry. (p.315)

By considering the broad nature of teachers' understanding of inquiry science, it is natural to expect to see different enactments of inquiry teaching in diverse classrooms. As current literature suggests, teachers do not have an easy set of steps to follow in order to implement inquiry in their classrooms. So they need to translate these broad definitions of inquiry into their own classroom situations. This creates diverse ways of understanding and implementing inquiry. Although teaching science through inquiry is almost a century long ideal, which was implied by Dewey (1910) and coined by Schwab (1962), our understanding of teachers' conceptions of and experiences with this type of teaching is still in its early developmental process (Barrow, 2006). Keys and Bryan (2001) noted, "We have little knowledge of teachers' views about the goals and purposes of inquiry, the processes by which they carry it out, or their motivation for undertaking a more complex and often difficult to manage form of instruction" (p.636). Windschitl (2004) expressed, "Despite the ubiquity of the term 'inquiry' in science education literature, little is known about how teachers conceptualize inquiry, how these conceptions are formed and reinforced,..., and if these ideas about inquiry are translated into classroom practice" (p.481). In order to gain better understanding of how inquiry is conceptualized and how these conceptions are projected into actual classroom environments, we clearly need more research on teachers' experiences with inquiry science teaching (Keys & Bryan, 2001; Keys & Kennedy, 1999; Songer et al., 2003). We need "the painting of portraits of inquiry-in-action in a variety of diverse settings" (Keys & Bryan, 2001, p.637). By considering the experiences of NBCSTs with inquiry science before, during and after NBC process, they can provide a rich picture for us to understand the dynamics of teachers' conceptions and actions of inquiry teaching.

Purpose and Significance of the Study

As the numbers of teachers who are granted NBC grows each year, the phenomenon of NBC is getting to occupy a more important place in the education system. Much time and money has been spent on NBC with an expectation of having more quality teachers in American schools (Kelley & Kimball, 2001). However, the field is somewhat uninformed in terms of how NBC serves as a professional development experience for teachers, especially what teachers learn from their certification experiences and how they benefit from what they learn. This naturalistic research study, in a most general sense, focuses on the lived experiences of NBCSTs with NBC performance assessment process. In addition to the role of NBC in professional development of science teachers, this research study investigates the different meanings attributed to classroom inquiry by NBCSTs by analyzing NBC portfolio entries of teachers, in-depth teacher interviews, and classroom observations. Since we know that NBCSTs successfully documented their students' engagement with inquiry science in their portfolio entries, the study intends to benefit from the expertise and the wisdom of these experienced teachers in developing better strategies for helping other teachers to use inquiry more effectively in their teaching practices. Especially, if we consider our limited knowledge about what makes a good inquiry science teacher and what it takes to be one, these teachers, whose accomplished teaching abilities are documented and recognized by NBPTS, might help us better understand how teachers conceptualize and enact inquiry, and ongoing challenges with inquiry-based teaching. The rich descriptions of teachers' diverse experiences with inquiry science teaching might help other teachers who wish to initiate inquiry in their classrooms and researchers who desire to learn more about teachers' various conceptions and different projections of inquiry science (Keys & Bryan, 2001).

Research Questions

I characterize my research questions under two categories. In the first category, my questions target NBCSTs' perceptions of their learning experiences with NBC as a professional development activity. In the second category, the questions aim to reveal

NBCSTs' conceptions and enactment of inquiry by considering their recognized capabilities and expertise in their teaching.

A) What does undergoing NBC assessment process mean for NBCSTs?

1. How do NBCSTs see the role of NBC in their professional development?
2. What learning experiences do NBCSTs identify with NBC assessment process?
3. Does NBC experience create a higher affiliation with science education reform ideas?

B) What is the meaning of practicing inquiry in classroom for NBCSTs?

1. What are NBCSTs' conceptions of classroom inquiry?
2. How did NBCSTs enact inquiry in NBC portfolios?
3. What do NBCSTs intend to accomplish with their students in their practices of inquiry?
4. What hurdles do NBCSTs identify with practicing inquiry?

Summary

The two most important factors that create significant differences in student achievement might be given as teacher quality and quality of teaching. NBC as a new generation of teacher assessment promises an improvement in the professional quality of science teachers. Inquiry is promoted as the central strategy of teaching science in science education community. My dissertation study brings these two promising educational phenomena together. An examination of NBCSTs' notions and practices of inquiry enriches the current literature with the perspectives of these accomplished science teachers. Judging the possible roles of NBCSTs in science education reform is contingent upon developing a better understanding of their views.

In Chapter 1, I provided a broad picture of the current issues in teachers' experiences with NBC and inquiry-oriented science teaching. Next chapter will be a further elaboration of these issues by examining current education literature. In Chapter 3, I will explain my research methodology and methods in order to investigate my specific research questions. In Chapter 4, I will present the personal and the contextual information about the participant NBCSTs as well as their views on teaching and learning of science. Chapter 5 will be an account of the role of NBC assessment

process in the professional development of NBCSTs. In Chapter 6, I will examine the classroom inquiry notions of participant NBCSTs. In Chapter 7, I will display the intentions and the hurdles of participant teachers in practicing inquiry with their students. Chapter 8 will exhibit the enactment of classroom inquiry by participant teachers in their NBC portfolios. The final Chapter 9 will provide the specific conclusions emerged from the cross-case comparisons of the teacher perspectives, which is blended with the discussions supported by education literature. Chapter 9 will end with the implications of the conclusions for the education community.

CHAPTER 2

LITERATURE REVIEW

Introduction

In this chapter, I provide a broader account of the issues discussed in the first chapter by examining research studies conducted on National Board Certification [NBC] and inquiry science teaching. Since my research study inquires into both “what NBCSTs learn from their NBC experiences” and “what it means to teach science by inquiry for NBCSTs”, my review of the relevant literature consists of two sections correspondingly. In the first section, I present information about how NBC process works and its role as a professional development experience for teachers. In the second section, I specifically focus on how classroom inquiry is described in science education community and how science teachers approach the concept of teaching science through inquiry.

Teaching as a Profession

Civilizations perpetuate their existence by transferring their wisdom to new generations. Teaching, in this respect, might be considered as one of the oldest occupations that existed throughout human history. Like any other civilization, American society owes much to teachers in regard to their major role in maintaining America’s upward development by conveying American values to subsequent generations. However, teaching, historically, has not been acknowledged as a highly skilled profession by American society but rather as a low status job (deCourcy Hinds, 2002; Hallinan & Khmelkov, 2001; National Center for Education Statistics [NCES], 1997). That is partly because teaching has not achieved a professional status (Darling-Hammond, 1990; NCES, 1997) in terms of “rigorous training requirements, positive working conditions, high prestige, substantial authority, relatively high compensation, and an active professional organization or association” (NCES, 1997, p.3). NBPTS

(2002) noted, “The term ‘professional’ is an honorific in our society, and denotes occupations characterized by certain attributes. Chief among these are a body of specialized, expert knowledge” (p.6). Since these attributes are, to some extent, missing from teaching profession, the professional status of teachers has long been questioned by scholars from different academic disciplines. Although educators have repeatedly spent many efforts to promote the image that “teaching, like other professions, is a highly complex kind of work that requires specialized knowledge and skill and, like other professions, deserves commensurate prestige, authority, and compensation” (NCES, 1997, p.1), these efforts have just been little successful (NCES, 1997).

In order to reverse this trend, reform movements to promote the professional status of teaching gained momentum in the beginning of 1980s (NCES, 1997). During this period, two teacher education reform movements, Holmes Group (1986) and Carnegie Task Force on Teaching as a Profession (1986), argued for the necessity of professionalizing teaching by increasing the level of academic knowledge that prospective teachers gain in their university education and creating further career opportunities for practicing teachers (Hallinan & Khmelkov, 2001). The rationale behind the efforts for improving the teaching profession was based on the assumption that teaching reforms would lead to improvements in the motivation and the performances of teachers, which, in turn, would ultimately result in higher student achievement (NCES, 1997). This period also saw the revival of the debate on what effective teachers need to know for quality teaching practice. Until the late 1980s, “unlike physicians, architects or accountants, teachers have not codified the knowledge, skills and dispositions that account for accomplished practice” (NBPTS, 2004a, p.6). By considering that a professional work “requir...[es] a high degree of skill and draw...[s] on a systematic body of knowledge” (Sockett, 1985, p.27), portraying that body of knowledge for accomplished teachers, which drives effective teaching, was thought to be essential in order to strengthen the professional status of teaching. In 1987, Shulman offered the concept of “the knowledge base of teaching” (p.5) in order to characterize the components of knowledge domains for effective teachers.

In 1986, the suggestion for the establishment of a National Board for Professional Teaching Standards [NBPTS] was first pronounced by *Carnegie Task*

Force on Teaching as a Profession in its publication of *A Nation Prepared: Teachers for the 21st Century*. The next year, NBPTS was born with the following mission statement:

To advance the quality of teaching and learning by maintaining high and rigorous standards for what accomplished teachers should know and be able to do, providing a national voluntary system certifying teachers who meet these standards, and advocating related education reforms to integrate National Board Certification into American education and capitalize on the expertise of National Board Certified Teachers. (NBPTS, 2003a, p.7)

As the first professional effort to define accomplished teaching (Darling-Hammond, 2001), National Board Certification [NBC] promises to contribute to the efforts of improving teachers' professional status. This is important because "too many Americans, school board members, administrators and many teachers included believe that any modestly educated person with some instinct for nurturing has the requisite qualifications to teach" (NBPTS, 2004a, p.6). NBPTS (2004a) "intends to change this view by presenting a compelling case for, and a more accurate description of, accomplished teaching" (p.6).

Teacher Quality and Performance Assessment

For many years, educators have discussed what educational variables have the highest effect on student achievement (Darling-Hammond, 1999c). Recent research findings persistently indicate that high quality teachers generate substantial improvement in student learning (Darling-Hammond, 1999b; Goldhaber & Anthony, 2003; Haycock, 1998; NCES, 1999; Wenglinsky, 2000). National Commission on Teaching and America's Future [NCTAF] (1997) phrased this reality as "no other intervention can make the difference that a knowledgeable, skillful teacher can make in the learning process" (p.8). However, it would not be fair to say that America was able to supply its classrooms with high quality teachers particularly in the last 40 years. Chronic teacher shortages contributed to the declining qualifications of teachers who entered into the profession because states attempted to resolve this problem by decreasing standards for newcomers rather than increasing incentives to keep qualified people on the job (deCourcy Hinds, 2002). Additionally, earlier reform efforts primarily

focused on improving school characteristics rather than teaching for better student achievement (deCourcy Hinds, 2002; Hallinan & Khmelkov, 2001; NCTAF, 1997). However, according to Ingersoll (2002), hiring new teachers with no action to improve the teaching profession was like “pouring water into a bucket with holes” (p.7).

The idea that each and every child deserves a high quality teacher is not a controversial issue. However, when it comes to defining what constitutes a high quality teacher, it seems that disputes readily arise (King Rice, 2003; NCES, 1999). That is because teacher quality is a complex topic with no simple definition (Korthagen, 2004; Mitchell, Robinson, Plake, & Knowles, 2001; NCES, 1999) and the criteria for its definition exhibit variations “from person to person, from one community to another, and from one era to the next” (Mitchell et al., 2001, p.19). In 1800s, when normal schools started in America, it was usual for teachers to be little more knowledgeable than their students because America needed large numbers of people with basic skills rather than highly qualified work force (Wise & Leibbrand, 2000). In early 1900s, teachers were expected to be good role models for their students with high moral characters (Mitchell et al., 2001). Around mid-20th century, the importance of teachers’ technical skills in implementing specific curriculum designs in their teaching practices came to the fore (Mitchell et al., 2001). And in 1980s, with the emergence of standards based movement for teacher education, which “define knowledge, skills, and dispositions that teachers should demonstrate” (Mitchell et al., 2001, p.22), the focus shifted from teachers’ personal traits and technical skills to “teachers’ ability to engage students in rigorous, meaningful activities that foster academic learning for all students” (Mitchell et al., 2001, p.22). Briefly, as the values and the concerns of the society changed so did the images of quality teachers.

In order to identify the characteristics of quality teachers, researchers generally focused on two broad aspects of teachers: teacher personal traits and teacher competencies (Korthagen, 2004). However, the research findings do not seem to be conclusive and consistent with respect to what specific teacher attributes lead to better student learning (Goldhaber & Anthony, 2003; King Rice, 2003). By reviewing various studies, Darling-Hammond (1999c) identified characteristics of teachers that have a link with student performances such as general academic and verbal ability, content

knowledge, knowledge of teaching and learning, teaching experience, certification status etc. Darling-Hammond and Youngs (2002) characterized teachers' verbal ability and subject matter knowledge as the most important qualifications of teacher effectiveness while teacher education and certification status appeared to be not related to teacher effectiveness (Haycock, 1998). Goldhaber and Anthony (2003) introduced teachers' academic proficiency as a better predictor of teacher effectiveness. Advanced degrees served as a poor predictor of teacher effectiveness and teaching experience was not helpful to predict teacher effectiveness beyond the first couple of years (Schacter, 2001). Although researchers found weak and few consistent relationships between teachers' personal traits and student success, some of the teacher attributes like enthusiasm, creativity, flexibility, and adaptability, etc. indicated some positive connection (Darling-Hammond, 1999c). As the definitions of teacher quality exhibit variations so do the methods that researchers used to study it (NCES, 1999). National Center for Education Statistics (1999) gathered these methods under four categories: a) observations of teachers' classroom practices, b) measures of teachers' basic literacy, subject matter and pedagogical knowledge by teacher tests, c) analysis of student achievement, d) collection of teachers' qualifications, attitudes and practices by large-scale surveys. However, especially the success of traditional teacher tests in determining the quality teachers has long been a matter of argument (Darling-Hammond, 2001).

In the last two decades, the development of a new generation of teacher assessments has "given lie to claims that no alternative to conventional teacher tests was available" (Shaker, 2001, p.74). The new generation of teacher assessments developed by recent standards-based teaching reform movements like National Board for Professional Teaching Standards [NBPTS] and Interstate New Teacher Assessment and Support Consortium [INTASC] differ from their earlier standardized counterparts that primarily depend on multiple choice tests of teachers' basic skills, subject matter knowledge, pedagogical knowledge and generic observations of teachers' classroom practices (Darling-Hammond, 2001). Earlier approaches of teacher assessments are heavily criticized for exhibiting a narrow view of teaching, representing the knowledge base of teaching poorly, failing to reflect teachers' complex decision making process

adequately, and being unable to offer criterion-related validity evidence (Darling-Hammond, 2001). The general approach of conventional teacher tests to measure teachers' subject matter knowledge and pedagogical knowledge in a separate manner by ignoring the context in which teaching takes place is inadequate to achieve that task (Darling-Hammond, 2001). Darling-Hammond (2001) emphasized that problem with standardized tests as "efforts to measure teaching knowledge without reference to the contextual factors and multiple bodies of knowledge that must guide teaching decisions fail to capture the essence of pedagogy" (p.17).

New teacher assessment strategies and the standards that constitute the foundation of these assessments reflect a more complex view of teaching than earlier ones (Darling-Hammond, 2001; Milanowski, Odden, & Youngs, 1998). National Board Certification [NBC] as an alternative teacher assessment procedure utilizes performance assessment rather than standardized testing in order to distinguish accomplished teachers. Performance assessment has been used in education field for over a period of two decades "with it[s] great promise of fairness and accuracy" (Shaker, 2001, p.74). INTASC (1992) supported this type of teacher assessment procedure because "the complex art of teaching requires performance-based standards and assessment strategies that are capable of capturing teachers' reasoned judgments and that evaluate what they can actually do in authentic teaching situations" (p.5). The rationale behind performance assessment is that an individual teacher is evaluated against predetermined standards of what s/he needs to know and be able to do whether the teacher demonstrates this knowledge through her/his performance in her/his teaching and in open-ended exercises (Schacter, 2001). The assessment of teaching performance has the potential to capture the critical interactions between teacher and students, and a better image of the specific context in which these interactions take place (Darling-Hammond, 2001). One of the unique aspects of NBC's performance assessment is that it evaluates not only subject matter and pedagogical knowledge of teachers, but also the actual demonstrations of teachers' knowledge and skills in their daily teaching practices. In order to achieve this, the assessment process relies on two major activities: a) assessment center exercises to evaluate the content knowledge of teachers and b) portfolio entries to examine the actual teaching practices of teachers

(NBPTS, 2003b). Assessment center exercises consist of six 30 minutes computer-based activities that were designed to allow teachers to demonstrate their content knowledge for their specific certification area (NBPTS, 2003a). Teachers are expected to create a portfolio that contains four entries, each of which provides direct evidence of teachers' demonstration of NBC teaching standards in their classrooms accompanied with written analytical, descriptive, and reflective explanations of the specific portfolio artifact (NBPTS, 2003a). While three entries focus on teachers' classroom practices that include two videotapes of teaching and student work samples, one entry documents the accomplishments of teachers out of their classrooms that reflect the interaction of the teachers with their colleagues, the families, and the larger community (NBPTS, 2003a). Once all these portfolio artifacts are submitted to NBPTS, they are assessed by two independent assessors who determine whether the applicant teacher demonstrates sufficient evidence that her/his teaching aligns with NBC's high and rigorous standards. After having an intensive training on how to score portfolio entries, these assessors are selected from qualified teachers who demonstrated that they have a good understanding of NBC standards and scoring guidelines.

New Generation of Teacher Certification

In 1980s, for the first time in history, with the emergence of standards-based reform movements, professional teaching standards were created that characterize the knowledge, skills, and dispositions that accomplished teachers need to possess (Delandshere & Arens, 2001). This development is important because "standards are one of the hallmarks of a profession. They serve as a set of quality indicators for individuals licensed to practice in the field" (Koppich & Knapp, 1998, p.21). NBC as standards-based advanced teacher certification symbolizes "professional teaching excellence" (NBPTS, 2002, p.1) with "a new generation of fair and trustworthy assessment processes that honor the complexities and demands of teaching" (NBPTS, 2002, p.1). NBC is offered on a voluntary basis for teachers with at least 3 years of teaching experience not as a replacement for state licenses but as a complement of them, that is, state licenses set the entry conditions for beginner teachers whereas NBC represents advanced standards for experienced teachers. NBC currently has standards

in 27 fields that reflect developmental levels of students such as Early Adolescence Science Certificate, Adolescence and Young Adulthood Mathematics Certificate, Early and Middle Childhood Music Certificate etc. Although the standards differ for each field, all standards build upon five core propositions for what accomplished teachers should know and be able to do. NBPTS (2002) explained these propositions briefly as:

1) Teachers are Committed to Students and Their Learning

By acknowledging that all students can learn, accomplished teachers are determined to making knowledge accessible to all students. They achieve that task by treating students equitably, recognizing the individual differences that distinguish one student from another, and taking these differences into account in their teaching practices. Accomplished teachers are knowledgeable about how students develop and learn. They integrate the theories of learning, cognition and intelligence in their teaching practices.

2) Teachers Know the Subjects They Teach and How to Teach Those Subjects to Students

Accomplished teachers understand the subject they teach in a rich manner. They have the appreciation of how knowledge in their subject is created, organized, linked to other disciplines and applied to real-world settings. Accomplished teachers are aware of their students' backgrounds, preconceptions, and difficulties in a specific subject and adjust their teaching accordingly. Their instructional repertoire allows them to use multiple paths to the subjects they teach. They are expert at teaching their students how to pose and solve their own problems.

3) Teachers are Responsible for Managing and Monitoring Student Learning

Accomplished teachers build instructional settings to catch and maintain the interest of their students and to make the most effective use of time. They know different instructional techniques and use them in an appropriate manner as needed. Teachers with outstanding practices know how to motivate their students and to engage groups of students in a learning environment. They have the ability to assess the progress of their students and the whole class by utilizing multiple methods.

4) Teachers Think Systematically about Their Practice and Learn from Experience

Accomplished teachers are good models for their students in terms of inspiring them to have the ability to reason, to take multiple perspectives to be creative, and to adopt a

problem-solving orientation. As life long learners, National Board Certified teachers critically examine their teaching practices, broaden their repertoire by drawing on educational research, increase their knowledge, sharpen their judgment and adapt their teaching to new findings, ideas and theories.

5) Teachers are Members of Learning Communities

Accomplished teachers help their schools to work more effectively by collaborating with other professionals on instructional policy, curriculum development and staff development. They take the advantage of specialized school and community resources for the benefit of their students. National Board Certified teachers keep in touch with parents and find ways to work collaboratively with them.

NBPTS is a private and nonprofit organization governed by a board of directors, which consists of classroom teachers, school administrators, school board leaders, state legislators, higher education officials, and community leaders. Standards are generated by committees of classroom teachers, teacher educators, and subject experts and finally approved by NBPTS board of directors. NBC is an extensive year long performance assessment of teaching practice and requires candidate teachers to create a teaching portfolio with two videotapes of their teaching, student work examples, reflective commentaries of candidates' teaching and student learning. NBC is issued for 10 years with an opportunity to renew it at the end of 10 years. Candidates pay \$2300 application fee to be a NBC candidate, the majority of which is funded by states as a part of their incentive efforts.

NBC was first offered in 1993-1994 assessment period in which 177 teachers were granted a certificate. In 2005-2006 assessment period, the figure climbed to 7815 successful candidate teachers in a year. As of January 2007, the total numbers of teachers who have NBC are 55,328. North Carolina leads the nation with 11,327 teachers who possess NBC. Florida follows with 9236 National Board Certified teachers. South Carolina comes third with 5076 teachers who hold NBC. Currently, 50 states offer regulatory and legislative support for NBC. States provide different incentives to attract qualified teachers to seek NBC. For example, Florida pays 90% of application fee, gives teachers who achieve NBC 10% salary increase for the life of certificate, and offers additional 10% salary increase to those who agree to mentor

public school teachers within the state who do not have NBC. 10% salary increase is calculated with reference to the previous year's statewide average salary for classroom teachers. In addition, the state provides applicant teachers a \$150 to cover the expenses of portfolio preparation.

Standards for Accomplished Science Teachers

NBPTS offers advanced teaching certificates for accomplished science teachers in two student age groups, Early Adolescence (ages 11-15) and Adolescence & Young Adulthood (ages 14-18+). The latter one comes with four specialty areas, earth & space science, physics, chemistry, and biology. NBPTS has a separate teaching standard for each of these two individual science certification areas of two different student age groups. In order to achieve NBC, science teacher candidates need to get a passing score in their assessment center exercises and demonstrate that their classroom practices meet teaching standards of the specific certification area in which they seek NBC.

Assessment center exercises specifically target evaluating science teachers' understanding of science content in their specialty area. For example, the exercises for Adolescence & Young Adulthood Science Certification area consist of six prompts, each of which covers these corresponding concepts; data analysis, interrelationships, fundamental concepts, change over time, connections in science, and breadth of knowledge. For instance, in the data analysis exercise, science teachers are asked to analyze, interpret, and infer data by using graphs or other data.

In order to complete their portfolio requirements, science teachers need to include four sections of artifacts into their portfolios. Each portfolio section supports a specific theme and contains the evidence for that specific section theme. For example, Adolescence & Young Adulthood Science Certification candidates need to organize their portfolios under these four section themes: teaching a major idea over time (Entry-1), active scientific inquiry (Entry-2), whole class discussions about science (Entry-3), and documented accomplishments: contributions to student learning (Entry-4). By sharing a similar vision with National Science Education Standards, NBPTS places heavy emphasis on inquiry-based science teaching. As Entry-2 suggests, science

teachers who seek NBC are expected to demonstrate clear evidence of their use of inquiry-oriented science teaching in their classrooms. According to NBPTS (2003b), “accomplished Adolescence and Young Adulthood/Science teachers engage students in active exploration to develop the mental operations and habits of mind that are essential to advancing strong content knowledge and scientific literacy” (p.39). In the classrooms of accomplished Early Adolescence Science teachers:

Students learn to recognize problems, ask relevant questions, formulate working hypotheses, determine the best way to observe phenomena, handle data with accuracy, reach tentative conclusions consistent with what is known, and express themselves clearly about the significance of findings. (NBPTS, 2003c, p.39)

In the active scientific inquiry (Entry-2) portfolio section, Adolescence & Young Adulthood Science teachers are required to provide two artifacts: a twenty minute videotape that shows teachers engaging students in active scientific inquiry and maximum thirteen pages of a written commentary that contextualizes, analyzes, and evaluates teachers’ inquiry-based science teaching demonstrated in the videotape. In choosing specific activities to engage students in classroom inquiry, NBPTS (2004b) suggested Early Adolescence Science teachers that:

The investigation should involve more than following predetermined or “cookbook” investigations in which the students simply follow a set of established procedures, verify known facts, or confirm expected results. The investigation must provide opportunities for students to engage in scientific inquiry as they put forth and consider questions and ideas. Therefore, activities that focus only on the development of laboratory skills (such as the use of a microscope, or other laboratory equipment) are unlikely to provide opportunities for scientific inquiry and discussions of data. (p.180)

Scoring of these portfolio artifacts is based on a four-leveled rubric, of which Level 4 represents the highest score. For example, a Level 4 teaching performance in active scientific inquiry (Entry-2) section “provides clear, consistent, and convincing evidence that the teacher is able to facilitate and support student learning through scientific inquiry as students actively engage in a science investigation” (NBPTS, 2004c, p.29).

A Critical Look

Many teachers with excellent teaching skills already work in the nation's schools, but their accomplished teaching practices go unrecognized and unrewarded by the community (NBPTS, 2002). That is because until the inception of NBC, there was no such mechanism in teaching profession to recognize and to reward teachers with exemplary teaching practices. Due to its great potential for improving teaching in schools, the phenomenon of NBC gets broad support from various groups such as legislators, teacher unions, school boards, education organizations, teacher educators, and classroom teachers etc. Although the broad implications of this phenomenon are difficult to predict precisely and may take several years to emerge (NBPTS, 2004), it has certain promises of improving the professional status of teaching, promoting a sense of collegiality in the profession, contributing to professional development of teachers, creating a consistent view of accomplished teaching, attracting qualified people into teaching profession, and eventually enhancing student performance (Serafini, 2002). Through the efforts of defining what accomplished teachers should know and be able to do, NBPTS has also substantial influence on the nature of teacher education programs and the licensing standards for beginner teachers (Darling-Hammond, 2001).

However, as it is the case for any imperfect entity, the phenomenon of NBC is also not exempt from criticism. To begin with, there are those researchers who are concerned about the adverse impact of NBC due to the relatively low percentages of African-American teachers who achieve the certification (Bond, 1997; Irvine & Fraser, 1998). While the overall success rate is 45% for all applicant teachers, the passing rate for African-American teacher candidates is only 11% (Kraft, 2001; Serafini, 2002). According to Klein (1998), this figure indicates that in comparison to teacher tests with multiple choice items, NBC portfolio assessment process puts teacher candidates with African-American origin into a more disadvantageous position. Another criticism directed to NBPTS is that it tends to value constructivist teaching strategies over didactic teaching forms (Ballou, 2003; Bond, 1997; Kraft, 2001; Serafini, 2002). Bond (1997) noted, "The assessment and certification system adopted by the Board privileges

and honors constructivist, student-centered, and permissive approaches to instruction over didactic, teacher-centered, and more authoritarian instructional styles” (p.15) although there is no clear evidence about which teaching method works better for a certain group of students (Klein, 1998). Some researchers argued that the didactic forms of teaching may be more effective for the students of African-American teachers and this may put them in a disadvantaged position in achieving NBC (Ballou, 2003; Bond, 1997). Serafini (2002) pointed out the possibility that NBC may create a competitive environment rather than a sense of collegiality among teachers as intended by NBPTS, which may lead to unnecessary distinctions between teachers.

Milanowski et al. (1998) questioned whether teacher performance assessed in a single context by relying on limited number of portfolio artifacts is representative of likely performance in another context. They commented that successful teachers whose teaching “performance [assessed] in a culturally homogeneous upper-middle-class school would not be able to do so...in a school with a culturally diverse, low socioeconomic status student body” (p.95). They reminded us that like virtually any other teacher assessment, NBC assessment procedure targets teachers’ capability of effective teaching rather than their typical teaching practices since teacher portfolios reflect teachers’ best practices. However, Milanowski et al. (1998) highlighted the general concern that “the performance...depict[ed by portfolios and videotapes] is further removed from typical performance than the results of other assessment methods, due to the potential for editing and refinement by the candidate” (p.95).

Burroughs (2001) turned our attention into another issue, the connection between writing skills and NBC success. Due to the limited usefulness of student work examples as one of the major portfolio artifacts, Ballou (2003) argued that the assessment procedure of NBC for “a teacher’s performance will necessarily rely heavily on the candidate’s written commentary....whether the teacher makes a coherent case, backed up with telling details and examples, for the approach she or he claims to be using in the classroom” (pp.208-209). In this respect, Burroughs (2001) stated that NBC procedure “is as much an evaluation of a teacher’s writing about his or her teaching as it is an evaluation of the teaching itself” (p.223). Burroughs et al. (2000) added, “The certification process can be characterized as based on written and decontextualized

language about teaching” (p.349). These scholars pointed out the advantage of those teachers with better writing abilities in achieving NBC and implied the possible problems with the ability of NBC assessment process to distinguish accomplished teachers with limited writing skills accurately.

Petrosky criticized NBC’s assessment procedure of reducing teacher performances to a set of numerical scores without providing any constructive feedback for teachers, which makes professional development aspect of NBC less effective (as cited in Serafini, 2002). Ballou (2003) noted, “The board’s process is too much a matter of pulling oneself up by one’s bootstraps. Unfortunately, the board offers candidates no feedback on their performance beyond the numerical scores” (p.214). Besides, candidate teachers who are unable to achieve NBC are not given the reasons for their failures (Ballou, 2003). Serafini (2002) discussed that “numerical ratings may be legally defensible and economically justifiable, but the question remains whether they support the improvement of teaching performance and the recognition of accomplished practice, both important goals of the NBPTS” (p.323).

Milanowski et al. (1998) emphasized the need for more information about NBC assessment procedure, particularly its criterion-related validity, in order to judge its measurement quality. By considering a limited number of studies that focused especially on criterion-related validity of NBC assessment procedure (Milanowski et al. 1998), Klein (1998) argued that “the validity of a test will be easier with a largely multiple-choice basic skills test...than it will with a purely open-ended test of teacher effectiveness” (p.136). By implying possible problems with criterion-related validity of NBC assessment procedure, Ballou (2003) expressed that “the board bases its assessments on a very limited amount of information. The board does not assess how much a teacher’s students have learned. It does not visit classrooms or consult with candidates’ supervisors” (p.217).

Those criticisms presented in this section of the chapter indicate that the assessment process of NBC needs more improvement in order to function its role more satisfactorily. This requires conducting more research studies on the phenomenon of NBC. In the following section of the chapter, I will discuss the professional development aspect of the certification process for teachers.

NBC as Professional Development Activity

One of the distinctive aspects of NBC process is that it not only assesses the classroom practices of teachers against high and rigorous teaching standards but also promotes teacher learning and improvement through teaching portfolios and open-ended exercises, which is a new dimension that was not envisioned by earlier generations of teacher tests (Darling-Hammond, 2001). According to NBPTS (2003a), “most teacher candidates find that the yearlong reflection and analysis process that National Board Certification candidacy entails is one of the most rewarding and meaningful experiences of their professional lives” (p.13).

NBPTS seeks more evidence of the impact of NBC on teachers and their students in order to strengthen its arguments that NBC determines accomplished teachers successfully and contributes to the professional development of teachers. The studies that investigated the former argument did so either by analyzing whether National Board Certified teachers generate higher student achievement than their non-National Board Certified colleagues or by examining whether National Board Certified teachers outperform other teachers with respect to their teaching performances. Some recent studies seem to be supporting the argument that NBC works successfully as an assessment procedure to distinguish exemplary teachers based on their students’ achievement (e.g. Cavalluzzo, 2004; Goldhaber & Anthony, 2004; Vandevort et al., 2004) and their teaching performances (e.g. NBPTS, 2000).

The majority of the limited number of published studies that reveal the impact of NBC on teachers’ professional development come in the form of surveys (e.g. Center for the Future of Teaching and Learning, 2002; Indiana Professional Standards Board, 2002; NBPTS, 2001a, 2001b) and teacher personal testimonies (e.g. Areglado, 1999; Benz, 1997; Buday & Kelly, 1996; Haynes, 1995; Kowalski, 1997; Moseley & Rains, 2002; Wiebke, 2000). Teachers in these studies underlined the supportive and reflective nature of NBC process in their learning and improvement as an effective teacher. For example, Haynes (1995) commented that NBC process “was, quite simply, the single most powerful professional development experience of my career” (p.60). Another teacher, Bzdewka (1996), reported, “I was a good teacher. But National Board

Certification was the gel that pulled everything together” (p.217). A teacher responded to the survey conducted by NBPTS (2001b) as “one of the strongest points of National Board Certification is the reflective nature of the process. You cannot go through the process without it affecting the way you look at and try to improve every aspect of your teaching” (p.5). The list can be extended with more teachers who professed their learning in NBC process. However, although these studies inform us about the high potential value of NBC for teacher learning, they do not provide a comprehensive account of teacher learning from NBC process but instead broad descriptions of teachers’ experiences with NBC, which lack specificity and details. These broad expressions do not help much in our understanding of how teachers improve by undergoing NBC process and how they translate their learning into their teaching practices. It seems that few studies investigated teacher learning from NBC process with a more comprehensive manner, majority of which focused on teachers in any certification area but not teachers in a specific subject area. According to what my literature review indicates, there are very few, if any, studies that specifically inquired into NBCSTs’ learning experiences in NBC process, and especially the inquiry-oriented science teaching aspect of NBC process. Therefore, we do not know much about how NBCSTs see the role of NBC in their improvement as an inquiry science teacher. Here, I briefly present some of the research studies that specifically investigated teacher learning from NBC process.

Research Studies on Teacher Learning from NBC

Sato (2000) studied the kinds of learning that teachers experienced as they underwent NBC process while she was coordinating a support group of 30 NBC candidates at Stanford University. Based on the interview data collected from 17 NBC candidates in a range of certification areas who participated in the support group, she reported that teachers identified their learning from NBC process in a variety of domains that include disciplinary content knowledge, teaching repertoire, their students, learning about oneself, and thinking metacognitively. Candidate teachers expressed that while constructing their teaching portfolios allowed them to examine their teaching practices and to try new teaching strategies such as small group work, new curricular materials, large group discussions, variety of writing assignments etc., preparing for assessment

center exercises stimulated their understanding of the specific content knowledge they teach. NBC process further encouraged teachers to examine their interactions with their students and to respond to the specific learning needs of individual students. For example, a fifth grade teacher stated:

I was not focusing on each individual students' needs and abilities as much as I thought I was....I learned that I need to take time to look at each student individually rather than in their group or in their whole class. (p.8)

Teachers also reported that NBC process worked as a mechanism to remind teachers their core values and how these values manifest themselves in their teaching. Last but not least, teachers gained new metacognitive understanding of their teaching practices by articulating these practices under the light of shared language of NBC standards.

Sato (2000) concluded that "no two teachers reaped the same learnings from the process and within each of these domains, each teacher took away something different" (p.12).

Lustick (2002) worked with two groups of Michigan science teachers, those of completed all NBC requirements and those of just began NBC process, in order to compare the effect of NBC process on teachers' learning gains. The researcher conducted interviews with both groups of science teachers in order to identify any qualitative distinctions between their ideas, thinking, and judgments about some common issues in teaching and learning of science. The study revealed that NBC assessment process promoted teachers' learning in managing more effectively three intrinsic issues of their teaching practices such as complexity of task, uncertainty of outcome and professional isolation. Teachers' analysis of their work and their students' learning helped them recognizing the complex nature of education and identifying its role in the process of education. Through NBC process, teachers seemed to be gaining a greater expertise at managing uncertainty of student learning in response to specific actions, decisions, and comments. According to teachers, NBC standards encouraged them to be less isolated as a teacher but rather more integrated into the professional community around them. However, Lustick (2002) professed that he initially expected that NBC process might help teachers to change their existing beliefs and values about

teaching but instead it “acted as a mirror for candidates to gaze into their practice and gain a much desired affirmation of their way of teaching” (p.18).

Chittenden and Jones (1997) inquired into teachers’ perspectives with respect to their professional growth as they progressed through NBC process. The researchers collected their data from those of the teachers in three different certification areas who attended a support group in South Brunswick, NJ. Overall, teachers mentioned about becoming more conscious of what they do and why they do it in their teaching practices. They further emphasized how they tended to become more reflective and analytical about their teaching but less intuitive in their decisions. Several teachers reported that NBC process helped them becoming clearer about their teaching philosophies and worked in a way of validating what they already believed. Chittenden and Jones (1997) noted that teachers “were saying that there were no major changes in everyday practice, but rather important modifications in how they understood what they did and why” (p.27).

In her dissertation, Iovacchini (1998) investigated how NBC serves as a professional development activity and what teachers learn from their NBC experiences by working with nine National Board Certified teachers in three different generalist certificate areas. By depending upon observations, interviews and portfolio artifacts, she reported that NBC process led teachers to develop a broader perspective on teaching and learning as a result of their exposure to teaching standards, national curriculum materials, and other teachers’ ideas. Most teachers emphasized improved confidence in their professional judgments, increased sense of professional responsibility, and renewed commitment to teaching profession. Teachers also expressed that they increased their curricular and pedagogical knowledge. Iovacchini (1998) concluded that NBC “assessment is functioning as professional development to initiate change in line with the standards....Research should be developed to ascertain the effects the assessment has on other selected groups including unsuccessful candidates and minorities” (p.183).

Taylor (2000) in her dissertation study sought to understand the effects of NBC on the professional growth of eleven Coloradan teacher candidates in Middle Childhood/Generalist certification area. Although teachers identified a variety of areas of

change as a result of undergoing NBC process, the areas that exhibited the most consistent change across teachers included planning, assessment, reflection, and family involvement. As a result of their experiences through NBC process, teachers tended to shift their planning from activity-driven to standards-driven, which resulted from teachers' willingness to satisfy NBC teaching standards. In the area of assessment, the perceived teacher changes displayed a variation from spending more effort to employ diverse assessment strategies for student learning to using assessment to change instruction. Teachers further reported that they placed more emphasis on parents' involvement in their classrooms. Taylor (2000) stated that two of the teachers who reported the most change in the study were unable to achieve NBC.

After discussing teacher learning and improvement from NBC process, I now turn my route to the concept of inquiry teaching and learning in science education. Articulating classroom inquiry is important because the meaning attributed to the term "inquiry" by NBCSTs is a question deserving a deeper investigation. In the following sections, I present diverse perspectives on classroom inquiry from science education literature.

Science as a Way of Knowing

We are living in a world with many unknowns. Throughout history, human beings' search for viable explanations to these various unknowns never came to an end. Curiosity sparked people's actions in the way of pursuing for more knowledge about the mystery of events. In this never ending quest for unknown, not one but multiple ways of knowing appeared to serve this aim. Royce (as cited in Sund & Trowbridge, 1967), for instance, categorized these ways under four major branches: thinking (rationalism), feeling (intuitionism), sensing (empiricism), and believing (authoritarianism). With the emergence of modern science in 16th century, by devising its own methods of investigation, science became a discipline that represents a systematic way of thinking. Therefore, science as one of these multiple ways of knowing "distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world" (NRC, 1996, p.201). Johnston (2000) noted,

“Science is not a book of knowledge sitting on someone’s shelf. Science is a way of knowing—a way of understanding and interpreting the world—but by no means is it the only way” (p.24).

However, historically science in schools was mostly treated as a body of knowledge that consists of facts and laws to be conveyed to the students whereas such aspects of science like nature of scientific knowledge, specific methods of scientific investigation and systematic ways of scientific thinking etc. did not find themselves enough space in science teaching. In other words, science instruction in schools mainly focused on teaching students “what science knows” but little, if any, attention was given to “how science knows.” Dewey argued that science teaching in schools needs to be restructured in a way to allow students to gain an understanding of systematic methods and thinking process of science in addition to scientific concepts (as cited in NRC, 2000). This approach paved the road for alternative teaching methods to introduce students the process of scientific inquiry and the cognitive processes of scientists in their classrooms. By 1960s, teaching science by inquiry gradually began to be pronounced more frequently in science education community through particularly Schwab (1962)’s leading role. Inquiry-based science teaching was thought to be essential for students to learn scientific concepts and to appreciate the process of scientific investigation.

Improving the quality of instruction in schools is one of the most critical components of educational reform. However, students have long been taught science mostly through traditional means of instruction (Weiss, 1997). This is still the case in most science classrooms today (Horizon Research, 2003; O’Sullivan & Weiss, 1999). According to a report written by the National Commission on Mathematics and Science Teaching for the 21st Century (2000), “despite the dramatic transformations throughout our society over the last-half century, teaching methods in mathematics and science classes have remained virtually unchanged” (p.20). However, the problem with the traditional methods of science teaching is that they are not as effective as one would expect in supporting students’ understanding of scientific concepts (van Driel et al., 2001). Besides, traditional approaches of science teaching have contributed to the decreasing popularity of science among students, which leads to the declining number

of students who pursue a career in a field related to the science (van Driel et al., 2001). Furthermore, educating future generations to understand science and technology issues in a rapidly changing world does not seem to be fulfilled through conventional science teaching strategies (van Driel et al., 2001). Current science education reform movements like AAAS (1993) and NRC (2000) are very clear in their intentions that science teachers should reduce the time they spent on didactic instruction of scientific facts and increase their use of classroom inquiry in order to generate student learning based on students' engagement with authentic problem solving contexts although they are not as clear about the classroom practices of inquiry-based science teaching (Southerland, Gess-Newsome, & Johnston, 2003).

Scientific Literacy

Any person who reads current science education reform documents would notice how such terms like scientific literacy, nature of science, classroom inquiry are repeated consistently in the natural language of the documents. Especially the term scientific literacy embraces all the concepts of current science education reform movements under its umbrella as an ultimate goal of science education. Whereas the term itself bears substantial significance for the science education community as an essential goal of science education, individuals who advocate scientific literacy as a desired outcome of science education are not all clear about what that means (DeBoer, 2000; Laugksch, 2000; Parsons et al., 2002). Although the term first appeared explicitly in Paul Hurd (1958)'s article "*Science Literacy: Its Meaning for American Schools*" (Laugksch, 2000), the cultural roots of the term go far back to the emergence of modern science in 1500s (Hurd, 1998). Since science as a discipline represents a systematic and logical way of thinking, the value of gaining such thinking abilities for students and larger population was frequently emphasized by many scholars. For example, Dewey stated, "The future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind" (as cited in Rudolph, 2003, p.71). Piaget (1964) expressed that "goal of education should be to form minds which can be critical, can verify, and not accept everything offered" (p.5). More recently, Lederman (2004) noted that "our citizens are expected to know enough about science content, inquiry, and NOS to be

able to understand scientific claims and make informed decisions” (p.402). Briefly, learning some of the important aspects of scientific inquiry such as “problem solving, decision making, and values clarification” (Welch, Klopfer, Aikenhead, & Robinson, 1981, p.44) constitutes an important purpose of schooling. Current science education standards movements like AAAS (1990) and NRC (1996) envision a scientifically literate society and it seems that they assign the major role to inquiry-based science teaching in order to accomplish the broad educational goals of scientific literacy (Britner & Finson, 2005).

In order to grasp a better understanding of these two organizations’ vision in science education, we need to take a closer look into what they mean by scientific literacy and what they expect from students to learn in their science classes. AAAS (1990) described scientific literacy as the ability to be able to think critically and independently, which was termed “scientific habits of mind.” AAAS (1990) considered such ability as one of the most essential outcomes of science education because “scientific habits of mind can help people in every walk of life to deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty.” Scientific literacy is also one of the main themes advocated by NRC (1996) as an important aspect of students’ learning in science. According to NRC (1996):

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. (p.22)

In order to generate a scientifically literate populace, NRC (1996) envisions science classrooms in which students gain both “abilities necessary to do scientific inquiry” (p.121) and an “understanding about scientific inquiry” (p.121) in addition to their learning of scientific concepts.

NBPTS (2003b, 2003c) shares a parallel vision with these two national organizations in regard to the importance of educating students with the goal of

scientific literacy. NBPTS (2003c) revealed its perspective on this issue as accomplished science teachers serves to generate “scientifically literate students by teaching them to think like scientists...[They] instill in students a never-ending curiosity about the world and to develop in them the skills necessary to investigate their questions” (p.1). NBPTS (2003b) defined a scientifically literate individual as the one who has a strong knowledge of:

(1) the nature of science, including a grasp of the various inquiry processes that scientists use to discover new knowledge as well as of the attitudes and habits of mind—honesty, skepticism, openness to new ideas, and curiosity—essential to an objective investigator; (2) the most important concepts from the body of scientific knowledge; and (3) the human context of science, including a familiarity with the history of its development and its reciprocal relationship with mathematics and technology, and their mutual economic, political, and cultural impacts on society. (p.2)

The bottom line is that the ideal of educating future generations equipped with the capabilities of scientifically literate people very much shapes current science education reform efforts with respect to specific science content for students, and teaching and learning strategies.

Inquiry as Doing and Teaching Science

Teaching science by inquiry is highly encouraged by NRC (2000) and AAAS (1993) in order to educate students with a better understanding of science. NRC (1996) promotes classroom inquiry as “the central strategy for teaching science” (p.31). NRC (1996) noted:

Students in all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about the relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments.(p.105)

Since classroom inquiry has been given that much importance in achieving the goal of a scientifically literate society, it is important to understand what is meant by inquiry and what educational outcomes are expected to be gained from inquiry-based science teaching and learning. However, before proceeding to articulate the meaning of inquiry for science education community, we need to distinguish two terms from each other because the word of inquiry refers to both the scientific method for doing science and the strategy for teaching science (Colburn, 2000; Harwood, Reiff, & Phillipson, 2002). Classroom inquiry, which is inspired by scientific inquiry, aims to engage students in the kinds of cognitive processes maintained by scientists as they go for the scientific knowledge. Sund and Trowbridge (1967) stated, "The only way a student learns to be scientific is to be placed in situations where he is actively involved in using scientific methods" (p.9). Since didactic teaching strategies fail to promote students' understanding and appreciation of the generation of scientific knowledge, doing inquiry in the classroom by investigating the authentic questions has been thought to be an effective way of providing to the students the necessary skills to understand the nature of the scientific knowledge. Therefore, in order to gain a better understanding of inquiry as the strategy for teaching science, we first need to clarify our understanding of inquiry as the methods of doing science because the rationale behind doing inquiry in the classroom ultimately gets its inspiration from real science even if they are not completely alike.

Inquiry as Doing Science

NRC (1996) described the scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (p.23). Lederman (1998) defined the scientific inquiry as "the systematic set of approaches used by scientists in an effort to answer their questions of interest." We might add more similar definitions of scientific inquiry but what is noticeable in most of these definitions is the fact that the scientific method of investigation embraces a variety of different approaches and ways that scientists employ in their efforts to offer a viable explanation to the natural events or the specific problems at hand. However, unlike these definitions, many textbooks portray scientific inquiry as a stable linear process through which scientists reach their conclusions and

generate scientific knowledge (Windschitl, 2003, 2004). Scientific research is obviously more than following a prescribed way of reaching the conclusions, that is, there does not exist a single method of scientific investigation universally followed by all scientists, quite the reverse, it may take several forms (AAAS, 1990; Hurd, 2002; McComas, 2005b; NBPTS, 2004d; Rudolph, 2003). AAAS (1993) stated that scientific inquiry is:

A more subtle and demanding process than the naïve idea of making a great many careful observations and then organizing them. It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as the scientific method. It is much more than just doing experiments, and it is not confined to laboratories. (p.9)

Scientific method of investigation is an iterative process that scientists construct, test, and modify their models continuously based on empirical evidence as they go through the inquiry process (Cartier & Stewart, 2000). Scientific research is a complex activity that involves using expensive equipments, complicated experimental procedures, highly specialized knowledge, and advanced techniques for data analysis (Chinn & Malhotra, 2002). Although scientific research may take diverse and complex forms, we can still identify certain noticeable patterns in the methods followed by scientists, for instance, “their capacity to recognize problems, ask relevant questions, formulate working hypotheses, observe phenomena, record and interpret data and graphs accurately, reach tentative conclusions consistent with data, and express themselves clearly about the significance of findings” (NBPTS, 2004d, p.149).

Inquiry in the classroom offers “a context in which students can learn to reason scientifically” (Chinn & Malhotra, 2002, p.175). In that respect, classroom-based inquiry can be thought of engaging students in classroom activities in which they can experience the problem solving nature of science and cognitive processes of scientists (Llewellyn, 2002). However, the question arises whether students can be introduced to the type of cognitive processes, which scientists maintain in their scientific investigations, in classroom conditions through simple inquiry tasks. Chinn and Malhotra (2002) argued that many simple inquiry tasks commonly used in schools bear very little resemblance to real scientific inquiry in terms of cognitive processes that students and scientists use, and the epistemologies that they represent. They expressed:

Many scientific inquiry tasks given to students in schools do not reflect the core attributes of authentic scientific reasoning. The cognitive processes needed to succeed at many school tasks are often qualitatively different from the cognitive processes needed to engage in real scientific research. Indeed, the epistemology of many school inquiry tasks is antithetical to the epistemology of authentic science. (p.175)

Rudolph (2003) emphasized the difficulty of representing scientific inquiry through simple classroom inquiry tasks. He noted, "The first is that no single 'nature of science' exists; and the second is that, even if one did, only a partial representation of it could ever be captured in the school experiences designed for students" (p.65). Hodson (1999) pointed out the limitations of simple inquiry tasks in promoting students' understanding of the essence of the scientific inquiry. He expressed that "learning about the nature of science involves more than learning how to conduct a 'fair test' by systematically controlling variables. Rather, it involves introduction into the established techniques, strategies, standards and criteria of science" (p.242). Although there is an intuitive assumption that students who engage in inquiry activities would automatically develop a good understanding of scientific inquiry, several research studies do not support this assumption (e.g. Khishfe & Abd-El-Khalick, 2002; Sandoval, 2003; Schwartz, Lederman, & Crawford, 2004). Lederman (2004) discussed that exposing students to inquiry activities in the classroom is not sufficient to help them learn about the nature of scientific inquiry because teachers also need to address this specific knowledge explicitly in their teaching and let students clarify their understandings through "reflection on these activities and the nature of the knowledge produced" (p.403). Schwartz et al. (2004) stated that "improving views of NOS should be planned for through objectives, instructional attention, and assessments...[and supported] through discussion, guided reflection, and specific questioning in the context of activities, investigations, and historical examples" (p.614). As the current literature suggests, a good understanding of the nature of scientific inquiry process does not develop implicitly in inquiry-oriented environments but rather it requires an explicit attention to be given to the certain aspects of inquiry activities.

After providing a brief description of inquiry as the method for doing science, let's discuss how inquiry as the teaching strategy is understood in science education community.

Inquiry as Teaching Science

Inquiry-based science teaching maintains its central position in science education reform agenda for a long time (Buck, Latta, & Leslie-Pelecky, 2007; Haefner & Zembal-Saul, 2004; Newman et al., 2004). However, despite its major importance for science education community, many scholars accept that the current definitions of classroom inquiry offer a vague description of the term and its classroom applications (Abd-El-Khalick, 2004; Anderson, 2002; Colburn, 2006; Cuevas, Lee, Hart, & Deaktor, 2005; Flick, 2000; Haefner & Zembal-Saul, 2004; Keys & Bryan, 2001; Wee, Shepardson, Fast, & Harbor, 2007; Windschitl, 2003). Flick (2000) criticized current models of inquiry-based instruction that they do not offer a clear explanation of how to teach the cognitive skills required for students to perform the complex cognitive tasks of science inquiry. Songer et al. (2003) stated:

Science educators and researchers often hold a narrow, somewhat idealistic representation of scientific inquiry as “the kind of thinking scientists engage in” or other poorly defined constructs, in part, because few other models, and few well-defined models, of inquiry science exist. Consistent with this representation, inquiry guides can often present a monolithic view of what inquiry should look like in classrooms. (pp.511-512)

Although current reform documents include the definition and the examples of inquiry-oriented teaching of science, these broad definitions provides little help to teachers in practicing such teaching in their classrooms (Anderson, 2002; Bodzin & Beerer, 2003; Keys & Bryan, 2001; Keys & Kennedy, 1999). Additionally, teachers have their own conceptions of inquiry and these conceptions may not necessarily match with the vision of the reform documents (Windschitl, 2003). Everyday, thousands of science teachers enact their favored teaching strategies of inquiry in their classrooms (Windschitl, 2004) but “what is enacted in classrooms is mostly incommensurate with visions of inquiry put forth in reform documents” (Abd-El-Khalick, 2004, p.398). Windschitl (2004) noted:

Different ideas about inquiry exist not only “in the heads” of science teachers, but are codified in authoritative documents, reinforced by textbooks, broadcast in the media, and embodied in the practices of educators who promote the use of inquiry as well as those who favor more traditional methods. (p.484)

Flick (1997) argued that our knowledge about inquiry-based science teaching has developed from the perspective of students’ behaviors and experiences in inquiry rather than teachers’ generation and management of these meaningful inquiry experiences. He added that “if inquiry is to become a viable, mainline approach to teaching science, researchers and teachers must become more explicit about the behaviors and thoughts of teachers engaged in inquiry teaching” (p.5).

Newman et al. (2004) noted that “the definition of inquiry in science education is dynamic and context dependent” (p.273). Keys and Kennedy (1999) believed that any attempt for an operational definition of inquiry-based science teaching needs to come “from grounded classroom practice” with the inclusion of teachers’ views. Keys and Bryan (2001) supported the idea that there does not exist one true definition of inquiry but each individual is expected to construct his/her own understanding of it. They expressed that “multiple modes and patterns of inquiry-based instruction are not only inevitable but also desirable because they will paint a rich picture of meaningful learning in diverse situations” (p.632). In that respect, providing a single definition of inquiry and its classroom applications is quite difficult (Henson, 1986).

Crawford (2000) presented some of the popular terms used by practicing teachers to refer inquiry teaching as doing science, hands-on science, and real-world science. Bonnstetter (1998) expressed that the definition of inquiry extends from “traditional hands-on” to “student research.” In order to characterize specific aspects of activities to be counted as inquiry, several scholars offered diverse understanding of inquiry-oriented science teaching. For example, Eick and Reed (2002) stated, “Activities that follow predetermined procedures and have known outcomes are generally not considered inquiry” (p.402). Hein (2002) more radically excluded all school laboratory work from his definition of inquiry teaching. He expressed:

Science inquiry consists of actions in the world that allow for multiple results. Any activity that is intended to lead to one result only should not be considered

inquiry. The definition excludes almost all school laboratory work, because that usually is intended to demonstrate a concept, not general, novel or diverse activity. (p.4)

Kluger-Bell (1999) noted, “Good science inquiry involves learning through direct interaction with materials and phenomena. One important sign of inquiry is the relative level of control that the students have in determining various aspects of the learning experience” (p.47). It seems that the nature of the learning outcomes, the design of the investigation procedure, and the degree of student control on the learning experience might be regarded as the most important determinant factors of a classroom activity to be considered as inquiry.

NRC (1996) described classroom-based inquiry as “the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (p.23). NRC (1996) further elaborated the inquiry process as:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p.23)

It seems that NRC (1996) does not reduce its definition of inquiry just into the primary sources but also includes the secondary sources into its definition. According to NRC (1996), inquiry in the classroom embraces several activities which involve “observation, data collection, reflection, and analysis of firsthand events and phenomena. Other activities encourage the critical analysis of secondary sources—including media, books, and journals in a library” (p.33). Sutton and Krueger (2001) stated, “Inquiry-based learning need not always be a hands-on experience. Reading, discussion, and research are fruitful techniques for practicing scientific inquiry when scientific questions and evidence-based arguments are used” (p.30). Hodson (1999) categorized inquiry experiences as either “literature/media based” or “field experience/laboratory-based”

(p.246). NRC (2000) presented essential features of classroom inquiry under five dimensions:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations. (p.25)

Levels of Inquiry Teaching

When talking about classroom inquiry, it is important to specify that not all inquiry activities deserve a full credit. Depending on the levels of students' control on choosing investigable questions, designing investigation procedures, and reaching meaningful conclusions, different levels of inquiry are defined (Eick, Meadows, & Balkcom, 2005; McComas, 2005a). For example, Schwab (1962) categorized inquiry laboratory activities under three levels with respect to their "openness and permissiveness" (p.55). NRC (1996) used "full inquiry" and "partial inquiry" (p.143) terms in order to distinguish the different levels of inquiry activities. With its most wide usage in science education community, inquiry-based science activities might take the forms of structured, guided, and open inquiry (Colburn, 2000; NWREL, 1997). In structured inquiry, students are provided the question(s) to investigate and the specific procedures/methods to follow, but they are expected to reach their own conclusions (Colburn, 2000; Llewellyn, 2002). Guided inquiry involves allowing students to design their own procedures/methods to investigate the specific question(s) provided by teacher (Colburn, 2000; Llewellyn, 2002; Windschitl, 2003). In open inquiry, students are allowed to raise their own questions and to devise their own procedures/methods to carry out their own investigations (Colburn, 2000; Llewellyn, 2002; Windschitl, 2003). Each level of inquiry is important and plays a distinct role in student learning. NRC (2000) stated:

Inquiry in the classroom can take many forms. Investigations can be highly structured by the teacher so that students proceed toward known outcomes...Or

investigations can be free-ranging explorations of unexplained phenomena...The form that inquiry takes depends largely on the educational goals for students, and because these goals are diverse, highly structured and more open-ended inquiries both have their place in science classrooms. (p.10)

However, it seems that there is some ambiguity whether confirmatory type of laboratory activities, also called “cookbook” science, can find themselves a place in the definition of inquiry as the lowest level of inquiry teaching because some researchers extend their definitions of inquiry to these traditional hands-on activities (e.g. Herron, 1971; Tafoya, Sunal, & Knecht, 1980; Windschitl, 2003) while many do not consider them as meaningful inquiry experiences (e.g. Colburn, 2000; Schwab, 1962). In cookbook science, students are expected to “confirm what is already known” (Llewellyn, 2002, p.67) by following a given procedure whereas structured inquiry proceeds through investigating a question provided by teacher with a prescribed procedure but with unknown outcomes by students (Colburn, 2000). According to Chinn and Malhotra (2002)’s analysis of middle and upper elementary textbooks, most hands-on science activities were based on these two types of experiences, that is, cookbook science and structured inquiry. Most science activities corresponded to three categories, which they called “simple experiments, simple observations, and simple illustrations” (p.179). In simple experiments, students conduct a straightforward experiment that involves investigating the effects of a single independent variable on a single dependent variable. Students, in simple observations, are expected to observe and describe objects. And in simple illustrations, students are led to follow a specific procedure “usually without a control condition, and observe the outcome” (p.179). However, using hands-on activities does not necessarily indicate that students are learning through inquiry. Rankin (1999) phrased this reality as “all hands-on is not inquiry; not all inquiry is hands-on” (p.34). NRC (1996) noted, “Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry” (p.23). NRC (1996) also stated, “Hands-on activities, while essential, are not enough. Students must have minds-on experiences as well” (p.2). If students do not know the outcomes of a hands-on activity beforehand, it is usually accepted as a structured inquiry, which is the lowest level of inquiry (Colburn, 2000). Consequently, it seems that the student

investigations conducted by given procedures and known outcomes by students are either considered not as inquiry or accepted as lower level of structured inquiry.

Since several levels of inquiry are defined in the science education community, it is imperative to know when to use what level of inquiry. It is well known that confirmatory type of science activities and structured inquiry are much more common than guided and open inquiries in science classrooms (Tobin et al., 1994). NRC (2000) welcomed both “partial inquiry” and “full inquiry” in science learning. When to use what level of inquiry is very much dependent on the expected learning outcomes and the specific needs of the students. Students are expected to gain both scientific inquiry abilities and scientific concepts in their science classes (NRC, 1996). Student exploration of problems suffers from highly structured activities while loosely structured activities minimize student conceptual understanding of science topics (Lynch & Zenchak, 2002). Structured inquiries may help students’ “conceptual change, [and] development of accurate scientific knowledge” (Keys, 1997, p.11). Open inquiries, on the other hand, may encourage students to “explore context and materials surrounding scientific concepts” (Keys, 1997, p.11).

Despite the importance of developing the ability to ask questions if the expected learning outcome is to acquire an understanding of scientific concepts, who posed the question becomes less important than what question is investigated (NRC, 2000). NRC (2000) expressed that students with little inquiry experiences usually need more structure. Llewellyn (2002) suggested using demonstrations in the beginning of the school year and continuing with structured activities, “teacher-initiated” and “student-initiated” (p.70) inquiries respectively as the semester progresses. Demonstrations may be used in the beginning of a topic in order to invite students for further inquiry by providing discrepant events (Llewellyn, 2002). Structured activities give the teacher an opportunity to observe that all students reach the same conclusion together while these type of experiences limit student creativity considerably (Llewellyn, 2002). “Teacher-initiated” inquiries are especially very valuable in terms of directing students to find their own ways to solve questions (Llewellyn, 2002). “Student-initiated” inquiries empower students as independent problem solvers by allowing them to conduct their own

investigations (Llewellyn, 2002). Consequently, all levels of inquiries find themselves a place in teaching science since each help to achieve a different learning outcome.

Personal Definition of Classroom Inquiry

Inquiry in its broadest sense is an active investigation process by which students seek an understanding of scientific ideas. In this process, students gain their own meanings by investigating the questions without knowing the answers beforehand. In order to investigate the question at hand, students may follow different investigation procedures either provided by teacher or developed by students. The investigation procedure is not limited to the simplistic understanding of scientific method such as observation, data collection, hypothesis testing, data analyzing etc. but it also includes other means of investigations such as analyzing written resources, discussion, reflection etc. However, inquiry in its essence is not the confirmation of the already known facts. On the contrary, students reach their own conclusions based on the evidence and understanding gained through the investigation process. In that sense, traditional hands-on science and structured inquiry differ since hands-on activities usually serve to verify known scientific ideas. All levels of inquiry may be used effectively in the classroom. However, open inquiry seems to be harder to achieve than structured and guided inquiries because students produce their own questions and develop their own investigation procedures and need to have considerable experience in the inquiry process. This type of investigation may be used effectively in science fair projects.

In the preceding section, I discussed the different levels of classroom inquiry. Student autonomy emerged as an important component of classroom inquiry, with the autonomy given to students displayed differences from one level of inquiry to another. Other than student autonomy, questions to be investigated by students play crucial roles in practicing inquiry. In the following section of the chapter, I present the inherent place of questioning in the process of student investigations.

A Quest for Questioning in Inquiry

Chin, Brown, and Bruce (2002) stated, "Questioning lies at the heart of scientific inquiry and meaningful learning" (p.521). Hogan and Berkowitz (2000) identified inquiry as "question-driven learning" (p.2). Gaining questioning skills constitutes one of the

most important aspects of inquiry learning. NRC (2000) noted, “In today’s science classrooms students rarely have opportunities to ask and pursue their own questions. Students will need some of these opportunities to develop advanced inquiry abilities and to understand how scientific knowledge is pursued” (p.36). Hodson (1999) underlined the importance of student investigation of authentic questions by criticizing laboratory activities in schools that give the students the impression that scientists are spending their time confirming what they already know. NRC (1996) stated, “Inquiry into authentic questions generated from student experiences is the central strategy for teaching science” (p.31). Therefore, student-generated questions might be considered as the soul of inquiry learning.

Questions when used appropriately can direct students’ natural curiosity into pursuing meaningful investigations. However, asking many questions does not necessarily mean that inquiry learning will occur (Llewellyn, 2002). The important nuance here is to be able to transform student questions into investigable forms by students. NRC (2000) identified two types of student questions, “existence questions” (p.24) which are usually presented by “why”, and “causal/functional questions” (p.24) which are usually posed by “how.” Since how questions are generally more investigable scientifically than “why” questions, many of “why” questions might be changed into “how” questions in order to lend themselves for a scientific inquiry (NRC, 2000). Thus, it is important for teachers to recognize “information and investigation-type questions” (Llewellyn, 2002, p.128) in order to encourage their students to investigate their meaningful questions.

After presenting the meaning of inquiry in relation to science education literature, I discuss the approaches of science teachers to the central reform idea of teaching science through inquiry in the following section of the chapter. This is crucially important because developing appropriate understandings of classroom inquiry by teachers determines the future success of the inquiry in the education system.

Teachers and Inquiry Science Teaching

Teachers occupy the central place in the success of educational reform efforts (Johnson, 2006; Jones & Eick, 2007; NRC, 1996). No single educational reform

movement would succeed without the cooperation of teachers, who are the ultimate agents to convey the reform efforts to their students and classroom context. This is also true for current science education reforms (Johnson, 2006). Achieving the goal of scientific literacy is very much dependent on whether teachers adopt the philosophy of the science education reform documents and they incorporate it in their teaching practices. However, this does not seem to be happening in science classrooms (Davis, 2003). According to Horizon Research (2003), teachers' practices have not gone through a significant change since the publication of National Science Education Standards. Although emphasis is placed on the importance of teachers' increasing use of inquiry-based science teaching in their classrooms, most teachers still build their teaching on didactic teaching methods with a heavy emphasis on textbooks (O'Sullivan & Weiss, 1999). "Alternative teaching methods are most commonly used as supplements to, rather than as replacements for textbooks, even among teachers who believe in structuring learning around activities other than textbooks" (O'Sullivan & Weiss, 1999, p.224). Any meaningful change in teaching practices ultimately rests on both teachers' willingness to change their practice and their capacity to do so (Horizon Research, 2003).

Teaching science by helping students engage in meaningful inquiry experiences is complex and sometimes challenging process (Crawford, 1997, 1999; Fradd & Lee, 1999) and being able to do so requires teachers to have reasonable experience in presenting science by this way. However, most teachers do not learn science in their undergraduate education in a way they are expected to teach their students (Newman et al., 2004). Most science teachers graduate from universities without having even a single authentic scientific inquiry experience (Windschitl, 2003). University science courses do not help teachers develop an understanding of scientific inquiry and abilities to enact inquiry in their classrooms. Deng (2001) emphasized the gap between what physics teachers learn in their university physics courses and what they actually teach in their classrooms. Deng (2001) further expressed that "a teacher is not a physicist, but rather a teacher of physics. They need to understand key ideas differently than a physicist does" (p.264). McDermott et al. (2000) noted, "Neither courses for majors nor for non-majors provide the kind of preparation required for teaching physics or physical

science by inquiry. Science methods courses cannot help teachers develop the depth of understanding needed for this type of teaching” (p.411). However, NRC (1996) stated, “Prospective and practicing teachers must take science courses in which they learn science through inquiry, having the same opportunities as their students will have to develop understanding” (p.60). NRC (1996) further articulated that “teacher learning is analogous to student learning: Learning to teach science requires that the teacher articulate questions, pursue answers to those questions, interpret information gathered, propose applications, and fit the new learning into the larger picture of science teaching” (p.68).

In order for inquiry-based science teaching to be a mainstream teaching strategy in American classrooms, teachers must possess adequate experiences and appropriate conceptions of classroom inquiry themselves before they can help their students develop similar understandings (Taylor & Dana, 2003). Southerland et al. (2003) underlined the reality that without significant changes in university science instruction, it would be unreasonable to hope that prospective teachers will be able to teach science differently. Windschitl (2003) stated:

Preservice teachers’ use of inquiry in the classroom is most strongly associated with previous research experience. Knowing then how potentially powerful these experiences can be, it suggest that teacher education programs should promote some authentic science research experiences either in conjunction with methods classes or within other areas of the preservice program. (p.140)

With this purpose, many universities promote different approaches to help preservice and inservice teachers experience the scientific inquiry process. Brown (2002) classified these approaches under three categories: institute, apprenticeship, and inquiry course model. In institute model, pre or inservice teachers are exposed to authentic scientific research experiences with the collaboration of scientists. These experiences are frequently referred as summer workshops and usually involves shorter amount of time than apprenticeship model. In apprenticeship model, teachers are placed into real scientific research activities to work alongside the expert scientists. Through apprenticeship model, teachers get a chance to experience the culture of scientific research. Inquiry course model offers preservice teachers opportunities to learn some

scientific ideas through engaging in inquiry-based laboratory activities. The experiences prospective teachers have in inquiry environments also promote their developing identities as inquiry science teachers (Volkmann & Anderson, 1998).

Challenges of Teachers with Inquiry Science Teaching

The science education literature reveals many challenges of teachers with inquiry-based science teaching. Most of these challenges are presented with the term “barriers” that prevent teachers from using inquiry in their classrooms. Anderson (2002) used the term “dilemmas” to reflect that most of the difficulties are internal to teachers rather than external implied by the former term. These dilemmas are mostly associated with teachers’ existing “beliefs and values related to students, teaching, and the purposes of education” (Anderson, 2002, p.7). Anderson (2002) presented these barriers and dilemmas in three dimensions: technical, political, and cultural dimension. The dilemmas and barriers in these dimensions extend from inadequate education of teachers, textbook dependency, new teacher and student roles, and difficulty of the assessment of inquiry learning to insufficient professional development opportunities, parental resistance, lack of resources, unresolved conflicts among teachers, and commitment to prepare students for the next level of schooling by covering the topics in student textbooks (Anderson, 2002). Teaching science by inquiry demands new roles and new ways of thinking from teachers quite different than traditional teaching of science (Levitt, 2001; Sandoval & Daniszewski, 2004). Additionally, teachers care more about what works in their classrooms than what research reports. According to Welch et al. (1981), the perceived difficulty of inquiry plays the most important role in teachers’ reluctance to use inquiry in their classrooms. They listed some other factors as the confusion about the meaning of inquiry, the belief that inquiry works well for high ability students, the commitment to teaching facts, and the responsibility of preparing students for the next level of schooling. Songer et al. (2003) highlighted the negative effects of high-stakes standardized tests on teachers’ willingness to try more risky and in-depth inquiry-based science activities. Crawford (1997) noted that “one possible reason that inquiry-based instruction remains a vision in the reforms, but an enigma in the classroom may lie in the fact that teachers have few operational models” (p.17). Keys (1997) asserted that teachers have difficulty of embracing inquiry-oriented science

teaching due to “the juxtaposition between freedom and privileging” (p.8). She expressed that students need freedom to establish their understanding of authentic knowledge through their own ideas but science is a discipline based on privileging some ideas over others. She added:

The majority of science teachers are confused and frustrated by rhetoric which calls on the one hand for students to design and conduct their own inquiries, and on the other hand for teachers to design inquiries that guide children to an understanding of difficult science concepts. (p.9)

Edelson, Gordin, and Pea (1999) provided some of the challenges that teachers have for successful implementation of classroom inquiry under five themes: (a) the necessity for the higher levels of student motivation due to the challenging and extended nature of inquiry science learning, (b) the need for students’ understanding of investigation techniques to be able to engage in meaningful inquiry activities, (c) the demand for students’ possession of science background knowledge to be able to formulate research questions, develop an investigation procedure, and collect, analyze and interpret data, (d) the difficulty of organization and management of complex and extended inquiry activities by students, and (e) the practical constraints of the learning context such as the restrictions of available resources and fixed schedules.

Crawford (2000) argued that teachers need high levels of pedagogical content knowledge and nature of science [NOS] in order to be able to implement inquiry into their teaching. However, many teachers possess an inadequate understanding of NOS (Bartholomew, Osborne, & Ratcliffe, 2004; Schwartz et al., 2004) that bears some negative connotations for the motivation and abilities of teachers to enact inquiry in their classrooms. Creating an inquiry-oriented environment is more challenging for beginner teachers who spend additional efforts just to survive on the job. Crawford (1999) sought an answer to the question of whether preservice science teachers can create an environment in which their students engage in meaningful inquiry experiences. The prospective teacher in the study was able to carry out two inquiry-based units successfully in her classroom. However, according to Crawford (1999), six key factors helped this particular preservice teacher in her effort to enact inquiry with her students: her prior research laboratory experience, her working experience in project-oriented

classrooms as a teacher's aide, having a clear understanding of the goals and objectives for the inquiry units that she carried out, her close relationship with her mentor teacher, getting support from experts outside the classroom, and her ability for consistent and thoughtful reflection on her practice. Crawford (1999) concluded that "preservice teachers, given certain caveats and adequate support, can feasibly create inquiry-based environments similar to those advocated in the National Science Education Standards" (p.189).

Roth, McGinn, and Bowen (1998) investigated whether beginning secondary teachers are prepared to teach inquiry and the strategies of data analysis in their classrooms. Although the majority of 32 teachers in the study had an undergraduate degree in a field of science, their scientific representation practices did not exhibit a higher level of sophistication than Grade 8 students. Roth et al. (1998) commented that the prospective teachers in the study, despite their science background, "did not use the representative practices in the way practicing scientists do. One has to, therefore, question whether these teachers would be able to enact the kind of science and mathematics curricula promoted by...[current reform movements]" (p.43). It seems that preservice teachers need considerable experiences in learning science through inquiry in order them to be able to teach their students with the similar strategies.

Need for More Research on Teachers' Conceptions and Enactment of Inquiry

Several researchers pointed out the importance of conducting more research studies on inquiry science teaching and learning in a variety of classroom contexts, which helps science education community gain a better understanding of teachers' conceptions and enactment of this type of teaching (e.g. Anderson, 2002; Buck, Latta, & Leslie-Pelecky, 2007; Jeanpierre, 2006; Keys & Bryan, 2001; Keys & Kennedy, 1999; Songer et al., 2003; Windschitl, 2004). A comprehensive examination of the education literature indicated the need for investigating NBCSTs' notions and practices of classroom inquiry. Although these teachers exemplified their teaching practices of science through inquiry in their NBC portfolios, their understanding of classroom inquiry was not scrutinized by researchers. Investigating the inquiry conceptions of NBCSTs would enrich the science education literature with the perspectives of these experienced science teachers. As we develop a better understanding of the perspectives of these

recognized science teachers, the science education community can make better decisions in how to utilize them in science education reform efforts.

Research on the experiences of preservice teachers with classroom inquiry mostly took place in science method courses or special inquiry-based science classes (e.g. Duran, McArthur, & Van Hook, 2004; Hayes, 2002; Newman et al., 2004; Volkmann & Zgagacz, 2004; Windschitl, 2003) whereas it seems that researchers generally focused on practicing teachers' implementation of specific inquiry curriculum units in their classrooms (e.g. Feldman, 2002; Sandoval & Daniszewski, 2004; Songer et al., 2003; Zion et al., 2004). However, additional research studies conducted on diverse teacher groups who manage inquiry in their natural classroom environments would inform researchers and other teachers about the workings and non-workings of inquiry-based teaching and learning of science.

Summary

In recent years, particularly after the publication of National Science Education Standards, the emphasis placed on inquiry-based science teaching and learning gained increased momentum in science education community. That is partly because such teaching strategy promises educating students with higher capabilities of systematic and critical thinking, termed as "scientific habits of mind." In a world driven by higher technologies and scientific innovations, the importance of having these capabilities comes to the fore. Although reform movements in science education consistently promote teachers' increasing use of inquiry teaching strategies in their classrooms, little success has been observed in this respect since the term inquiry entered into science education literature almost a half century ago. Current science education research literature indicates the need for more research studies conducted on teachers' conceptions and enactments of such teaching strategies in order to enhance our understanding of teachers' diverse approaches to inquiry-oriented science teaching. Although inquiry-based science teaching occupies an important place in achieving NBC, my literature review revealed specific research studies conducted neither on NBCSTs' learning experiences with classroom inquiry in NBC process nor their understandings and enactments of classroom inquiry. Thus, my study aims to fill this gap.

After providing the relevant literature about NBC and classroom inquiry in this chapter, I present the research methodology and methods in the following chapter.

CHAPTER 3

RESEARCH PERSPECTIVE

Introduction

Since the first release of National Board Certification in 1993-94 period, many teachers have experienced this rigorous performance-based teacher assessment. By 2007, over 55,000 teachers in total were awarded their advanced teaching certificates with NBC. As teachers go through this reflective professional development process, each individual teacher attaches a specific meaning to his/her NBC experiences. In this dissertation study, I as a researcher seek to understand these specific meanings constructed by NBCSTs with their NBC learning experiences. Furthermore, I also strive to gain an understanding of what it means to teach science by inquiry for NBCSTs. However, my goal, by no means, is to pursue universally generalizable conclusions but I attempt to provide a “photographic slice of life” (Lincoln & Guba, 1985, p.155) that represents a “here-and-now” (Lincoln & Guba, 1985, p.155) account of NBCSTs’ lived experiences. I hope what my study reveals find itself a fit in others’ life experiences (Wallen & Fraenkel, 2001). I see my main role as a researcher is more than simply a “technician-gathering-info[r]mation” (Guba & Lincoln, 1989, p.10) but rather an “orchestrator of the negotiation process” (Guba & Lincoln, 1989, p.10), who keeps participant teachers cognizant of other teachers’ meaningful constructions and provides teachers opportunities to reflect on others’ perspectives. In order to gain an understanding of teachers’ meaningful constructions, I employ a naturalistic (constructivist)² inquiry methodology in the research process. In figure 1 below, I

² I use naturalistic inquiry and constructivist inquiry terms interchangeably in my paper. Lincoln & Guba (1985) used former term in their book of *Naturalistic Inquiry* whereas they (1989) preferred latter term in their later book of *Fourth Generation Evaluation*.

represent my general research perspective by picture frames. These frames display the basic tenets of what I follow through the research process.

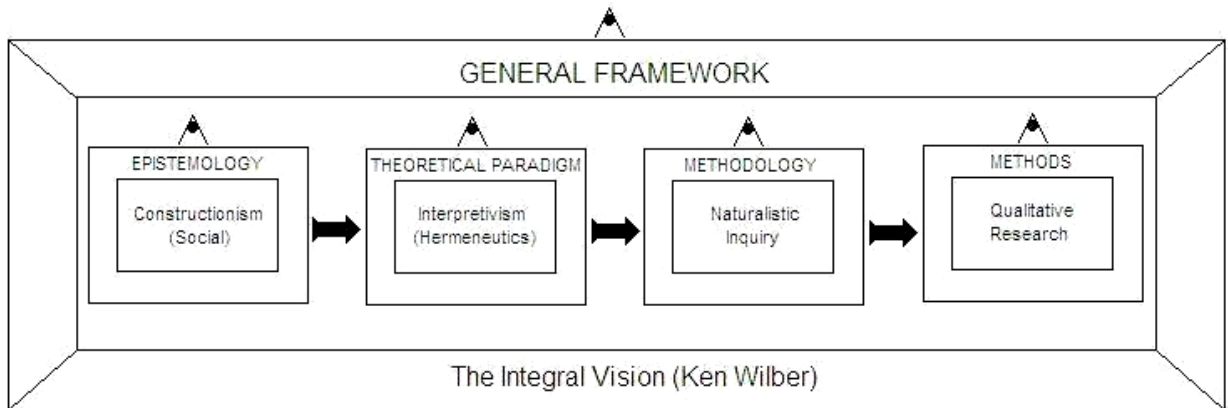


Figure 1 General Display of Research Perspective

In figure 1 above, the outer frame provides me the bigger picture, which helps me to situate and to keep my investigation in an appropriate research path. The inner frames exhibit the principles of research mechanism in an organized manner. In the subsequent sections, I will further elaborate what all these frames mean for my research study.

The Integral Vision

Wilber (1997a) proposed an integral vision model, which embraces and honors all knowledge forms in an integrated manner. His model is based on the premise of the existence of “the four faces of truth” (1997a, p.12) and represented by a four-quadrant diagram. “Each [quadrant]... tell...[s] us something very important about various aspects of the known world” (Wilber, 1997a, p.11). “Each of the quadrants has a different ‘type of truth’ or validity claim—different types of knowledge with different types of evidence and validation procedures” (Wilber, 1997b, *The Contours of Consciousness*, ¶ 2). In Figure-2 below, right and left hand side quadrants respectively represent exterior and interior aspects of events while the upper and lower quadrants correspond to individual and collective forms of knowledge respectively. Right hand side quadrants stand for objective realities, which can be investigated by empirical methods.

Subjective-Intentional Truthfulness Sincerity Integrity Trustworthiness	I N D I V I D U A L	Objective-Behavioral Truth Correspondence Representation Propositional
INTERIOR		EXTERIOR
Intersubjective-Cultural Justness Cultural Fit Mutual Understanding Rightness	C O L L E C T I V E	Interobjective-Social Functional Fit System Theory Web Structural-Functionalism Social Systems Mesh

Figure 2 The Integral Vision-Four Quadrant Model (Ken Wilber)

However, left hand side quadrants symbolize subjective realities, which require interpretive methods to be understood. In the upper quadrants, individual meanings are the central focus whereas lower quadrants center on collective meanings.

I personally think that this model is a very useful tool in terms of helping one to have a better conceptualization of his/her research study. It keeps one informed about the general borders of the specific type of truth represented by one's research focus and the appropriate ways of pursuing and validating this represented truth. In Wilber's model, each quadrant has a different view of how the world works. Operating on a quadrant requires one to adopt the specific views of this quadrant. And "different ways of viewing the world shape different ways of researching the world" (Crotty, 1998, p.66). Dilthey asserted that natural and social sciences differ with respect to the type of realities they represent. Dilthey expressed that natural sciences seek *causal explanations* whereas human sciences pursue *subjective understanding* (as cited in Prasad, 2002). The main purpose in my study is to gain understanding of the meanings

constructed by participant teachers out of their inquiry science experiences with NBC phenomenon. Seeking for understanding of teachers' subjective meanings compels me to function with the norms of left hand side quadrants due to the fact that left side quadrants represent interior (subjective) aspects of individually and collectively experienced events. Wilber's model approaches all knowledge forms with an equal distance. No individual quadrant is privileged in terms of the type of truth it represents. Choosing to operate on the left hand side does not put me in a position to believe in either one or another. I respect and value what right hand side has to offer but for the specific purposes I seek in this study, I perform my research investigation with the fundamental tenets of left hand quadrants. Sexton (1997) summarized some of the characteristics of these fundamental tenets as "the perspective of the observer and the object of observation are inseparable; the nature of meaning is relative; phenomena are context-based; and the process of knowledge and understanding is social, inductive, hermeneutical, and qualitative" (p.8).

Meaningful Constructions

Human beings' search for answers to fundamental questions like "What is reality?" and "How can we come to know what is real?" is as old as human history. What answers a researcher gives to them is important because one's approach to answering to these questions determines one's way of inquiring into them. However, there is no one way of answering these questions. Lincoln and Guba (1985) identified four types of realities: objective, perceived, constructed and created realities. What objective reality standpoint asserts is that there exists a tangible reality, which perpetuates its existence free from our interaction with it and can be known fully by experiencing and investigating it. While acknowledging a self sustainable reality independent from its observer, perceived reality position, on the other hand, opposes the idea of fully knowable objective reality because what we perceive as real is an incomplete view of "a limited number of parts of the whole" (Lincoln & Guba, 1985, p.83) but not the whole picture. According to constructed reality perspective, it is questionable whether there is a real reality because we can never know that (von Glasersfeld, 1991), but what we accept as real is our constructed meanings from out of our experiences in a socially and culturally

interwoven world. Created reality viewpoint argues that no reality exists at all, in that, what we experience as real is no more than our created illusions. In the left side quadrants, reality is either constructed or created by individually or collectively under social and cultural influences. My personal stance is that I prefer to conceptualize meaning as social constructions, that is, different individuals construct their own unique realities by interacting in a social environment. In that sense, social constructionism informs my research study epistemologically.

Despite inconsistencies of how the terms constructivism and constructionism are used in terminology (Raskin, 2002), the latter one is generally recognized with the emphasis it puts on the social dimension of meaning (Crotty, 1998). In a constructionist position, “the emphasis is...not on the individual mind but on the meanings generated by people as they collectively generate descriptions and explanations in language” (Gergen & Gergen, 1991, p.78). Constructivism conceptualizes individuals as beings making sense of the objects in the world whereas constructionism asserts that we are introduced directly to a whole world of meanings (Crotty, 1998). According to Gergen (1985), the term constructivism is also used to refer to Piagetian theory and a movement in 20th century art. Gergen (1985) noted that the term constructionism prevents any confusion with theories and movements mentioned above and also provides a linkage to Berger & Luckmann’s (1966) classical book, *The Social Construction of Reality*. Crotty (1998) noted that constructionism is based on the premise that “all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context” (p.42).

Constructionist standpoint is neither objective nor subjective (Crotty, 1998). What constructionism asserts that there is no objective reality waiting to be discovered. Subjective meaning is created “out of nothing” (Crotty, 1998, p.9) with no involvement of an object at all. However, constructionist meaning is not discovered or created but generated “out of something” (Crotty, 1998, p.9). This something is our world and the objects in it. “The object[s] may be meaningless in [them]...sel...[ves] but [they have]...a vital part to play in the generation of meaning” (Crotty, 1998, p.48). However, meaning

comes into existence only by the engagement of a conscious mind with the objects in the world. Crotty (1998) noted, "What kind of a world is there before conscious beings engage with it? Not an intelligible world...Not a world of meaning. It becomes a world of meaning only when meaning-making beings make sense of it" (p.10).

Understanding of constructionism's ontological position is sometimes troublesome because there is no consensus on whether constructionist stance is in favor of realism or idealism. For example, Crotty (1998) stated that it "is at once realist and relativist" (p.63), that is, constructionism in epistemology does not contradict with realism in ontology. Chiaro and Nuzzo (1996) noted that different constructivist perspectives attempt to construct a bridge between realist and idealist approaches. They (1996) characterized two broad understandings of constructivism: epistemological and hermeneutic constructivism. The former one does not reject the existence of an objective reality free from its knower but we make sense of it through our constructions and we can never know whether these constructions correspond to this independent reality. von Glasersfeld's radical constructivism can be given as an example of this approach. von Glasersfeld (1991) expressed:

Constructivism deals with knowing not with being. There is no simple argument to justify the distinction between experiential reality and ontological reality....As a constructivist I have never said (nor would I ever say) that there is no ontic world, but I keep saying that we cannot know it. (p.17)

The latter one, on the other hand, does not recognize an independent objective reality. All meaningful reality is generated through linguistic activities in social discourse (Raskin, 2002). Gergen's social constructionism can be considered as an example of hermeneutic constructivism approach. Guba and Lincoln (1989) expressed that "constructions are...created realities. They do not exist outside of the persons who create and hold them; they are not part of some 'objective' world that exists apart from their constructors" (p.143). Any attempt to describe one's experiences with the world is subject to the rules of discourse because whenever we think or talk about the world, we automatically begin to represent it (Edley, 2001). That is why "reality cannot exist outside of discourse, waiting for fair representation. Instead, it is the product of discourse" (Edley, 2001, p.437). Burr (1998) noted, "Even if there were some ultimate or

fixed reality behind discourse and social constructions, we could never describe it, since to do so would inevitably mean to offer an account of it, thus transforming it into a discursive event” (p.19). In summary, it would be appropriate to say that constructionist approaches one way or another seek for the truth in meaningful constructions but not in somewhere else. While the concept of independent objective reality is approached suspiciously, the perspective of multiple representations of reality is fostered. However, these individual or collective constructions by no means represent an absolute truth but they are all meaningful representations of reality for their constructors.

Through the research process, I as a researcher spent all my effort on making sense of NBCSTs’ meaningful constructions. In my search for an understanding of these meaningful constructions, I supported the notion that “no one owns the truth and everyone has the right to be understood” (Doll, 1993, p.155). These constructions emerged in a shared context through our interactions with each other. However, in our interactions with each other, the purpose was not to prove the betterness of ideas but to reach a consensus of multiple perspectives. What we shared as a negotiated meaning was the most informed construction at a time, which formed a reality for us but did not imply a greater degree of reality (Guba & Lincoln, 1989).

Understanding Meaningful Constructions

On the left hand side quadrants, the major goal of a researcher is to understand what individual and collective constructions mean for their constructors. In order to understand these subjective meanings, the researcher needs to immerse himself into the particular context where these meanings are generated and to interact with the people who have a hand in generation of these meanings because understanding takes place through dialogue and interpretation (Gadamer, 1989; Wilber, 1997a). Gadamer (1989) expressed that the “miracle of understanding...is not a mysterious communion of souls, but sharing in a common meaning” (p.292). This common meaning comes into existence as we have dialogue with others (Schwandt, 1999). Gadamer (1989) considered conversation as the basis of understanding what others say by stating:

Conversation is a process of coming to an understanding. Thus it belongs to every true conversation that each person opens himself to the other, truly accepts his point of view as a valid and transposes himself into the other to such

an extent that he understands not the particular individual but what he says.
(p.385)

Through conversation, meaning becomes an intrinsic aspect of the social world. In this social world, meaning is gotten across by language.

The role of language is very crucial in social construction of meaning. We create our unique meanings by communicating with others and the language we use in our communication with others is the medium upon which we base our understanding of others. Gadamer (1997) stated:

Language is the element in which we live, as fishes live in water. In linguistic interaction, we call it conversation. We search for words, and they come to us, and they either reach the other person or fail. In the exchange of words, the thing meant becomes more and more present. (p.22)

However, language cannot be conceived simply as a mirror of reality (Edley, 2001; Nightingale & Cromby, 2002) but rather it plays an active role in construction of meaningful reality (Wilber, 2000). Edley (2001) expressed that "language...is productive rather than (merely) reflective. 'Reality' isn't so much mirrored in talk and texts as actually constituted by them" (p.435). However, regardless of its role in construction of meaningful reality, language is at the center of understanding (Crotty, 1998).

Because language is a shared entity, the meaning people construct in that sense is not subjective but inter-subjective (Schwandt, 1999). However, we gain an understanding of these inter-subjective meanings by inquiring into people's subjective experiences. von Glaserfeld (1995) noted:

Every learner of a language must construct his or her word meanings out of elements of individual experience....There is no doubt that these subjective meanings get honed, modified, and adapted throughout their use in the course of social interactions. But this adaptation does not and cannot change the fact that the material an individual's meanings are composed of can be taken only from that individual's own subjective experience. (p.137)

Gaining understanding of what these subjective experiences mean for their owners involves interpreting what they say about their experiences. According to Gadamer (1989), "Understanding occurs in interpreting....[and] all understanding is

interpretation” (p.389), and it is the only way for a deeper understanding of people’s interior worlds (Wilber, 1997a). Wilber (2000) noted:

You can see my surfaces, but in order to understand my interior, my depths, you will have to enter into the interpretive circle (the hermeneutic circle). You, as a subject, will not merely stare at me as an object, but rather you, as a subject, will attempt to understand me as a subject—as a person, as a self, as a bearer of intentionality and meaning. You will talk to me, and interpret what I say; and I will do the same with you. We are not subjects staring at objects; we are subjects trying to understand subjects—we are in the intersubjective circle, the dialogical dance. (p.161)

My study was interpretive in nature due to the fact that I as a researcher sought a comprehensive understanding of NBCSTs’ personal meanings. Through my continuous dialogues with participant science teachers, I tried to build a good rapport with them. I believe that this encouraged teachers to share their sincere thoughts with me. In my exploration of the meanings held by participant teachers, I used the hermeneutic dialectic circle (Guba & Lincoln, 1989). I elaborate the working mechanism of the hermeneutic dialectic circle in the subsequent section.

Hermeneutic Dialectic Circle

Hermeneutics as a word derives originally from the Greek word *hermeneuein*, which means ‘to interpret’ or ‘to understand’ (Crotty, 1998). Through its historical development, hermeneutics became the science of interpretation and different forms of hermeneutics emerged. Three major forms of hermeneutics can be classified: classical, philosophical, and critical hermeneutics (Prasad, 2002). For classical hermeneutic theorists such as Schleiermacher and Dilthey, the purpose of interpreting a text, broadly speaking, is to recover the original meaning intended by the author of the text (Prasad, 2002). In that sense, the goal of classical hermeneutics is to guide the methodological process of correct interpretation and understanding. On the other hand, in Heidegger’s and Gadamer’s philosophical hermeneutics, the main concern is not to provide a prescriptive theory of the practice of interpretation but to scrutinize “what is constitutively involved (in a deep, philosophical sense) in each and every act of interpretation”

(Prasad, 2002, p.15). Critical hermeneutic theorists such as Apel and Habermas argue the necessity of including a critique of the ideological aspects of the text into the practice of interpretation (Prasad, 2002).

Within the hermeneutic tradition, it is a common practice to conceptualize the relation of an interpreter and a text with a circular movement, known as hermeneutic circle (Prasad, 2002) but no single understanding of this circular movement exists (Rasmussen, 2002). Hermeneutic circle assumes that understanding emerges with the mutual interactions of whole and parts. In other words, in any event of interpretation, the understanding of parts can only be achieved by grasping the meaning of whole and vice versa (Wilber, 1997a; Snodgrass & Coyne, 1997; Grondin, 2002; Prasad, 2002). For instance, we cannot understand the individual meanings of the words that make up a sentence before we locate them in the context of the whole sentence, and we cannot understand what a whole sentence means until we understand the individual words that comprise the sentence (Snodgrass & Coyne, 1997). From a hermeneutic perspective, understanding in hermeneutic circle is more than a “logical and analytical process” (Prasad, 2002, p.18) but in some respect, it also involves “intuitive and divinatory” (Palmer, 1969, p.87) aspects. According to Gadamer (1989), interpreter’s prejudices play an important role in understanding of a text because the interpreter approaches the text not as empty minded but with his/her expectations and preunderstanding of the specific historico-cultural context to which the text belongs (Prasad, 2002). These prejudices constitute the horizon of the interpreter’s understanding. For Gadamer (1989), understanding of a text is achieved as a result of the fusion of the interpreter’s and the text author’s horizons. Gadamer (1989) further regards understanding as coming to an agreement between two parties in dialogue. He (1989) stated that “to understand means to come to an understanding with each other...Understanding is, primarily, agreement...Thus people usually understand...each other immediately, or they make themselves understood...with a view toward reaching agreement (p.180).

Guba and Lincoln (1989) expressed that naturalistic (constructivist) inquiry paradigm employs hermeneutic dialectic methodology. Guba (1990) explained hermeneutic and dialectic aspects of this methodology as:

The hermeneutic aspect consists in depicting individual constructions as accurately as possible, while the dialectic aspect consists of comparing and contrasting these existing individual (including the inquirer's) constructions so that each respondent must confront the constructions of others and come to terms with them. (p.26)

Figure-3 below displays some of the details of how the hermeneutic dialectic circle guides the interpretation process. In Figure-3, R stands for a "Respondent" and C represents a "Construction" generated jointly by the researcher and a respondent with the involvement of other emerging constructions.

In naturalistic inquiry perspective, the selection of respondents for the circle is not arbitrary but purposive (Lincoln & Guba, 1985). The purpose is not to generalize over a larger population but rather to gain "the broadest scope of information" (Guba & Lincoln, 1989, p.178) from the respondents. However, while this is the case in the beginning phases of hermeneutic circle, as some of the themes become more apparent, selection of new respondents is based on the consideration to articulate these salient themes further. My respondents in the hermeneutic dialectic circle were four NBCSTs. I purposefully selected those NBCSTs for my study. My selection of those experienced science teachers was due to their recognized teaching abilities by NBPTS. In addition, they had experienced the NBC portfolio assessment process and demonstrated their capabilities of enacting inquiry with their students in their NBC portfolios. My selection of NBCSTs to participate in the dissertation study was also at my convenience. I preferred to work with science teachers who taught in a school located at the same county in which I had been living. In order to make a better sense of the constructions of teachers emerged in the study, I needed to familiarize myself with their specific classroom contexts in which those constructions were formed. By that purpose, I spent a prolonged time in their classroom contexts by observing several of their classes. Working with teachers who taught in nearby schools provided the opportunities to me to have more interactions with them.

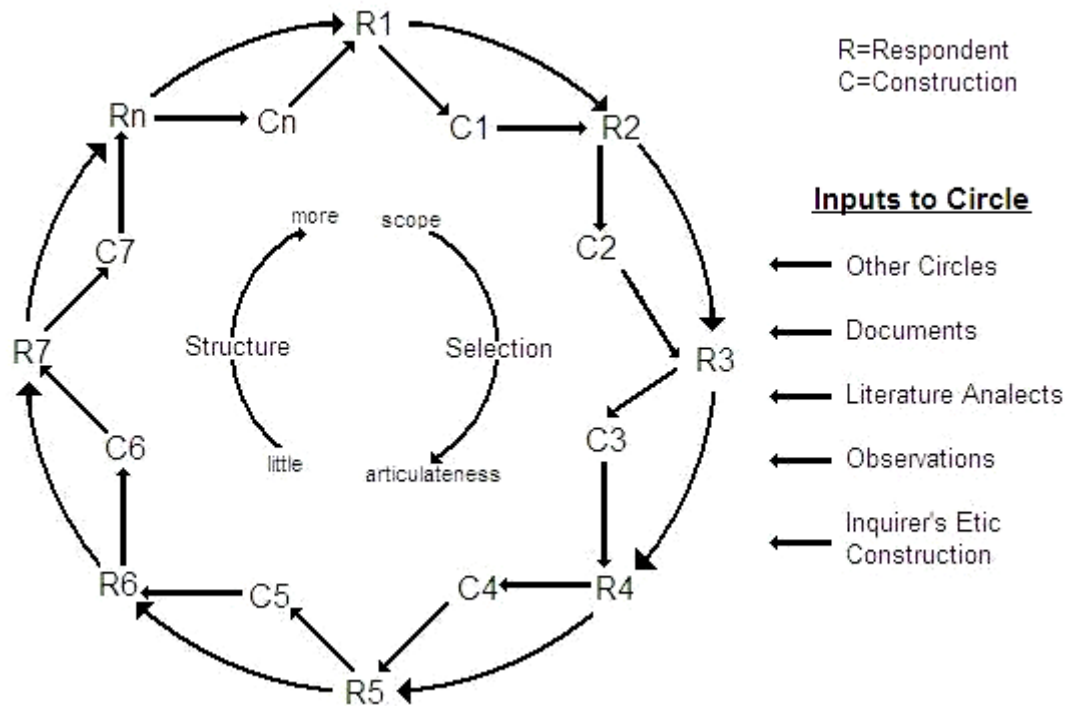


Figure 3 The Hermeneutic Dialectic Circle (Guba & Lincoln, 1989)

The process of hermeneutic dialectic circle starts by conducting an in-depth interview with one of the respondent teachers (R1). This initial interview, which includes mostly open-ended questions in order to allocate more freedom to the respondent teacher (R1) in expressing his/her views with his/her own terms, generates a construction (C1) between the researcher and R1. The researcher next interviews second respondent (R2) by allowing him/her same freedom of expression as was R1. However, the researcher additionally introduces R2 some of the themes emerged from C1 and allows R2 to comment on these themes. Therefore, the interview with R2 generates information not only about R2 but also a critique of R1's construction (C1). The analysis of the second interview results in the formation of C2. The researcher then introduces C2 to the next respondent (R3) and invites R3 to comment on some of the salient themes from C2. Likewise, subsequent teacher interviews in the hermeneutic circle proceed by introducing the earlier construction back into next interview process. The circular movement continues with new respondents until the information obtained from respondents either becomes redundant or produces two or more constructions that stay systematically in dispute with each other (Guba & Lincoln, 1989). As the

respondent teachers criticize the preceding respondent's construction, a joint construction, which exhibits a consensus among all responded teachers, begin to emerge. This joint construction can be considered as "the most informed and sophisticated construction that it is possible to develop in this context, at this time, with these respondents" (Guba & Lincoln, 1989, p.179). However, even if no consensus occurs, the process is empowering and educative for the participants anyway (Guba & Lincoln, 1989). It is empowering because each respondent teacher, including the researcher, shares the power and each single construction is taken into account in searching for a joint agreement. It is also educative because each respondent becomes cognizant of other teachers' constructions and reaches new levels of information by developing a criticism of others' and as well his/her own constructions. Besides, the information gained through the hermeneutic circle need not be confined to just what participant teachers bring to it but other forms of inputs such as salient themes from teacher observations, information from documents, relevant topics from the literature etc. can also be introduced to the process.

I started the hermeneutic dialectic circle by interviewing Mary first. In the interviewing process, I posed open-ended questions to Mary to give freedom to her in expressing her thoughts with her own terms (see Appendix-B). In my original plans, I wanted to transcribe the whole interview before conducting a new interview with the second teacher. However, this did not work as I expected because transcribing the interviews required hard work and took much longer than I originally expected. Then, I decided to listen to the interviews carefully to get an idea about the overall thoughts of the teachers. As I listened to their interview audiotapes, I took some notes on the salient issues emerged from their interview responses. This process helped me to ask better informed questions to the succeeding interviewees and to obtain their views on these emerging salient issues. I conducted the interviews with other teachers approximately a week apart. The second interviewee in the hermeneutic circle was Jennifer. Like Mary, I allowed Jennifer to express herself freely in response to my interview questions. However, at the end of the interview process, I posed additional questions to Jennifer in order to get her ideas about some of the constructions emerged from Mary's interview responses. This was helpful to create synchronization between teachers' peculiar

perspectives. At the same time, it allowed teachers to become cognizant of other teachers' views. After listening to and taking notes from Jennifer's interview audiotape, I conducted another interview with Patricia a week later. Before introducing the constructions of other teachers to Patricia, I allowed her freedom to provide her answers to the open-ended interview questions. The first rounds of formal interviews ended by following the same process with Martha. After the first interviews with the teachers, the semester ended and the teachers took their summer break holidays. In the summer, I worked on transcribing the interview responses of the teachers. I also prepared the questions for the second round of interviews with teachers. In the interview questions, I included some of the salient issues emerging from my preliminary analyses of teachers' first interview responses. The second rounds of formal interviews started approximately 4 months later. This time, Martha was the first teacher in the second rounds of interviews. The hermeneutic circle process continued in the same manner as discussed earlier. Throughout the interviewing process, in addition to expressing themselves freely, the teachers were given the opportunities to reflect on the constructions of other participant teachers.

Naturalistic (Constructivist) Inquiry

In an attempt to grasp an understanding of multiple perspectives held by NBCSTs with respect to NBC assessment process and inquiry-based teaching of science, my dissertation study utilized the methodology of naturalistic inquiry. This methodology:

Rejects the controlling, manipulative (experimental) approach that characterizes science and substitutes for it a hermeneutic/dialectic process that takes full advantage of the observer/observed interaction to create a constructed reality that is as informed and sophisticated as it can be made at a particular point in time. (Guba & Lincoln, 1989, p.44)

Figure-4 below displays some of the characteristic aspects of naturalistic inquiry, of which follows a further explanation below.

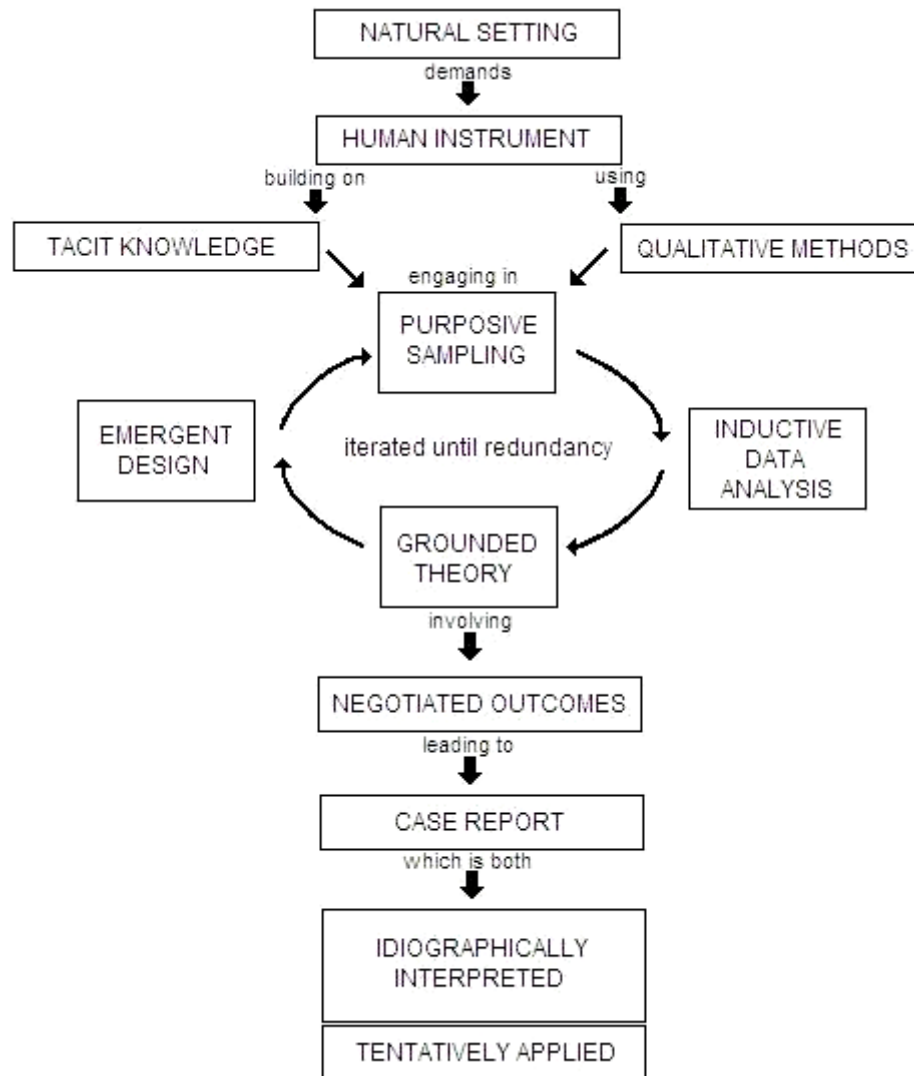


Figure 4 The Flow of Naturalistic Inquiry (Lincoln & Guba, 1985)

What a naturalistic inquirer believes is that meaningful realities cannot be understood properly in isolation from their contexts because these multiple realities “take their meaning as much from their contexts as they do from themselves” (Lincoln & Guba, 1985, p.189). That is why naturalistic inquiry supports the necessity for subjects or events to be investigated in their natural settings. Naturalistic inquiry further considers social, cultural, and political elements as integral parts of the inquiry process. “Rather than attempting to circumscribe or negate such elements with the artifice of method, constructivist...[inquiry] treats social, cultural, and political features as elementary properties of human circumstance and incorporates them into the inquiry

process” (Guba & Lincoln, 1989, p.253). My research study took place with NBCSTs in their natural classroom contexts. As I observed the teaching practices of participant teachers, I always tried to make sense of their particular school and classroom contexts. In my visits to their classrooms, I took notes on my specific experiences with the participant teachers. This allowed me to gain a better insight into how the teachers performed their roles in their natural environments.

For constructivist inquiry, the human is regarded as the primary data collection instrument since no other instrument other than humans can have an infinite adaptability to multiple realities held by different individuals and diverse contexts in which these realities flourish (Lincoln & Guba, 1985). Because human-as-instrument generally moves into a situation with a little idea of what is salient in it, s/he uses her/his tacit knowledge in addition to propositional knowledge in sensing the noticeable issues to examine further (Guba & Lincoln, 1989). Besides, much of the interaction between inquirer and respondent develops at tacit level, and some of the nuances in multiple realities can only be appreciated by the involvement of tacit knowledge (Lincoln & Guba, 1985). A constructivist inquirer prefers to employ qualitative methods since “qualitative methods are more sensitive to and adaptable to the many mutually shaping influences and value patterns that may be encountered (Lincoln & Guba, 1985, p.40). In addition, because “humans collect information best, and most easily, through the direct employment of their senses: talking to people, observing their activities, reading their documents assessing the unobtrusive signs they leave behind, responding to their non-verbal cues, and the like (Guba & Lincoln, 1989, p.176), qualitative methods “come most readily to hand for a human” (Guba & Lincoln, 1989, p.175).

According to Lincoln and Guba (1985), “the object of the...[naturalistic inquiry] is not to focus on the similarities that can be developed into generalizations, but to detail the many specifics that give the context its unique flavor” (p.201). Thus, naturalistic inquirer picks out the participants of the research with the purpose of gaining extensive information about the specific phenomenon at hand. Although the inquirer in the early stages of the investigation may look for individuals who have different perspectives than others for the sake of increasing the scope of information gained so far, on the other hand, in later stages as some of the elements become more evident s/he seeks for new

respondents to elaborate these certain elements further (Guba & Lincoln, 1989). Designing the constructivist inquiry process beforehand with a great detail is impossible because the researcher cannot predict, ahead of time, the nature of the interaction with the respondents and the patterns of many multiple constructions that emerge throughout the inquiry process. The constructivist inquirer enters the research site as a learner with having no claim about salient elements in research context. However, “as the constructivist inquirer becomes better acquainted with what is salient, the sample becomes more directed, the data analysis more structured, the construction more definitive” (Guba & Lincoln, 1989, p.180). The naturalistic inquirer employs an inductive data analysis approach because s/he “attempt[s] to make sense of the situation without imposing preexisting expectations on the [specific] phenomenon [and context]” (Patton, 1990, p.44), and allows the respondents “to answer [the questions] from their own frame of reference rather than from one structured by prearranged questions” (Bogdan & Biklen, 1998, p.3). Hence, theory does not precede data collection but rather builds on what emerges from the inductive analysis of raw data because no a priori theory can anticipate the nature of multiple realities constructed in the inquiry process, nor enclose the variety of factors that play an important role at the local level (Lincoln & Guba, 1985).

The naturalistic inquirer aims to reach an informed construction negotiated by respondents who are involved in the inquiry process. The major role of the inquirer is to convey the emerging constructions from one individual or group to another. However, not all inquiries end up with a consensus simply because participants “agree to disagree” (Guba & Lincoln, 1989, p.253) but all respondents reach new levels of information by reflecting on their and others’ constructions. The naturalistic inquirer never considers any constructions as the natural end point where the truth is finally known but rather these negotiated constructions are regarded as “the most informed and sophisticated constructions that it has been possible to evolve” (Guba & Lincoln, 1989, p.254). By interpreting the data idiographically, the constructivist inquirer does not assume the generalizability of her/his findings, but rather it is up to the readers to decide whether the findings can find themselves a place in the readers’ life experiences and be transferable to the readers’ own contexts. Case report serves well the aim of achieving

transferability by providing a “thick” depiction of the constructions and the contexts in which these constructions come alive. Lincoln and Guba (1985) noted that “if the description is sufficiently ‘thick’, then reading it is very similar to being there and being able to sense elements too nebulous to be stated propositionally” (pp.214-215).

Research Settings and Data Collection Methods

In my dissertation study, I worked with four experienced science teachers with accomplished teaching capabilities recognized by NBPTS. In the process of finding teachers to participate into the dissertation study, I searched the names of NBCSTs in the teacher directory of NBPTS’s official website. As a result of my search, I located the names of fifteen NBCSTs, who had been working in the same city that I lived. By visiting the websites of each teacher’s school, I obtained the mailing and the e-mail addresses of teachers. My major professor and I prepared an invitation letter for teachers to request their participation into the dissertation study (Appendix C). In the letter, we explained the purpose of the dissertation study and the potential benefits of their involvement in it. In addition to the invitation letters, I sent follow up e-mails to teachers. Four of those fifteen science teachers agreed to participate in the study. In the study, I used pseudonyms for the participant teachers in order to protect their confidentialities. I named teachers as Jennifer, Patricia, Martha, and Mary. Whereas Jennifer was a high school chemistry teacher, other three of the teachers were teaching science in a middle school. Jennifer and Patricia had received their advanced teaching certificates with NBC in 2003. Martha and Mary had become NBCSTs in 1999 and 2000 respectively. Understanding of teachers’ perspectives involves spending extensive time in the research setting and maintaining active interactions with participant teachers because “in social research, the data are not just sitting there waiting to be gathered, like rocks on the seashore. Rather,...the facts are produced as part and parcel of the social interaction of the researchers with the participants” (Klein & Myers, 1999, p.74). For that purpose, I maintained close interactions with the participant teachers. I visited their classrooms on regular bases for more than 6 months. In my visits to teachers’ classrooms, I usually attended two class periods. Those visits allowed me to have more conversations with teachers and to experience their classroom environments. NBC

assessment process as a professional development experience encouraged these teachers to reflect on their teaching. This dissertation study was a continuation of the reflection process for teachers with an inclusion of other NBCSTs' perspectives as well.

I used qualitative data collection methods such as classroom observations, in-depth teacher interviews, and document analyses in my dissertation study because as a qualitative inquirer I believe that I "can get closer to...[NBCSTs'] perspective[s] through detailed interviewing and observation" (Denzin & Lincoln, 2000, p.10). Qualitative data collection methods, according to Patton (1990), "permit the...researcher to study selected issues in depth and detail; the fact that data collection is not constrained by predetermined categories of analysis contributes to the depth and detail of qualitative data" (p.165). Qualitative data can provide a rich description of other people's experiences, feelings, emotions, desires, and expectations and so forth. Patton (1990) emphasized this reality by stating that "qualitative methods typically produce a wealth of detailed data about a much smaller number of people and cases" (p.165). Miles and Huberman (1994) expressed that "words, especially organized into incidents or stories, have a concrete, vivid, meaningful flavor that often prove far more convincing to a reader than pages of summarized numbers" (p.1). They further noted, "Qualitative data...are a source of well-grounded, rich descriptions and explanations of processes in identifiable local contexts. With qualitative data one can preserve chronological flow, see precisely which events led to which consequences, and derive fruitful explanations" (p.1). The qualitative methods in my dissertation research study helped me to gain a deeper understanding of NBCSTs' perspectives. Each type of qualitative data in the study served to answer a specific research question. Following is a list of the research questions and the role of each qualitative data sources in answering them.

Table 1 Data Sources and Corresponding Research Questions			
Research Questions	Classroom Observations	Teacher Interviews	Document Analyses
A-1		☀	
A-2		☀	☀
A-3	☀	☀	
B-1		☀	☀
B-2			☀
B-3	☀	☀	☀
B-4		☀	

A) What does undergoing NBC assessment process mean for NBCSTs?

1. How do NBCSTs see the role of NBC in their professional development?
2. What learning experiences do NBCSTs identify with NBC assessment process?
3. Does NBC experience create a higher affiliation with science education reform ideas?

B) What is the meaning of practicing inquiry in classroom for NBCSTs?

1. What are NBCSTs' conceptions of classroom inquiry?
2. How did NBCSTs enact inquiry in NBC portfolios?
3. What do NBCSTs intend to accomplish with their students in their practices of inquiry?
4. What hurdles do NBCSTs identify with practicing inquiry?

Classroom Observations, In-Depth Interviews, and Document Analyses

Bogdan and Biklen (1998) identified observations and in-depth interviews as the best known representatives of qualitative methods. These two data collection methods play distinct roles in our understanding of other people's behaviors, experiences, thoughts, meanings, actions and so forth. While observational data provide information about people's external behaviors, interview data are invaluable in developing understanding of people's interior constructions. Patton (1990) underlined that reality as "observations provide a check on what is reported in interviews; interviews, on the other hand, permit the observer to go beyond external behavior to explore the internal states

of persons who have been observed” (p.245). Patton (1990) provided some characteristics of observational and interview data as:

The data from interviews consist of direct quotations from people about their experiences, opinions, feelings, and knowledge. The data from observations consist of detailed descriptions of people’s activities, behaviors, actions, and the full range of interpersonal interactions and organizational processes that are part of observable human experience. (p.10)

One of the advantages of observations is that they “allow...the inquirer to see the world as his subjects see it, to live in their time frames, to capture the phenomenon in and on its own terms, and to grasp the culture in its own natural, ongoing environment (Guba & Lincoln, 1981, p.193). However, we do not have a chance to observe everything especially the events that occurred in the past, which play an important role in formation of persons’ meanings. Interviews, in that sense, “permit...the respondent to move back and forth in time—to reconstruct the past, interpret the present, and predict the future, all without leaving a comfortable armchair” (Lincoln & Guba, 1985, p.273). Documents are rich sources of information, which are available at any time needed (Lincoln & Guba, 1985). One can easily gain insight into the particular context at hand by reading the specific documents because the documents reflect the natural language of this specific context (Lincoln & Guba, 1985).

With respect to their degree of structure, interviews can be categorized as either structured or unstructured. In structured interviews, the questions to inquire about the problem at hand are set beforehand and the interviewees are expected to answer them in terms of interviewer’s framework and description of problem (Guba & Lincoln, 1981). In unstructured interviews, on the other hand, the problem is expected to arise from interviewees’ responses to the broad issue introduced by the interviewer (Guba & Lincoln, 1981). In other words,

The structured interview is the mode of choice when the interviewer *knows what he or she does not know* and can therefore frame appropriate questions to find it out, while the unstructured interview is the mode of choice when the interviewer *does not know what he or she doesn’t know* and must therefore rely on the respondent to tell him or her. (Lincoln & Guba, 1985, p.269)

According to Bogdan and Biklen (1998), good interviews provide very rich data full of words revealing the perspectives of the respondents. Good interviewers are good listeners at the same time (Bogdan & Biklen, 1998). Good interviewers allow respondents to talk freely about their point of view without imposing them their own ideas because the interviewer is “not there to change views, but to learn what the subjects’ views are and why they are that way” (Bogdan & Biklen, 1998, p.99). Observations and interviews contribute a lot to our understanding of others’ perspectives by allowing us to explore people’s external and internal constructs respectively. In the following subsections, I will describe my data collection methods in the study.

Classroom observations: Throughout the research process, I visited the classrooms of the participant teachers several times. My classroom visits started in April 2005 and continued until December 2005. Due to summer break for 2 months, I was not able to observe the teachers in June and July. As an average, I observed each teacher 8 times in this time frame. However, I had fewer opportunities to observe some teachers’ practices of science. Due to the fact that Patricia had most of her classes taught by an intern teacher at the time, I had to prearrange my visits with her. With other teachers, I did not necessarily ask for a specific day and time to visit their classes. At the beginning of my classroom visits, students were highly curious about my presence in their classrooms. Their curiosity declined in time as the teachers introduced me to their students and my visits became more regular. In my classroom visits, I usually attended two class periods of each teacher. I prepared a notebook for each teacher to keep notes in my visits to their classrooms. I collected science activity handouts used by the teachers with their students.

Visiting the teachers in their classrooms was important for familiarizing myself with the natural working environments of the participant teachers. Those visits gave me the opportunities to learn more about teachers, their students, their classroom contexts, their teaching practices of science, etc. Gaining more insights into the classroom contexts of the teachers gave me more confidence in making assertions about the teachers. In a sense, experiencing the specific contexts of the teachers was supportive to my understanding of their thoughts in their interview responses. My classroom visits

were also crucial in terms of keeping in touch with teachers. Having more interactions with the teachers was needed to build a rapport with them. Developing good relationships with the teachers allowed me to get into their sincere thoughts. Having conversations with the teachers in classroom visits were helpful for clarifying some of their formal interview responses. Although my primary intentions with classroom visits of the teachers were to develop a broad perspective on their classroom contexts and their teaching practices of science, I also wanted to see their practices of inquiry with their students. Science Teacher Inquiry Rubric (STIR) (Appendix A) developed by Bodzin and Beerer in 2003 guided me in my observations of science activities used by the teachers in their teaching practices of science. The rubric was built on five essential elements of classroom inquiry proposed by NRC (2000).

In-depth teacher interviews: I conducted two formal interviews with each participant teacher. In those semi-structured interviews, I posed open-ended questions to the teachers in order to allow them to express themselves freely with their own terms. However, when I heard an interesting or unclear statement from the teachers, I produced spontaneous questions for stimulating the conversations and understanding their ideas better. Therefore, the semi-structured interview design allowed me to introduce additional questions to the interviewing process depending on the responses coming from the teachers. This helped a deeper understanding of the teachers' thoughts. In conducting the formal interviews, I followed the hermeneutic dialectic circle as described in detail previously in this chapter. The hermeneutic circle based on the idea of introducing the key ideas of previous interviewees to the succeeding interview respondents. In order to achieve this, I included some of the important ideas expressed by teachers into the next interviewing process. First rounds of interviews lasted 2 hours as an average in comparison to the second tours of interviews with 1.5 hours long. I recorded each interview with digital audio recorder. Digital recording was helpful to transcribe the interviews by transferring the audio files to the computer. I used QuickTime Player software in tedious process of the verbatim transcription of teacher interviews. The software was user friendly in going back and forth in the transcription process. Other than two formal interviews, I also had several informal conversations with the participant teachers in my classroom visits. Those informal conversations were

the moments in which I had the opportunities to learn more about the thoughts of the teachers and to clarify some of the unclear points in their formal interview responses. They were also important to build a rapport with the teachers. Those informal talks did not necessarily follow a specific template. Most of the questions that I posed to teachers emerged spontaneously depending on my observations in their classrooms. The formal and informal interviews that I conducted with the participant teachers constituted the major data source of my dissertation study. I was able to find rich information in those interview responses. I discuss the analysis of that rich information in a meaningful way in the next section of the chapter.

Document analyses: The portfolios submitted by the teachers to the assessment center of NBC included important pieces of data to be used in my dissertation research study. In these portfolios, the participant teachers had demonstrated their science teaching capabilities and exemplified their practices of inquiry with their students. In addition to two videotapes of their teaching practices, the portfolios contained written commentaries of the teachers about their teaching practices of science. The teachers had kept a copy of their portfolio artifacts. Upon my request for using their portfolio artifacts in my dissertation research study, they agreed to send an electronic copy of the written commentaries to me. They all sent those documents to me through e-mail. Except Mary, other three teachers were able to locate the videotape copies of their teaching practices. Although Mary spent every effort to find her videotapes, her search failed to produce any result. Therefore, I obtained VHS videocassettes of Jennifer, Patricia, and Martha. As soon as I converted the videos of the teachers into the digital format, I returned their videocassettes back to them. Having a digital copy of their videos eased my analyses of their inquiry teaching practices. In the computer environment, I had the opportunity to watch the different segments of the videos several times by easy forward and backward. In my analyses of the inquiry practices of teachers in their NBC portfolios, I used Science Teacher Inquiry Rubric (STIR) developed by Bodzin and Beerer in 2003. I give more details about the analyses of the teacher videos in the following section of the chapter. In the following tables, I provide a brief list of the content of the teachers' NBC portfolios based on NBPTS's requirements.

Table 2 Early Adolescence Science Portfolio (Patricia, Martha, and Mary)

Entry-1 Designing Science Instruction ▪ Three instructional activities and related instructional materials with two student responses attached to each of them. ▪ Written commentary that provides a context for teacher's instructional choices and describes, analyzes, and reflects on the student work and your teaching.
Entry-2 Probing Student Understanding ▪ One videotape that shows teacher engaging students in an initial discussion of a new science concept. ▪ Written commentary that provides a context for the videotape discussion and describes, analyzes, and reflects on the discussion, student understanding, and the teaching practice.
Entry-3 Inquiry through Investigation ▪ One videotape that shows teacher engaging students in a discussion that focuses on the interpretation of data that have been collected during the course of the investigation. ▪ Written commentary that provides a context for the videotape discussion and describes, analyzes, and reflects on the discussion and students' development of inquiry skills.
Entry-4 Documented Accomplishments: Contributions to Student Learning ▪ Description and analysis of activities or accomplishments that clearly and specifically describe why they are significant in teacher's context and what impact they had on student learning. ▪ Documentation that supports teacher's accomplishments that s/he has chosen to describe. ▪ A reflective summary that reflects on the significance of teacher's accomplishments taken together and teacher's future plans to improve student learning.

Table 3 Adolescence and Young Adulthood Science Portfolio (Jennifer)

Entry-1 Teaching a Major Idea over Time ▪ Three instructional activities and related instructional materials with two student responses to each of them. ▪ Written commentary that provides a context for teacher's instructional choices and describes, analyzes, and reflects on the student work and the teaching practice. ▪ Culminating assessment instrument or a description of any alternative means of assessment.
Entry-2 Active Scientific Inquiry ▪ One videotape that shows teacher engaging students in scientific inquiry during three discrete segments of science inquiry. <u>Segment 1</u> will show teacher interacting with students to begin the inquiry by identifying questions to investigate. <u>Segment 2</u> will show teacher interacting with students as they collect data as part of the investigation. <u>Segment 3</u> will show how teacher engages students in analyzing, interpreting, and synthesizing the results of the investigation. ▪ Written commentary that contextualizes, analyzes, and evaluates the teaching practice throughout this process of scientific inquiry.
Entry-3 Whole Class Discussions about Science ▪ One videotape that shows teacher and students involved in a whole class science discussion. ▪ Written commentary that contextualizes, analyzes, and evaluates the teaching practice through whole-class discussion.
Entry-4 Documented Accomplishments: Contributions to Student Learning ▪ Description and analysis of activities or accomplishments that clearly and specifically describe why they are significant in teacher's context and what impact they had on student learning. ▪ Documentation that supports teacher's accomplishments that s/he has chosen to describe. ▪ A reflective summary that reflects on the significance of teacher's accomplishments taken together and teacher's future plans to improve student learning.

Analysis of Qualitative Data

Data analysis is a continuous process in naturalistic inquiry methodology. The systematic interviewing procedure in the hermeneutic dialectic circle already compels the researcher to engage with the interview data earlier because s/he needs to convey the central ideas of previous interviewees to the next interview process. In my dissertation study, I constantly spent more efforts to make a better sense of teachers' ideas. As soon as I finished an interview with a teacher, I listened to the interview responses carefully from the audiotape in order to determine the central ideas expressed by the teacher. This made me better informed about the thoughts promoted by the teachers. The transcription process of interviews also helped me identify the salient themes in teachers' responses. Before starting the analysis of interviews at the end of data collection process, I had already constructed some preliminary assertions to make in the study.

I employed Miles and Huberman (1994)'s data analysis method in my dissertation research study. They described data analysis in three stages: Data reduction, Data display, and Conclusion drawing. "Data reduction refers to the process of selecting, focusing, simplifying, abstracting, and transforming the data that appear in written-up field notes or transcriptions" (Miles & Huberman, 1994, p. 10). With the completion of the data collection process, I was in the midst of abundant teacher data. In order to start analyzing the available data, I needed to organize the mass data and put it into a more manageable form. For that purpose, I created a data folder for each individual teacher in my computer. I placed available data artifacts of the teachers such as field notes, interview transcripts, and written commentaries from teacher portfolios into these folders. I kept hard copy documents in binder folders assigned for each teacher. Although this process put the available data in a more accessible form, it was no help in reducing the volume of the data into more manageable format. In order to analyze the available data in the folders, I used HyperRESEARCH 2.6 qualitative data analysis software. This software was very helpful in coding the data in the folders. The following figure displays a sample view of the coding process.

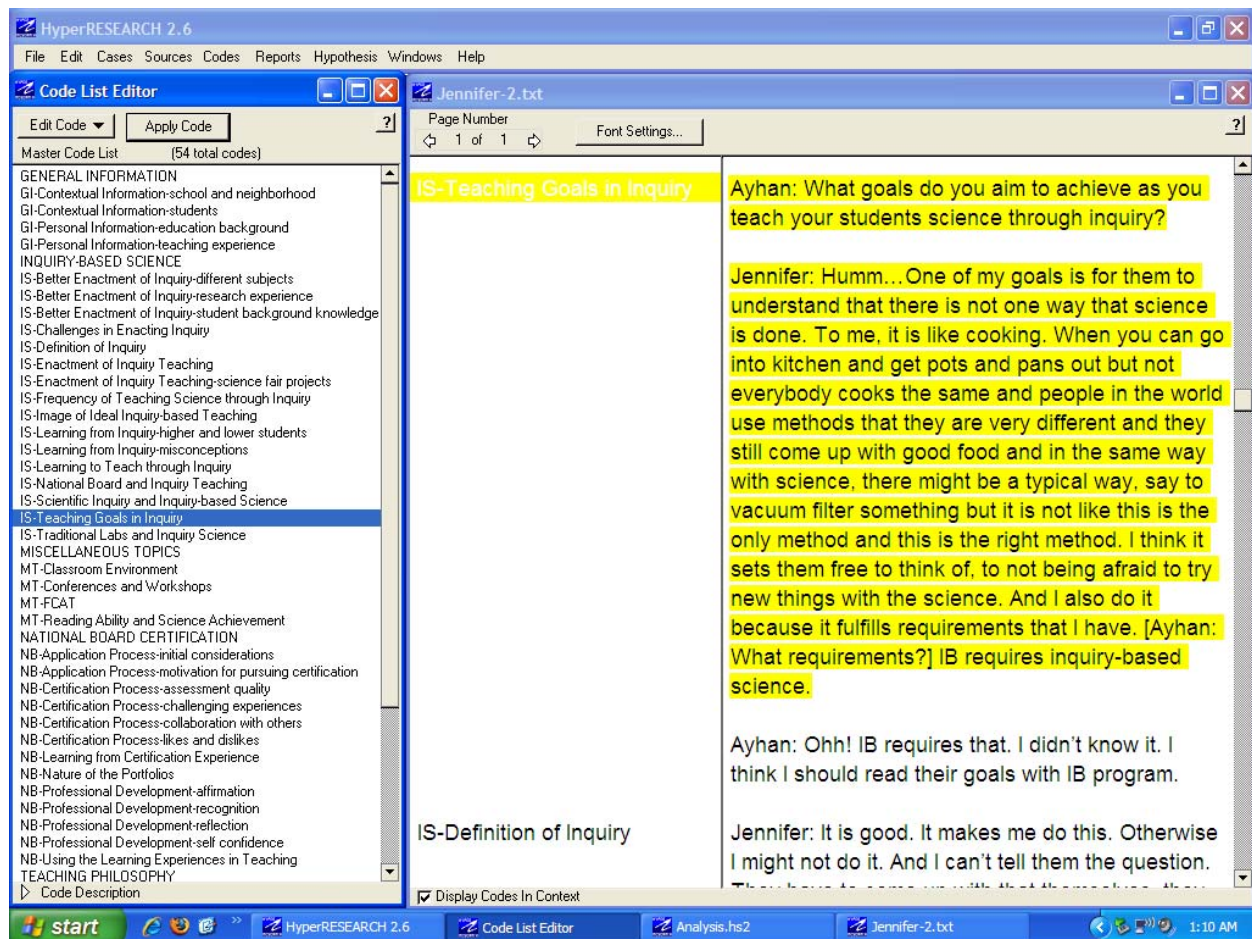


Figure 5 Sample View of Data Coding Process

The software worked on the basis of teacher cases. In my study, I had four teacher cases. I coded every single data artifact with the help of qualitative data analysis software. I used major codes and sub-codes in order to allow the data analysis software to list the relevant codes together. The coding process tremendously reduced the amount of usable data because it gave me the opportunity to review all available data artifacts and to eliminate some of the irrelevant data.

The next stage of the data analysis process involved displaying the data in a more visible form. Data display put “organized information into an immediately accessible, compact form so that the analyst can see what is happening and either draw justified conclusions or move on to the next step of analysis” (Miles & Huberman, 1994, p. 11). A display can be in a text, diagram, chart, or matrix form. HyperRESEARCH 2.6 had the capability of producing reports sorted either by case name or code name. I

created data reports in both forms. Sorted reports by code name placed all relevant teacher information under their corresponding codes. This gave me the opportunity to see the relevant quotes from all teachers under their respective data codes. I printed the reports produced by the data analysis software. Having printed copies of the data reports was helpful to have a visual access to all teacher data at the same time. And whenever I needed to see a specific quote from a teacher in its written context, the software displayed the highlighted quote in the whole document.

In the final stage of the data analysis, I drew my conclusions from the coded data. The printed data reports displayed the extracted quotes of all teachers under their relevant data codes. This made comparing and contrasting of the teacher cases easier. My careful analyses of teacher responses in the same coding categories resulted in developing conceptual themes. Based on those key conceptual themes, I created my assertions. In order to support the assertions that I made, I wrote each teacher's case and placed under their corresponding assertions. Although my assertions emerged from the earlier comparison of the cases of the teachers, I made cross case analysis again between the teachers. I created comparative tables to display the similarities and the differences between the teachers. Based on the feedback that I received from my dissertation advisor, I had to reduce the data used in presenting some of the teacher cases. This was important for preventing the redundancy in the dissertation study.

I used an adapted version of the Science Teacher Inquiry Rubric (STIR) in analyzing the teaching videotapes of the participant teachers (Appendix A). This rubric instrument was presented in the article written by Bodzin and Beerer in 2003. In my choice for this instrument to analyze the videotapes of the teachers, the following two factors played the major roles. Firstly, the researchers developed STIR instrument based on the five essential features of classroom inquiry promoted by NRC (2000). Secondly, according to Bodzin and Beerer (2003), STIR instrument produced a perfect inter-rater reliability ($r=1$) to be considered as an effective observation tool. However, the instrument was not successful with a lower reliability ($r=0.58$) to be used as a self-assessment tool by teachers. Before starting the analyses of the videotapes, I familiarized myself with STIR instrument. I read each cell in the rubric carefully and reflected on the meaning of the rows and the columns of the rubric. I prepared an

adapted version of STIR to use in the study (see Chapter 8). STIR instrument consisted of 6 rows and 4 columns. Each row represented a different item. And each item was one of the essential features of classroom inquiry promoted by NRC (2000). I created a single page for each item with four rows for the teachers. I wanted to analyze inquiry practices of the teachers on each item of STIR instrument. Afterwards, I decided the specific column of each teacher on those items. I had converted the teacher videotapes into the digital format previously. Before doing a detailed analysis of the videotapes, I watched them completely in order to gain a broad insight into inquiry teaching practices of the teachers. In addition, I read the reflective descriptions of inquiry practices of the teachers written by themselves for NBC portfolios. As I watched the different segments of the videos several times, I searched for any evidence to satisfy the specific items of STIR instruments. Based on four columns in each teacher row, I assigned the inquiry practice of the teachers to one of those four columns. I put my explanations into each corresponding cell of the instrument. The four columns in the rubric represented the levels of inquiry practiced by teachers in their videotapes. I prepared a bar graph to illustrate the inquiry levels used by the teachers in each item of STIR instrument.

Quality Criteria

In Wilber's four quadrant model, each quadrant "has its own particular type of truth or type of 'validity claim'—the ways in which it goes about accumulating and validating its data and its evidence" (Wilber, 1997a, p.12). In upper-right quadrant, truth value of a statement is determined by its correspondence with an objective fact (Wilber, 1997b). In other words, "a statement is [said to be] true if the map matches the territory" (Wilber, 1997b, *The Contours of Consciousness*, ¶ 2). However, in upper-left quadrant, the appropriate question is "not, does the map match the territory? but can the mapmaker be trusted?" (Wilber, 1997a, p.13). The validity claim here is not whether my statements match an objective reality but whether what I say truthfully and authentically expresses my inner meanings (Wilber, 1997a). The validity claim in lower-right quadrant is concerned with a proper "expla...n[ation of] the status of the individual members in terms of their functional fit with the objective whole" (Wilber, 1997a, p.15). "The validity claim...[in lower-left quadrant] concerns the way that my subjective consciousness fits

with your subjective consciousness, and how we together decide upon those cultural practices that allow us to inhabit the same cultural space” (Wilber, 1997b, *The Contours of Consciousness*, ¶ 4).

Since naturalistic inquiry functions on the left side quadrants, it follows the corresponding quality criteria for these quadrants to validate the trustworthiness and authenticity of its own conclusions. Lincoln and Guba (1986) developed some criteria to increase the trustworthiness of naturalistic studies. These criteria for naturalistic studies are parallel to the conventional criteria, which are used by researchers who conduct quantitative research studies. These conventional criteria “include exploring the truth value of the inquiry or evaluation (internal validity), its applicability (external validity or generalizability), its consistency (reliability or replicability), and its neutrality (objectivity)” (Lincoln & Guba, 1986, p.74). I provide further details about naturalistic quality criteria below.

Credibility

Credibility is the corresponding criterion in naturalistic studies for internal validity. Guba and Lincoln (1989) described credibility as “the match between the constructed realities of respondents...and those realities as represented by the...[inquirer]” (p.237). Some of the strategies in order to increase credibility of a naturalistic inquiry include:

Prolonged engagement: “Lengthy and intensive contact with the phenomena (or respondents) in the field to assess possible sources of distortion and especially to identify salencies in the situation” (Lincoln & Guba, 1986, p.77). Prolonged engagement is also critical in terms of developing a close relationship with the respondents and understanding the cultural aspects of the setting (Guba & Lincoln, 1989). For 6 months, I visited the participant teachers in their classrooms on a regular basis. As an average, I visited each teacher 8 times in this time period. In most of my visits, I attended two class periods of the teachers in order to see them interacting with different students. The classroom visits were helpful in two ways. Firstly, visiting the teachers helped me learn more about their school cultures, classroom contexts, and student characteristics. Through those visits, I had the opportunities to observe the teachers in performing their roles in their natural environments. Secondly, my regular visits were crucial in establishing the foundations of developing close relationships with the teachers. At the

initial stages of the research process, the teachers saw me as an outsider. However, as I spent more time with them in their classrooms, we started to understand each other better. As I developed a rapport and a mutual trust with the teachers, I was able to have conversations with the teachers in a more informal manner. In those informal conversations, I had the opportunities to clarify the unclear points in their perspectives.

Persistent observation: “In-depth pursuit of those elements found to be especially salient through prolonged engagement” (Lincoln & Guba, 1986, p.77). This strategy involves observing the research context sufficiently to identify the salient aspects of events which are relevant to the study. In order to satisfy persistent observation strategy, I spent sufficient time in the classrooms of the participant teachers and observed their everyday teaching practices several times. In my observations, I tried to make a better sense of the teaching contexts of the teachers. When I felt unclear about the underpinning reasons of classroom actions of the teachers, I talked to them to clarify my understanding of their thoughts.

Triangulation: Denzin (1978) identified four kinds of triangulation: data triangulation-the use of multiple data sources, investigator triangulation-the use of multiple researchers, theory triangulation-the use of multiple perspectives to analyze the data, and methodological triangulation-the use of multiple methods to collect data. In my dissertation research study, I worked with four science teachers. Therefore, I based my assertions on the ideas of those four science teachers. In addition to working with different subjects, I used different data collection methods such as classroom observations, teacher interviews, and teacher portfolio analyses in my study. Although I was the principle researcher to construct the assertions related to the participant teachers, my major professor helped me identify the key elements that emerged from the available data artifacts throughout the research process.

Peer debriefing: “Exposing oneself to disinterested professional peer to ‘keep the inquirer honest’, assist in developing working hypotheses, develop and test the emerging design, and obtain emotional catharsis” (Lincoln & Guba, 1986, p.77). Throughout the dissertation research process, I kept in touch with my major professor. In our interactions, I had the opportunities to discuss my learning experiences with her. Her expertise with qualitative research methods guided me in developing better

perspectives on my further efforts for investigating the salient issues in my research project. In addition to my personal communications with my major professor, I attended research group meetings with other doctoral students on a weekly basis. In these meetings, I was able to present my preliminary learning experiences to the members of the research group. The comments made by other graduate students helped me clarify my thoughts in the research project. Sharing the similar struggles with other doctoral students supported me emotionally in most stressful times. In one of the departmental colloquium meetings, I presented some of my findings to the members of science education community. The suggestions made by faculty members and graduate students were helpful in improving my dissertation study. Presenting some of my results to the other members of the department also enhanced my confidence as a science education researcher.

Negative case analysis: “The active search for negative instances relating to developing insights and adjusting the latter continuously until no further negative instances are found” (Lincoln & Guba, 1986, p.77). In order to increase the robustness of my assertions, I continuously sought for the instances that contradicted with my assertions. Conducting cross case analyses unveiled the different ideas promoted by the participant teachers. In order to display these differences, I placed a summary table at the beginning of each assertion. In the study, the teachers did not share the same ideas all the time but rather developed different perspectives on certain topics.

Member checks: “The process of testing hypotheses, data, preliminary categories, and interpretations with members of the...groups from whom the original constructions were collected” (Guba & Lincoln, 1989, pp.238-239). The member checking was a continuous process in the dissertation study. When I felt unclear about their ideas or actions, I tried to confirm the meaning of their thoughts through posing additional questions in my informal conversations with the teachers. I discussed some of the unclear ideas in their interview transcripts with them. I also presented my descriptions and comments to them in order to obtain their further insights into my dissertation study.

Transferability

Transferability is the criterion which corresponds to external validity in quantitative paradigm. Transferability refers to the applicability of the study by others into their similar situations. The study should provide a rich database in order to facilitate the transferability of the results by other people having similar situations. In order to increase transferability of a study, Lincoln and Guba (1986) suggested thick description strategy.

Thick description: “Narrative developed about the context so that judgments about the degree of fit or similarity may be made by others who may wish to apply all or part of the findings elsewhere” (Lincoln & Guba, 1986, p.77). In order to enhance the transferability of my conclusions by readers to their peculiar contexts, I attempted to give a detailed description of the participant teachers and their classroom contexts. I hope that my depiction of the research context assists the readers to get a clear picture of the teaching contexts of the participant teachers.

Dependability

Dependability is what corresponds to reliability in conventional research paradigm. Dependability can be described as “stability of the data over time” (Guba & Lincoln, 1989, p.242). The major technique to increase dependability of the study is dependability audit.

Dependability audit: The technique in which an independent auditor reviews the activities of the researcher in order to see if the researcher is following the strategies for meeting the credibility and transferability standards. My major professor acted as a dependability audit in my dissertation study. Throughout the dissertation process, our interactions kept her informed about the procedures followed in the research.

Confirmability

Confirmability is the criterion in naturalistic paradigm, equivalent to objectivity in quantitative research paradigm. According to Guba & Lincoln (1989), “Confirmability is concerned with assuring that data, interpretations, and outcomes of the inquiries are rooted in contexts and persons apart from the...[inquirer] and are not simply figments of the...[inquirer]’s imagination” (p.243). The major technique to fulfill confirmability criterion is confirmability audit.

Confirmability audit: The technique in which an independent auditor checks if the interpretations and the conclusions are constructed through the involvement of the available data. In the study, I made several assertions about the participant teachers. I supported the assertions with each teacher's case. In the research process, my major professor confirmed the consistency of the assertions and the available teacher data. In other words, she made sure that the assertions were supported properly with the collected data.

Guba and Lincoln (1989) also devised authenticity criteria that have their roots and origins in constructivist assumptions. In other words, these criteria were not created in a parallel manner to their positivist counterparts as in the case of trustworthiness criteria but rather they are all originally invented for constructivist inquiry paradigm. Guba and Lincoln (1989) described five types of authenticity criteria: fairness, ontological authenticity, educative authenticity, catalytic authenticity, and tactical authenticity. I will discuss first three of these criteria in my research study.

Fairness

This criterion "refers to the extent to which different constructions and their underlying value structures are solicited and honored within the...[inquiry] process" (Guba & Lincoln, 1989, pp.245-246). In my research study, I gave equal chances to all participant teachers to express their views freely. I represented their voices fairly in my conclusions. My role as a researcher was to understand the diverse perspectives of the teachers rather than judging their thoughts. Therefore, I valued all of the diverse views held by the teachers.

Ontological Authenticity

Guba and Lincoln (1989) described this criterion as "the extent to which individual respondents' own emic constructions are improved, matured, expanded, and elaborated, in that they now possess more information and have become more sophisticated in its use" (p.248). In my dissertation research study, the participant teachers had chances to reflect on their own views and practices. The stimulating interview questions encouraged the teachers to think deeper on their experiences with NBC assessment process. This allowed them to make a better judgment on the role of NBC portfolio assessment experience in their professional development as a science

teacher. In addition to reflecting on their NBC experiences, the teachers articulated the meaning of practicing inquiry in their classrooms. In order to keep the participant teachers better informed about the conclusions of my study, I will provide them a copy of the dissertation research study, which, I believe, will contribute to their learning positively.

Educative Authenticity

This criterion is related to “the extent to which individual respondents’ understanding of and appreciation for the constructions of others outside their stakeholding group are enhanced” (p.248). In the research process, the participant teachers were informed about the perspectives of the other teachers in the study. In the interviewing process of hermeneutic dialectic circle, the teachers were introduced to some of the ideas expressed by the previous interviewees. This kept the participant teachers cognizant of the constructions of other teachers in the study.

Research Ethics

Bogdan and Biklen (1998) characterized two broad areas in research ethics which a researcher should consider:

1. Subjects enter research projects voluntarily, understanding the nature of the study and the dangers and obligations that are involved.
2. Subjects are not exposed to risks that are greater than the gains they might derive. (p.43)

In the study, I strictly maintained the confidentiality of the participant teachers. In order to protect the confidentiality of them, I used a pseudonym for each teacher. Before starting the research process with the participant teachers, I presented an informed consent letter to them (Appendix D). In the informed consent letter, I provided a description of the dissertation research study. The informed consent letter also specified that the participation into the study was completely voluntary and they might withdraw from the study at any time. As a constructivist inquirer, I have the responsibility to inform the participant teachers of my findings in the study. Therefore, after I complete my research study, I will send a copy of the dissertation study to the participant teachers in order to keep them informed about the conclusions of the study.

CHAPTER 4

ENTERING INTO THE CONTEXT OF NBCSTs

Introduction

In this chapter of the dissertation study, I present general information about NBCSTs. In addition to personal and contextual information about teachers, the chapter provides the views of participant teachers on teaching and learning science. Due to qualitative nature of this dissertation study, the study does not claim any generalizability of the conclusions. Rather, it is the responsibility of the readers to decide the transferability of the findings into their own contexts. Providing a rich description of participant teachers helps readers transfer the findings of this dissertation study into their own contexts. Before transitioning to the presentation of information about teachers, I make the following assertion.

Assertion-1: NBCSTs are not equally open to science education reform ideas.

In order to support the specific assertion that I made above, I display each teacher's information in the following subsections. My presentation starts with Jennifer's case.

Personal and Contextual Information about Jennifer

Jennifer was an experienced high school chemistry teacher. She had an undergraduate degree in biology and a master's degree in chemistry with an emphasis on biochemistry from a southeastern American university. Jennifer had 25 years of science teaching experience, 8 years of which she had been working in her current high school as a chemistry teacher. However, her teaching experience was not limited to

high school level but also included college level. In her earlier teaching career, she taught chemistry in a community college for 13 years as an adjunct faculty member. For a period of 4 years before her community college position, she worked as a chemistry teacher in another high school in the same school district in which her current high school was located. Although Jennifer had an undergraduate degree in biology, she followed a teaching career in chemistry. Her interest into chemistry grew exponentially in her graduate studies. She felt that chemistry offered the explanations for the fundamental underpinnings of biological phenomena, and that attracted her to chemistry.

At the time of my visits to her classes, Jennifer was teaching honors, pre-IB (International Baccalaureate), and senior IB chemistry classes. Although the school population was dominated by minority students³, her classes did not necessarily match with the school characteristics because she taught in a magnet program. That was why she defined the magnet program as “a school within a school” (Entry 3, NBC portfolio). The magnet program recruited brighter students, who scored 75th percentile or higher on FCAT [Florida Comprehensive Assessment Test]⁴, from all over the school district. After many years of work in the community college, Jennifer decided to teach in this high school because she could earn more money in her current position than she did with her adjunct faculty position in the community college. In addition, she worked with “brighter” students in the high school due to the fact that these students were chosen based on their FCAT scores to attend to the magnet program. In her following interview excerpt, Jennifer expressed her satisfaction with teaching in her high school:

To be honest, I like teaching science here more than teaching at the community college. When I came here, I was amazed. The kids can read. The kids can do math. I don't have to teach them how to do math. I just teach them chemistry. Some of these kids can talk chemistry, and it is wonderful. Very few students were like that in the community college. (Jennifer, Personal Conversation, November 9, 2005)

³ The school was comprised of 74 % of black students, 21 % of white students, 3 % of Asian students, and 1 % of Hispanic students.

⁴ FCAT is a standardized test given in the State of Florida to determine the achievement levels of students in the areas of science, mathematics, reading, and writing.

Jennifer enjoyed teaching in a context with “bright” students. Due to the fact that Jennifer was teaching to an elite group of students, she had high expectations from them in their future careers. She predicted that many of her students would pursue a profession related to science. Table-4 below displays the general student profile of Jennifer’s high school. However, Jennifer’s classes did not necessarily reflect these student characteristics because she was teaching in the IB program.

Table 4 Information about Jennifer's High School									
Student Population					Free/ Reduced Lunch	Teacher/ Student Ratio	Minority Rate	Number of Students	Number of Teachers
Black	White	Asian/Pacific Islander	Hispanic	Migrant	43%	1:20	80%	1389	68
74%	21%	3%	1%	1%					
2004-2005 School Accountability Report									
Meeting Standards in Reading	Meeting Standards in Math	Meeting Standards in Writing	2005 Grade	2004 Grade	2003 Grade	2002 Grade	2001 Grade	2000 Grade	1999 Grade
36%	66%	93%	D	C	C	C	C	C	C

As can easily be noticed from the table above, Jennifer’s high school served to a high percentage of minority student population. Jennifer’s high school was not successful on standardized tests. However, this did not mean that same was true for Jennifer’s students. The success of Jennifer’s students in IB program was much higher than the rest of the school.

Jennifer’s Classroom Context

Jennifer had a large rectangular classroom with a well equipped laboratory. Thirty individual student desks filled the front part of the classroom. Three laboratory counters were located in the rear of the classroom. On the opposite side of the entrance door, another door adjacent to a fume hood opened to the storage room. On the other side of the fume hood, Jennifer’s chair and personal computer were located just on one edge of the whiteboard in front of the classroom. On the hidden part of the wall behind the fume hood, Jennifer kept her framed teaching related honorary documents. A periodic table dominated the wall and a white screen hanging on the whiteboard covered

most of the left side of the whiteboard. A table between whiteboard and the desks but closer to the whiteboard separated the whiteboard area from the rest of the classroom. Just in front middle of the table, an overhead projector looked toward the white screen hanging on the face of the whiteboard. Near to Jennifer's chair and computer, there stood a television set with a VCR and a CD player. The back wall behind three laboratory counters was covered with commercially prepared posters. There were many old looking books about AP chemistry on the shelves of a cabinet under the window located on the opposite side of the entrance door. On one of the lab counters closer to the window, many glass chemistry lab equipment and cleaning materials rested.

Becoming a NBCST

Jennifer received her National Board certificate in 2003. She achieved her certificate in her first try. She was certified as an Adolescence and Young Adulthood Science Teacher with a specialty area of chemistry. Jennifer heard about NBC for the first time in 1997 and it took her another 6 years to decide to apply for the certification. She attributed her decision to pursue her advanced certificate with NBC to the informative meetings regarding the process held at a local university. As a result of these meetings, she felt that she was capable of achieving her advanced teaching certificate with NBC. Although monetary incentive was a big factor in her decision process, Jennifer also attributed her decision to her personality for willingness to take challenges: "If there is a challenge out there, I always like to take it. I am just that kind of person. Sooner or later, I have had to do this" (Jennifer, Interview, May 12, 2005).

During the certification process, Jennifer obtained the most help from a history teacher, who was working at the same high school and had achieved her certificate a year before. Since Jennifer and this history teacher had the same students, their conversations about their students, educational terminologies, and the psychological reasoning of classroom events were enlightening for Jennifer in the reflective writing process of NBC portfolio assessment:

It is like if I am working with this kid, I don't know my specific reasons because I am not that kind of a person that verbalizes those things. And being a science person, I am not that much into all the reasons why psychologically I do this. But she was more in tune with that so we could talk about it and I have a lot of the

reasons that they have been stated in there but I had never talked about them.
(Jennifer, Interview, May 12, 2005)

When I first contacted Jennifer to invite her to participate in my study, she was hesitant to become involved in a study inquiring into the experiences of teachers with NBC because she had some negative feelings about the certification experience. In her e-mail response to my dissertation advisor, she stated:

I feel that I am not that supportive of the idea of National Board Certification even though I have done it. It was good for me to go through the process, and it provides me with confidence, but I am afraid I might be somewhat cynical. I doubt that is what Ayhan is looking for. I think he wants to understand how the national board process benefits a teacher. Don't think I am totally cynical about the process--I am not. It is just that I am not totally enamored with it, either.

(Jennifer, E-mail Response, March 11, 2005)

However, she was convinced to participate into the study after she realized that her “cynical” feelings about NBC assessment process would bring alternative perspectives into my dissertation study. As the study progressed, her negativity changed as she reflected more on the process. The study encouraged her to think more deeply and to clarify her thoughts better.

Views on Teaching and Learning Science

Jennifer did not complete a formal teacher education. Her first introduction to academic field of education took place with her attendance to some graduate level education classes in order to satisfy her teaching certification requirements. However, her experiences with education classes did not create an affiliation with the academic field of education. On the contrary, she was doubtful about the potential value of educational theories:

I started to take some graduate level education classes. They are just so full of theory that just seems so unrealistic for the classroom. I think I am a little cynical about the educational theories. I feel like a lot of times the professors have these glorified ideas of what we can really do in a school. When it comes down to it, can I just make my kids sit down in their desk? And teach them which side of the

arrow the reactants are on. I feel like, yes, I am cynical about it. (Jennifer, Interview, May 12, 2005)

Jennifer enjoyed teaching chemistry and interacting with children. However, she avoided identifying herself as an educator. Rather, she felt herself “a chemist kind of a person” (Jennifer, Personal communication, May 19, 2005). Although Jennifer had been teaching science for a long time, her education background in science played the most important role in shaping her views about teaching and learning of science. Teaching higher level chemistry in community college might be considered as a contributing factor in her doubtful approach to the field of education.

Jennifer described teaching with explaining and learning with applying in her following interview response:

I love to teach. I enjoy explaining things, and to me teaching is explaining things in a way that they [students] can understand. And then giving them opportunities to apply it so that they can learn. I need to understand my material and I need to be able to present it. (Jennifer, Interview, May 12, 2005)

Jennifer visualized a science teacher as a content expert. To her, the major role of the teacher involved “getting across” the information to students in a best comprehensible manner. Jennifer identified herself as a traditional science teacher. She believed that the context in which she taught necessitated using more conventional teaching strategies:

I still believe I am a traditional teacher because I feel like higher level classes demand it. I think the higher you go, the more traditional you can be with this. I think low level classes you can do all of these stuff to help them understand but the high level kids, they just need to get the information in a fast way. (Jennifer, Interview, May 12, 2005)

Jennifer believed that the role of teacher involved delivering the available knowledge to students in a more direct way. Teaching science to a group of select students promoted her traditional views of teaching science. She argued that the role of teacher was more crucial with lower level students.

Jennifer approached to advanced science teaching standards of NBC with a resistance. She felt that most of the ideas promoted in the standards fitted to lower level students: “I feel about NBC standards that I could do it for lower levels. But I feel like the

higher up students get, the less they apply” (Jennifer, Interview, May 12, 2005). Jennifer thought that those standards were hardly applicable to her classroom context because she pursued different goals to achieve with her students. She saw her students as the potential candidates for prestigious professions related to science:

As far as what I do, I am very purposeful. I want my kids to move on because my kids are not like that. My kids are the future doctors, you know, the research scientists. I want to get them move along as quickly as they can so that they can be successful and accomplish things in their careers. (Jennifer, Interview, May 12, 2005)

Jennifer wanted her students to develop strong knowledge base of science. She criticized progressive ideas of teaching science for lowering the standards for students. She found her presentation of chemistry topics with her overhead projector and chemical experiments superior to using computer applications:

I think you cheat your kids if you make it too low level. Following these standards makes it low level. That is how I feel that I am not doing all of these. You know, the people talk about “covering a little in great detail, making PowerPoint presentations, and using the web”, and all of these. I just think those are superfluous. I feel like I, overhead projector, and the chemicals in the labs are a million times better than doing a simulation on the computer or doing a web search where they can get it in a book. They can learn it and then as they want to go on and discover more, they can do that. (Jennifer, Interview, May 12, 2005)

Jennifer’s interview response above indicated her resistance to accept innovative ideas in her teaching practices of science. Jennifer supported traditional views of teaching science but this did not mean that she based her teaching practices on textbooks. She thought that the emphasis placed on classroom inquiry by NSES [National Science Education Standards] was necessary for science teachers who relied on textbooks in their teaching: “I think the emphasis though on inquiry is good for teachers who would be the kind who have just kids read books” (Jennifer, Interview, May 12, 2005). This denoted that Jennifer supported the promotion of inquiry teaching strategies for reducing the textbook dependency of science teachers. However, she did not consider herself in this group of teachers.

Personal and Contextual Information about Patricia

Patricia was a middle school science teacher with 28 years of active teaching experience. She had been working in her current middle school for the last 14 years. Patricia had a bachelor's degree in elementary education from an eastern American university and a master's degree in middle grade science education from another eastern American university. In 1988, she took 2 years off from her teaching career and started her PhD education in a southeastern American university. However, after a while, she realized that it was not for her and quit the PhD program. She phrased her decision as "I am not a theorist. I am a practitioner. So it is better for me. I am better in the classroom. It just wasn't for me. It wasn't my cup of tea" (Patricia, Interview, May 19, 2005). At the time of her participation into this study, Patricia was teaching 8th grade physical science in IB and pre-IB program and a drama class for mixed students at different grade levels. Patricia enjoyed teaching drama. Her drama teaching experience started in her earlier science teaching career while she was working in a middle school at another state. Because there was no drama teacher in the school at the time, she volunteered to take the responsibility of teaching it. Since then, she always enjoyed teaching drama class along with her other teaching duties. In order to learn how to direct theater performances, she attended a theater and worked with the director for 3 years.

The student profile of the middle school in which Patricia worked consisted of a high percentage of minority⁵ students. However, the student profile in IB program was usually different from rest of the school's student population. Unlike the school's general student characteristics, Patricia's classes had a higher percentage of white students. The number of students from migrant families was also noticeably higher in IB classes. Due to the fact that the students in the IB program were selected based on their earlier academic achievements, Patricia taught a group of motivated students. As an average, the economical status of the families whose children were attending to IB program was better than the general school average. Most of Patricia's students became Jennifer's students after they graduated from the middle school. That was because the IB program

⁵ The student population includes 64% of black, 31% of white, 3% of Asian, and 1% of Hispanic students.

in Patricia's middle school fed the IB program in Jennifer's high school. That was why Jennifer and Patricia knew and supported each other. In one of my visits to Patricia's classes, I happened to observe Jennifer's senior IB students in groups of two presenting chemistry demonstrations to Patricia's students. The senior IB students also gave some information about the IB program in their high school. Table-5 below displays the student demographics in Patricia's middle school.

Table 5 Information about Patricia's Middle School									
Student Population					Free/ Reduced Lunch	Teacher/ Student Ratio	Minority Rate	Number of Students	Number of Teachers
Black	White	Asian/Pacific Islander	Hispanic	Migrant	53%	1:21	75%	878	41
64%	31%	3%	1%	1%					
2004-2005 School Accountability Report									
Meeting Standards in Reading	Meeting Standards in Math	Meeting Standards in Writing	2005 Grade	2004 Grade	2003 Grade	2002 Grade	2001 Grade	2000 Grade	1999 Grade
64%	65%	89%	B	B	B	B	A	C	C

In the table above, it was possible to see that Patricia's middle school consisted of a high percentage of students from minority families. However, this picture did not necessarily reflect the student profile of Patricia's classes because she was teaching in the IB program.

Patricia's Classroom Context

When I visited Patricia's classroom for the first time, my first impression was about its chaotic appearance because most of the lab equipment and papers were dispersed around the visible areas like on the lab counters and the rear of the classroom. In my earlier visits to Patricia's classroom, I noticed that the classroom walls did not extend all the way up to the ceiling and there was space between the walls and the ceiling. Therefore, the noise coming from the hallway and other classes were a constant concern for Patricia. However, over the summer, the school administration decided to remodel the walls through joining them to the ceiling. The noise was not a problem in Patricia's classroom anymore. The entrance door of Patricia's classroom

was located in the rear part of the classroom, in that, student seats faced away from the door. The three laboratory counters extended from one wall had a myriad of things on them such as papers, folders, paper boxes, rulers, staplers, electronic balances etc. A big periodic table poster hung on the right hand side wall above lab counters. Other than this poster, the walls were plain with no other posters or student work samples on them. The left side of the classroom through the left hand side wall was filled with student desks. A long whiteboard lied through the most part of the left hand side wall. Students did not turn their face towards this whiteboard but instead a white screen located on the front wall of the classroom. Just in front of this white screen, there resided an overhead projector that Patricia used in her instruction most of the time. A couple of large white papers attached to the whiteboard to represent each class period with an alphabetic letter listed the specific topics to be covered on certain dates for each corresponding class period. The front wall was covered with a long counter with cabinets over it. While the fume hood sat on the right side of this long counter, the TV set with VCR and DVD player looked toward student desks on the left side of the counter. Patricia's table with her computer on it was located on one side of the rear of the classroom near to the entrance door. Patricia's table looked unorganized with several objects on it. The back wall of the classroom was covered with couple of cabinets with several tattered books on them. Just above these cabinets, a Scottish flag hung from the ceiling as a memory of Patricia's recent visit to Scotland. In front of the cabinets, there was a sofa and a table near to it. The table had many items on it, the most noticeable of which were toy cars, red measurement devices, a paper box with full of different shaped wooden blocks, and many rulers. Another table with a computer on it occupied the area where the back wall joined to the wall with the whiteboard on it.

Becoming a NBCST

Patricia completed her NBC requirements in 2003 and was granted her National Board certificate on the area of Early Adolescence Science Teaching in her first attempt. She heard about NBC when it first came out but she did not consider applying it because she was taking some online courses through National Science Teachers Association [NSTA] at the time in order to fulfill the requirements of the renewal of her teacher certificate. When she first heard about NBC process, she was hesitant whether

this new event promised any long term acceptance in the education community. She expressed her feelings at the time as “I wasn’t sure if that was really what I wanted to do. I wanted to wait and see if it was going to be established or it is going to be a ‘here today, gone tomorrow’ event” (Patricia, Interview, May 19, 2005).

Although money was a contributing factor in Patricia’s decision to go for NBC assessment process, it wasn’t the only one. She saw it as an opportunity to do something new after so many years of developing habitual behaviors in her teaching of science:

I felt like I needed to do something for me as a teacher. After you teach in the same area for so long, you begin to get stale. You either need to move or do something different because you get stale. So it was time for me to do something either go somewhere else or do something to make it fresh again. And that is what I did. (Patricia, Interview, May 19, 2005)

Before her decision for undergoing NBC process, Patricia learned more about the process through reading NBPTS’s website. In the process, Patricia sought help from her colleagues at her school. One of her colleagues who received her National Board certificate on Mathematics in the previous year was her biggest help in reviewing her writings. Patricia reported having particular difficulty analyzing her teaching videotapes. One of her colleagues sat and watched the videotapes with Patricia and made a lot of suggestions about what was happening in Patricia’s teaching.

Views on Teaching and Learning Science

Patricia described the role of a teacher in the learning process as follows: “The teacher’s job is to give some information and direct students to other information. You teach basic information first and then let students explore more” (Patricia, Interview, May 19, 2005). Before engaging students in laboratory science experiences, Patricia thought that students needed to be taught the basic information about the topic. Her teaching strategy consisted of three stages:

It is a three part process; theoretical, concrete, and back to theoretical again. The abstract, so they have got a clue about where you are going and build some vocabulary about the topic. The concrete, so they have got something to hang what you have said. And then back to theoretical again to tie those two things

together, which is a kind of conclusion or closure. (Patricia, Interview, September 13, 2005)

Patricia's teaching philosophy of science involved starting a new science topic by instructing students on the important information about the topic. When students built an understanding of the fundamental knowledge on the topic, laboratory science activities followed in order to give them concrete experiences. In her following interview response, Patricia saw student exploration of basic information as a time-consuming process:

You can't let somebody explore basic information without it taking way too long in lots of cases. A lot of times, you have to tell it to them anything in lecture kind of format, and then have them experiment with it so they can see how you said applied to something else. (Patricia, Interview, May 12, 2005)

Patricia conceptualized the laboratory experiences of students as a platform for applying their knowledge of science rather than learning new scientific information. This suggested that Patricia conceptualized student learning of science as a result of direct instruction. In her following excerpt from NBC portfolio, Patricia associated learning with retention of new information: "It has been my experience that learning while having fun is the best method for retention of new information. We remember the fun stuff" (Patricia, Entry 3, NBC portfolio). From Patricia's comments, it would be possible to infer that she saw laboratory activities of students as supplementary experiences to their learning of science through direct instruction.

Unlike Jennifer who defended irreplaceable status of actual laboratory experiences of students in their learning of science, Patricia felt that computer simulations offered valuable experiences to students. Although she did not necessarily consider computer experiences of students as an alternative to their laboratory experiences, she thought that computer-based laboratory activities would resolve many safety issues:

Your laboratories could be done through simulations. That doesn't mean that actual do-it-lab experiences are not valuable. They are very valuable but there are a lot of labs especially now in the state of "excuse me! You burned my hand. So I am going to sue you." Safety issues are so big. So that is why I really like my

computer-based labs. I found a couple of pretty good simulations previously. Like one of my favorite setups dealing with inertia. You can change the friction of the surface and you can change the mass, and then you can accelerate it to the certain rate to see how it would go, where it would stop. And your job is to manipulate the acceleration positive and negative, so it would stop at a certain point. It is a real problem solving. That was cool. (Patricia, Interview, May 19, 2005)

In her interview excerpt above, Patricia appeared to be open to innovative ideas in teaching of science. She was especially willing to integrate more technology into her teaching practices of science.

Although Patricia shared the general vision proposed in NSES for science teaching and learning, she was critical about the standards considered as a content checklist to be satisfied by teachers:

There is some real good ideas, real good concepts, real good ways of looking at science in those standards. In this age of accountability, they were meant to be visions and then those standards have been turned into documentable check it off. However, I believe that the vision is supposed to be a vision not a checklist. (Patricia, Interview, May 19, 2005)

Patricia questioned the standards for being imposed on science teachers to follow in their teaching practices of science. She supported the standards to be treated as a vision to enlighten the pathway of teachers. Like Jennifer, Patricia maintained a distance from the ideas of academic field of education. She found many of the educational theories impractical for actual classroom conditions:

It has been a good 8 or 9 years since I have been done any serious reading in science education of philosophy and theory. A lot of the stuff is just impractical in the classroom. It is nice pretty thoughts but. (Patricia, Interview, May 19, 2005)

In her interview excerpt above, Patricia indicated her lack of confidence in the ideas proposed by academic field of education. This could be regarded as a sign for her resistance to the reform ideas of science education.

Personal and Contextual Information about Martha

Martha was a middle school science teacher who worked at the same middle school with Mary. She had been teaching middle school science for the past 12 years, 11 of which she had been working in her current school. She graduated from a southeastern American university with bachelor's degrees in two majors. She double majored in biology and science education. After finishing the requirements for her biology degree, she was told that she could get another degree if she stayed one more year at the university. Since she was not sure what to do with her biology degree at the time, she considered having her second degree in science education as a backup. After her graduation from the university with her double degrees, she started working in a State job. Her major responsibility involved handling insurance and compensation claims of workers. Martha had already enough experience in insurance business because it was the type of job that she had worked in her university years. Martha did not pursue a teaching career just after her graduation from the university because she was not sure if that was what she wanted to do. Besides, Martha expressed that it was a little bit harder to find a teaching position in the city that she had been living because the new teacher graduates of the local universities were already filling most of the teaching positions in the city. After a year, the teacher with whom she completed her internship for her science education degree called her to let her know about an open teaching position. Martha accepted the position and her teaching career took a start after one year of her graduation from the university. Martha taught 6th grade science at this middle school for one year. The next year, she accepted another teaching position at her current middle school in the same school district. She had been working at her current middle school since then.

At the time of this dissertation study, Martha was teaching 7th and 8th grade integrated science. In addition to her science teaching responsibility, she also taught an 8th grade reading class to a group of chosen students based on their test scores. In Martha's middle school, all teachers were required to teach one reading class because this was one of the school policies in order to enhance the reading capabilities of all students in the school. Martha thought that limited abilities of students in reading were a

very big issue in her school because that eventually was affecting negatively their learning of science and their FCAT test scores on science.

Table 6 Information about Martha's and Mary's Middle School									
Student Population					Free/ Reduced Lunch	Minority Rate	Teacher/ Student Ratio	Number of Students	Number of Teachers
Black	White	Asian/Pacific Islander	Hispanic	Migrant	80%	78%	1:16	668	42
66%	29%	2%	3%	1%					
2004-2005 School Accountability Report									
Meeting Standards in Reading	Meeting Standards in Math	Meeting Standards in Writing	2005 Grade	2004 Grade	2003 Grade	2002 Grade	2001 Grade	2000 Grade	1999 Grade
40%	40%	83%	C	C	C	C	C	C	C

As can be seen easily from the table above, majority of the students in Martha's middle school came from the families whose socioeconomic status was under average. The number of the minority students had been increasing steadily every year since Martha started working in this middle school. With the introduction of new school grading system, parents with higher socioeconomic status desired their children to attend higher graded schools. Because Martha's middle school had been keeping its C school status for some time, the student profile of the school had been shifting toward more minority students. This led Martha to address a more challenging student population in the succeeding years.

Martha's Classroom Context

In Martha's classroom, the whiteboard covered most of the wall on the right hand side of the entrance door. The white screen hung down in the middle region of this wall by covering some part of the whiteboard. On the right side of the whiteboard, there was a panel that had some pictures of scientific laboratory tools. Martha usually spared the left hand side of the whiteboard for listing the specific classroom tasks on certain dates for each grade level that she taught. On the wall area above the left side of the whiteboard, Martha exhibited some of her professional honorary documents that she had been granted throughout her teaching career such as her National Board certificate document, the document given to her by LAST for her "Excellence in Middle School

Science Teaching”, the plate presented to her by school district to acknowledge her as “Campus Teacher of the Year” in 2001. Just on the left side of these framed honorary documents, the TV was fixed on the wall near to the door opening to the storage area and connecting to Mary’s classroom. Three rows of laboratory counters with blue stools around them were located in the middle of the classroom. A long table covered with papers, books etc. extended to the end of the whiteboard with some space between them. Just in front of this table, there was an overhead projector pointing towards the white screen on the wall with whiteboard on it. A projector attached to the ceiling also pointed toward the same white screen. The wall opposite to the entrance door was plain with an empty panel on it. The window extended from one side of the wall to the other side in the upper region of the wall. The table under the window had two computers with printers on it. The fume hood was located at the joint of this wall with the wall opposite to the whiteboard. This wall on the opposite side of the whiteboard had nothing on it other than a big picture painted on the wall, which depicted a natural view with an erupting volcano and a small fall of water. The painted picture on the right hand side of the wall had two burning stars dispersing fire around them. In an aquarium in front of this painted wall, Martha fed a pet snake. One of her students had given it to her because her parents did not let her keep it at their home. The wall on the left hand side of the entrance door was covered with cabinets full of textbooks. On one side of the cabinets near to the entrance door, Martha kept the glass laboratory equipments. On the windows of the cabinets, there were a couple of posters with cartoon characters on them.

Becoming a NBCST

Martha completed her NBC requirements in 1999 and received her National Board certificate at the end of that year. She was certified on the area of Early Adolescence Science Teaching in her first try. At the time, Martha and Mary attended a presentation given by a National Board Certified Teacher at their middle school. They were not able to find an answer for all of their questions on that day because the presenter was an art teacher and had a limited knowledge about the certification process of science teachers. Martha and Mary decided to sign up for NBC assessment process on that day. Martha explained her motivation for undergoing the certification

process with her willingness to accomplish a challenge in her teaching career. In addition, the monetary incentives offered to NBCSTs were attractive enough to convince Martha to pursue her National Board certificate.

During the certification process, Martha and Mary supported each other. Since it was the second year that NBC was being offered to teachers, there was not much information around about NBC assessment process yet. For example, Martha was not sure how they would score her portfolio entries because she was not able to obtain a scoring guideline at the time. That was why she felt that they were “the guinea pigs for the science certificate” (Martha, Interview, May 26, 2005). She was able to review NBC portfolio of a science teacher who achieved her advanced teaching certificate in previous year. However, this was more discouraging for Martha than helpful because she thought that this teacher was so extraordinary in her teaching work:

She was who we called “superwoman.” She had a section in her portfolio working with community of parents. She was a science teacher with published books. She had worked with the governor. She had done all those things. And I was thinking that this was not me. I didn’t have a published book. I didn’t have a PhD. I was just a teacher. And I thought maybe this was just not for me. Therefore, I didn’t have a lot of confidence. (Martha, Interview, May 26, 2005)

Although Martha was discouraged by her review of this science teacher’s NBC portfolio, she was able to pass NBC assessment process successfully in her first attempt. She felt that choosing the right activities to include in her portfolio and having good writing skills helped her achieve the advanced teaching certificate with NBC.

Views on Teaching and Learning Science

Martha saw the nature of science classes different from other classes of students. She conceived a classroom environment in which students were given more freedom in their learning experiences of science:

I think that science class should be a very different class from other classes. I think that the students should be able to investigate and do things a little bit differently. I tell the kids that this class is very different than math and language arts classes because I am not going to be screaming at you every time that you

stand up. I think the kids need to have more flexibility depending on our specific activity on that day. (Martha, Interview, May 26, 2005)

Martha conceptualized student investigations as an intrinsic aspect of science classes. In a learning environment driven by student investigations, she promoted the flexibility given to students in interacting with others as an essential element of this learning environment. Martha felt that teaching science at the middle school level involved capturing the interests of her students. In order to keep her students engaged with science lesson, she spent extra effort in bringing interesting topics to the attention of her students:

So when I was coming up with my topics, I am so working on them. I am trying to pick some topics that stimulate my students' excitement. That is really the key with middle school students that you have to find something that they are interested in. They are tough audience. Even they want to learn something, they can be a tough audience. (Martha, Interview, May 26, 2005)

Martha wanted to make learning science a fun experience for her students. This required using variety of different activities in her teaching practices of science to attract her students' attention.

Martha described her major role as a facilitator of her students' learning of science. Facilitating student learning involved engaging students into appropriate classroom experiences to allow them build their own understanding of scientific ideas:

I would see myself as a facilitator. I like to give students experiences and let them come up with some of their own information. And then we discuss it. So I try to do as much activities and projects as I can to give my students the opportunities to build their own information. (Martha, Interview, May 26, 2005)

In order for students to be able to generate meaning from their classroom experiences, Martha knew the importance of providing autonomy to them in their classroom investigations:

I think if you let students do little exploration on their own, you can definitely get a little bit further with them. It goes back to one of the qualities of being a good teacher is giving your students some choices. However, I am not the kind of person that would say "Ok! We are going to just experiment all day and you just

choose.” I certainly teach more structured than that. (Martha, Interview, May 26, 2005)

Although Martha saw autonomy given to students as an important component of constructing their own understanding of scientific concepts, she found higher levels of student autonomy unrealistic for actual classroom conditions. That was why she opposed the idea of giving the total control of learning to the students.

Martha was open to accept new ideas in her teaching practices of science. She used technological tools in her teaching. She especially found computers helpful in motivating students on their classroom learning tasks:

Students are a lot more cooperative if they can get on the computer and do something. And I got my projector up there and that really help a lot because I can demonstrate many things. I can show them how to write a formula in Excel, and they can actually go and do it. I can show them how to use inserting sounds into a PowerPoint presentation. So that really opened a lot of options. (Martha, Interview, May 26, 2005)

Like Patricia, Martha was willing to integrate more technology into her teaching practices of science. She wrote small grants to school district in order to get funding for some technological tools to use with her students. One of those technological tools that Martha purchased recently was Qwizdom—audience response system. With this immediate response device, Martha wanted to involve all of her students into the interaction process in the classroom.

Personal and Contextual Information about Mary

Mary was a middle school science teacher with 13 years of teaching experience. All of her teaching experience had been at her current middle school. Mary attributed her long stay in the same school to the participatory approach of school administration: “In many schools, the administration tells you what to do, how to do it, and how long you have to do it. In this school, we have an input in everything” (Mary, Interview, May 5, 2005). Mary had a bachelor’s degree in geology from a central American university and a master’s degree in science education from a southeastern American university. At the time of my visits to her classes, she was teaching 7th grade integrated science. Other

than her teaching task of science, she was also teaching a reading class to 6th grade students because it was the school policy that each individual teacher was required to help the students improve their reading skills. According to Mary, this was the only school in the district that implemented a school-wide reading program like that. Mary supported the reading program because many students were having difficulty with reading in her middle school. The majority of the students⁶ in Mary's middle school came from economically disadvantaged minority families. Mary found working with these students challenging because most came to school with their family problems. She was not happy with the level of parental involvement in her middle school: "It is just like pulling teeth to get parents to come out and support us in any way even athletics" (Mary, Interview, May 5, 2005).

During the semester, Mary collaborated with a doctoral physics student from the local university as a part of GK-12⁷ program. Whereas she acted mostly as a teaching consultant and sometimes as a content consultant in life science, the graduate student helped her with physics content and technical details. As a result of this collaboration, physics graduate student had a chance to become involved with middle school teaching and students. Mary had the opportunity of having a physics content expert and a technical assistant in her classroom. She had less confidence in physical science: "We all have our specialties. Mine is not in physical science. I had to do a lot of study. And I don't feel that comfortable with it. That is why I have a lot of resources" (Mary, Interview, May 5, 2005).

Mary's Classroom Context

Because Mary and Martha were working at the same middle school with adjacent classrooms, their classrooms were symmetrical. Mary's classroom was colorful with a butterfly, a dragonfly, and a bird with big wings made from colorful papers. They were hanging down in the middle of the classroom ceiling. Three laboratory counters with blue stools around them were located in the middle of the classroom. Unlike Jennifer's high school classroom, Mary's students had to use laboratory counters and stools for all

⁶ The school was comprised of 66 % of black students, 29 % of white students, 2 % of Asian students, and 3 % of Hispanic students.

⁷ GK-12 is a NSF funded research program. The program was intended to improve the collaboration between science teachers and science graduate students by placing graduate students into the classrooms of K-12 teachers.

of their class activities. The wall on the right hand side of the entrance door displayed variety of student work created in different fun activities. Mary identified the different class periods with different colors such as yellow, green, blue, and red. The four panels on the wall with their corresponding colors representing the class periods included the names of some of the students with their assigned tasks like FCAT stamper, clean-up lab supervisor. At the other end of the right hand side wall, a fume hood was present. Mary's computer and printer sat on the table near to the fume hood. On the left hand side of the entrance door, a long cabinet with many shelves covered the entire wall. The shelves of the cabinet were filled with textbooks, one of which I noticed was "Science Voyages." On the other end of the cabinet, there were several pieces of chemistry glassware. The classroom window extended through the entire upper part of the wall on the opposite side of the entrance door. On the windowsill, Mary exhibited several different rock specimens, which revealed her geology background. Under the window, there were a couple of panels, one of which noticeable was "Word Shower" with several science-related words on it. The whiteboard and screen were located on the wall opposite to the other wall exhibiting the student work. The door on the right hand side of this wall opened to the storage room and at the same time connected Mary's classroom to Martha's. There resided a TV set with a VCR just on the edge of this door. A whiteboard and a screen were located in the middle of the wall. On the left hand side of the whiteboard, a couple of posters covered the wall. In front of the whiteboard and screen, a long table with many papers dispersed on it created a small space between the whiteboard and the classroom. A projector and a voice enhancement device were fixed on the ceiling. Two live plant flower pots were found on the TV and metal cabinet under the window.

Becoming a NBCST

Mary was a National Board certified teacher since 2000. She achieved her certificate in her second try. She missed her first try with a couple of points so she decided to resubmit one of the portfolio entries to increase her overall score. Therefore, she did Entry 3—Inquiry through Investigation—twice and received her Early Adolescence Science Teacher certificate in her second attempt. Mary heard about NBC for the first time in 1998 when a National Board certified high school art teacher working

in the same school district made a presentation about her NBC experience. After the presentation, Mary and three of her colleagues in her school decided to go through the NBC process. While one of her colleagues was not able to complete the process, Mary's classroom neighbor, Martha, and her other colleague, a social science studies teacher, achieved their certificates in their first tries.

Mary was not completely confident with her teaching. She considered the assessment process of NBC as an opportunity to get an affirmation of her teaching quality:

I tended to have little some insecurity about that [my teaching]. I guess all teachers do. I mean you have some confidence in a lot of areas of teaching but when it comes to improving yourself, I can always be better. I think that was one of these ways that I thought I could make myself better. (Mary, Interview, May 5, 2005)

Throughout the NBC portfolio assessment process, Mary and Martha supported each other. They continued to interact since they were teaching in adjacent classrooms. At the time, Mary had two young children and writing her portfolio artifacts was challenging for her. She spent a lot of effort on her portfolio artifacts. However, her first efforts did not pay off because her score was not enough to achieve the National Board certificate. When she received her score, she felt very upset:

That was very hard for me. You have to tell people that you are doing this because you need their cooperation. Your principal knows and then suddenly you don't make it. It is like "Ok! You are a failure." You have to really work through that and understand that it is not all about that one time shot. It is a process. And that was the hardest for me. My ego took a blow. That was the hardest part for me. I cried for a whole weekend. (Mary, Interview, May 5, 2005)

After a while, her initial sense of failure receded to be replaced by ambition for success. She thought that the teachers who passed the assessment process were not any better than her. She achieved her advanced teaching certificate by resubmitting one of her portfolio artifacts.

Views on Teaching and Learning Science

Mary supported that middle school students needed to be introduced to science in a way to excite them. She felt that science learning at this age level needed to be centered on classroom activities to stimulate student interest in learning science:

I think the content has just gone overboard. I think we push the content so much. I am not saying that content is not important. It is but I just think middle school science should be all about getting students excited, all about getting them interested. Understanding some basic concepts sounds to be more appropriate at the middle school level. (Mary, Interview, May 5, 2005)

At the middle school level, Mary criticized the content-oriented structure of science education. She argued reducing the intensity of science content knowledge to understanding basic science concepts. In order to make science learning an exciting experience for students, Mary considered hands-on activities as an inseparable element of teaching science:

I just find it difficult to teach a concept that the kids can't get their hands on it. I just think it makes more sense and my job is to help them make those connections and wrap it up well, which I don't always do very well. That is something I had to work out over the years. I am still not good at it. I tend to move on to the next thing because I am pressured by how many standards I have got to get taught and I tend not to do wrap up very well. (Mary, Interview, May 5, 2005)

Based on Mary's argument in her interview excerpt above, it would be possible to suggest that hands-on science constituted the essence of her philosophy of teaching science. She wanted her students to recognize that science permeated very aspect of their lives. Hands-on activities played critical roles in making the necessary connections with their lives:

Science is every part of their life. I think that our job is to have them make those connections. I think if it is taught out of a book with nothing is hands-on, nothing is related to their lives, they tend to think that science is this thing that they go to school to learn. (Mary, Interview, May 5, 2005)

Mary's conception of teaching science centered on activities. She supported active process of learning science through conducting hands-on activities.

Mary saw her role as a science teacher as guiding and facilitating her students' learning of science: "Many times I am a guide. And other times I facilitate a lot" (Mary, Interview, May 5, 2005). When she knew the specific answers to be reached by her students, she guided them to the proper direction. However, when something came up naturally that she did not know the answers, she facilitated learning of students by directing them to appropriate resources to find their own answers: "Sometimes I know what direction that I want them to go. So I guide them and I want them to kind of figure it out as we go. There are times when I don't know what direction I want them to go. So I facilitate their learning" (Mary, Interview, May 5, 2005). Although Mary supported that students would learn science best by doing, she thought that they needed to be taught specific science terms with more traditional strategies in order them to communicate effectively:

There are some times when I use traditional means. We talk, we have to learn the science terms in order to communicate about certain things. So that is more traditional but I think kids learn science by doing, I always have. I think they need to have hands-on. (Mary, Interview, May 5, 2005)

Mary did not base her teaching on textbooks. She used variety of resources in her teaching practices of science. In her following interview response, she described some of the resources that she benefited in her teaching of science:

I use a lot different ones. I use a lot of hands-on with Project WET, Project WILD, GEMS. I pull things from all kinds of things. I read some journals. I talk to science teachers and I pull ideas from that and modify them. And sometimes I just come up with things just on my own. I use a little bit everything. I mean I am not textbook-driven although some textbooks have some pretty good activities and hands-on things. (Mary, Interview, May 5, 2005)

Mary always searched for new science activities to use with her students. She opposed centering teaching of science on textbooks.

Mary shared the ideas proposed in science education reform documents. She emphasized the parallel ideas promoted in advanced science teaching standards of NBC with NSES:

NBC standards are all based on National Science Education Standards. Your teaching has to be aligned with the standards. Otherwise, you wouldn't be certified. Like I said before, if you don't buy into that, then this is waste of your time. But I happen to believe in those standards are the direction where we need to go. I just wish I was better at it. (Mary, Interview, May 5, 2005)

In addition to sharing the vision of science education standards, Mary wanted to improve herself to be better in enacting the science teaching vision presented in the standards.

Comparative Overview

All teachers in the study were females. Except Jennifer, they were teaching science at the middle school level. Jennifer was a high school chemistry teacher. Except for Martha, the participant teachers had master's degrees. Martha had a double major in biology and science education. Martha and Mary were working in adjacent classrooms at the same middle school. Like Martha and Mary, Jennifer and Patricia knew each other because IB program in Patricia's middle school was feeding IB program in Jennifer's high school. Many of Patricia's students became Jennifer's students after they graduated from middle school.

The schools in which those participant teachers worked were dominated by a minority student population. However, in comparison to Jennifer and Patricia, Martha and Mary were working with a more challenging group of students. Due to the fact that Jennifer and Patricia were teaching science in IB programs, they were addressing to a select group of student body even if their schools were populated with minority students. The students in IB program were selected based on their scores on standardized tests. The curriculum followed in IB program tended to be more content-intensive than the integrated science taught by Martha and Mary in their middle school. Jennifer and Patricia had higher expectations from their students. They expected their students to pursue prestigious jobs related to science.

All teachers in the study had many years of teaching experience. In addition to K-12 teaching experience, Jennifer worked at a local community college as an adjunct chemistry instructor for several years. Through many years of teaching experience, participant teachers had been able to establish their ways of teaching science, which were all successful on their own respect. They proved their accomplished teaching capabilities in NBC portfolio assessment process. None built her teaching practices of science on textbooks. Rather, they all used variety of resources in their teaching practices of science. However, their views of teaching and learning science were not equally open to science education reform ideas. Jennifer and Patricia kept a noticeable distance from the ideas promoted by academic field of education. They found many educational theories impractical for actual classroom conditions. They expressed some resistance to ideas originating from education reform movements. With a content-driven motive, Jennifer felt that the ideas promoted in science education standards did not fit into her classroom context. As opposed to her higher level students in IB program, she argued that teaching ideas proposed in NBC standards would help lower level students learn science better. In comparison to Jennifer and Patricia, Martha and Mary displayed a more reform-minded science teacher portrait. They supported the ideas included in science education reform documents. In their teaching practices of science, Jennifer and Patricia appeared to depend more on their overhead projector located in front of their classrooms. Many times, they instructed their students from a chair in front of the overhead projector. Martha and Mary's use of PowerPoint projectors was more limited in presenting science topics. They seemed to situate their teaching of science more on science activities. Therefore, the frequency of direct instruction used by Martha and Mary with their students was relatively less than Jennifer and Patricia. The different views of teaching science identified by teachers in the study suggested that NBCSTs were not necessarily open equally to science education reform ideas.

CHAPTER 5

NBC AS PROFESSIONAL DEVELOPMENT EXPERIENCE

Introduction

As mentioned in previous chapters, beyond being an alternative teacher assessment procedure to recognize teachers with accomplished teaching abilities, NBPTS also claims to have the mission for the professional growth of teachers as an additional benefit of their involvement with NBC performance assessment process. Such a claim is a new dimension of teacher assessment that was not included in more conventional teacher testing approaches of the earlier generations (Darling-Hammond, 2001). However, whether this new educational phenomenon has positive contributions to the professional growth of teachers is a question waiting for a research-based answer.

The teacher education community needs more research studies investigating the professional development dimension of NBC portfolio assessment procedure in order to be informed better about the professional development experiences of teachers in their journey with NBC portfolio assessment process. This chapter aims to provide such evidence. In the chapter, I inquired into what it meant for NBCSTs to pursue their advanced teaching certificate with NBC in regard to their professional development as science teachers.

It has long been the goal of the science education community to create an affiliation with the ideas of science education reform among science teachers. Advanced teaching standards of NBC for science teachers are built primarily on the ideas of recent education reform movements. Therefore, NBPTS like several of its counterparts supports the central tenets of science education reform ideas in their documents of advanced teaching standards. In parallel to this, teachers who undergo the performance assessment process of NBC are expected to become more inclined to

support science education reform ideas. Does NBC really have the power to awaken such consciousness of reform ideas in science teachers? If not, what role NBC plays in science teachers' professional development? And could we say that the teaching notions and the practices of those of the science teachers who successfully passed the performance assessment of NBC are necessarily aligned with the central ideas of science education reform efforts? In the following sections of this chapter, I seek an answer for those questions through basing my arguments on the perspectives of four experienced science teachers who received their advanced teaching certificates with NBC in various years.

Affirmational Role of NBC in Professional Development of Teachers

Three of the four teachers who participated in the study achieved their advanced teaching certificates with NBC in their first attempts. In Mary's case, her portfolio score fell a couple of points short of the score required to pass NBC assessment process in her first try. Therefore, she had to revise and resubmit her portfolio a second time. Despite being disappointed, Mary did not suffer too much in completing her second entry and achieved her advanced teaching certificate the next year. The teachers in the study started their NBC portfolio assessment journey with many years of science teaching experience. Successful completion of NBC assessment process by these teachers in their first attempts indicates that they started the NBC process with high teaching capabilities. The perspectives of teachers, who fail to achieve their advanced teaching certificates or start the assessment process of NBC with less teaching experience, on NBC as professional development experience might exhibit different characteristics from those experienced science teachers in the study. The NBC experiences presented by the teachers in this study represent the ideas of successful teachers in NBC assessment process. In Table-7 below, I present the views of the participant teachers on the professional development dimension of NBC assessment process.

Table 7 At First Glance: NBC as a Professional Development Experience		
	Professional Development	Assessment Quality
Jennifer	▪ NBC strengthened her existing views of teaching science. ▪ Gained a higher confidence into her teaching of science. ▪ Avoided to give an impression that she started teaching differently as a result of NBC experience.	▪ Acknowledged NBC as a fair way of determining teachers with accomplished teaching practices. ▪ Doubted the possibility of passing NBC assessment procedure by unqualified teachers.
Patricia	▪ NBC affirmed her accomplished teaching capabilities of science. ▪ Questioned any long-term effects of NBC experience on teachers. ▪ Attributed the ultimate success of NBC as a professional development experience to the willingness of teachers to grow professionally.	▪ Stressed the important role of good writing skills in passing NBC assessment process. ▪ Saw teaching videotapes as strong evidences to support the written descriptions of teaching practices.
Martha	▪ NBC served as documenting her good teaching skills rather than struggling with new ideas. ▪ Claimed that teachers who support more traditional views of teaching science would be influenced more from their NBC experiences. ▪ Tied the effectiveness of NBC as a professional development experience to the willingness of teachers to grow in their profession.	▪ Discussed the importance of good presentation of written portfolio reflections in achieving NBC. ▪ Criticized the lack of scoring guidelines at the time she went through NBC assessment process.
Mary	▪ NBC confirmed her professionalism and the quality of her teaching practices. ▪ Considered the intentions of teachers in pursuing NBC as an important factor in their professional development. ▪ Found NBC more beneficial for teachers who are open to accept reform ideas.	▪ Described NBC as a robust way of determining accomplished teachers despite failing to observe their actual classroom teaching practices. ▪ Questioned the insufficiency of the feedback given to teachers other than numerical scores.

Before presenting each teacher's case in the study, I make the following assertion based on teachers' perspectives of NBC portfolio assessment procedure as a professional development experience.

Assertion-2: Undergoing NBC performance assessment process strengthened teachers' existing views of teaching science rather than allocating new accommodations in their science teaching practices.

In order to support the assertion that I made above, I give an account of each teacher's views of NBC as a professional development experience. Afterwards, I make a comparative discussion of the place of NBC portfolio assessment experiences in the professional lives of the participant teachers.

Jennifer

Jennifer started her science teaching career without completing a formal teacher education program. After her graduation from the university with a biology degree, she found herself teaching chemistry in high school level. The early mechanism of Jennifer's teaching practices was primarily shaped by the observations of her teachers during her time as a student. She modeled the teaching styles of her science instructors in the university. And she improved her teaching abilities through several years of classroom teaching experience. Jennifer always identified herself as a traditional teacher. She did not find her teaching innovative and open to trying new things: "I was a traditional teacher and I could never stand up with other people who try all of these experimental ways like jigsaws and all of these kinds of teaching methods" (Jennifer, Interview, May 12, 2005). Because Jennifer felt that she was a traditional teacher, she was not optimistic for satisfying the advanced teaching standards of NBC. She felt insecure about her traditional teaching practices of science and never anticipated to pass the rigorous assessment process of NBC:

I felt like what they [NBPTS] espoused and what I was doing were different, which was one of the reasons why I was afraid for going for NBC because I thought I was a traditional teacher. I realized that I was doing those things that they talked about although they were just not exactly the form that they taught. (Jennifer, Interview, May 12, 2005)

Although Jennifer started her NBC assessment journey with a lack of confidence into her teaching practices of science, she was able to achieve her advanced teaching certificate with NBC in her first attempt.

When I questioned Jennifer for her overall feelings about NBC as a professional development experience, she appeared to be confused about the positive and the negative aspects of her experience with NBC. At the beginning stages of my interviews with her, she approached to the NBC phenomenon with more caution and doubt. She felt that teaching standards of NBC targeted primarily to low achievement levels. Since Jennifer was teaching in IB program with select students, she did not necessarily think that NBC standards fit well into her specific context: "I feel about NBC standards that I could do it for lower levels. But I feel like the higher up they [students] get, the less they

[NBC standards] apply” (Jennifer, Interview, May 12, 2005). In her following interview response, Jennifer displayed her dissatisfaction in proving her teaching capabilities for financial incentives offered for NBCSTs:

What I feel is that I am teaching with my whole heart and my kids are learning. It is just not right to have to take the time away from teaching and prove this in such a way, for me to do that for money. I see that there is a variety of qualities of teachers. And we are paid the same amount regardless of how well we teach or how poorly we teach. I wish there were a way to show that but there probably is no way to show that. Anyway I kind of resent having to prove myself like this for more money. (Jennifer, Interview, May 12, 2005)

As Jennifer articulated more about her NBC experience in the interviewing process, her earlier cynical approach to NBC took a milder form. Although she still found NBC as a professional development experience for teachers a little bit unrealistic, she came to the conclusion that the assessment quality of NBC process was fair enough to determine the teachers with accomplished teaching capabilities: “I don’t think if you are a bad teacher you could pass it. So in that way, it is fair. But I think the professional development part of it is a little bit far out” (Jennifer, Interview, May 12, 2005). In the following interview excerpt, Jennifer explained her diminishing negative attitude to NBC assessment process:

I am not as negative as I thought I was. Well, I mean some of your questions made me think about it better like “Do you think it is fair way of determining teachers with accomplished teaching practices?” and you know, that makes me think well. If you are a bad teacher, you couldn’t get it. So in that way, it is good. It does reward somebody who could get it but then on the other hand, should we have to do this to prove it. (Jennifer, Interview, May 12, 2005)

From Jennifer’s expressions above, it appeared that she valued the assessment quality of NBC process. Yet, she was not clear cut about the place of NBC in her professional development as an experienced science teacher.

For Jennifer, NBC experience played the affirmational role in her professional teaching career. Achieving NBC was a good indication of her quality teaching practices. In a sense, passing NBC assessment process was an important sign for indicating her

successful teaching performances with her students. That was encouraging for her because she always felt that her teaching stationed on the traditional side of the teaching spectrum. Jennifer expressed the place of NBC in her professional development as follows:

Whenever you have an outside validation, it helps you to feel good. You don't always get that from your students and nobody else really sees you teach so you never know really. Some people love you and some people hate you as parents and students and sometimes that just goes along without you knowing it while they do well in your class. So it is a little bit hard to judge. Just because you feel good about your teaching doesn't necessarily mean that it was good. (Jennifer, Interview, May 12, 2005)

For Jennifer, NBC was an outside validation of good teaching, which was something hard to obtain from inside of her classroom.

Before obtaining her advanced teaching certificate, Jennifer was insecure about her teaching. Yet, after becoming a NBCST, it was another story. She still considered herself as a traditional teacher but her confidence into her teaching practices grew exponentially. The outside affirmation obtained from NBC assessment process led her gain more confidence into her teaching. Achieving her NBC with her natural teaching practices with traditional orientation was particularly an important contributing factor to her developing self-confidence as a science teacher: "For me, to use my normal teaching techniques and pass it [NBC] gives me a lot of confidence. I didn't have to contrive things except the group discussion. I have got to say I did, you know" (Jennifer, Interview, May 12, 2005). With her growing confidence as a NBCST, Jennifer was planning to have an intern teacher in the following year. In her following statements, it was apparent that the confidence that she gained from her experience with NBC process was the major factor in her decision to accept an intern teacher into her classroom the next year: "I am going to take an intern next year. Without NBC, I wouldn't have had the confidence to do that because I think what I would really have to offer anybody" (Jennifer, Interview, May 12, 2005). Jennifer approached to the field of education with some doubts and prejudices. Her science background kept her from being enculturated into the community of science education. She identified herself as a

science person rather than an educator. Throughout many years of teaching experience, Jennifer developed her own way of science teaching, which did not necessarily compromise with the ideas of science education reform movements. Jennifer felt uncomfortable for being the subject of educational research studies. Her agreement to participate in my dissertation research study was the direct result of her developing confidence into her teaching abilities:

If I weren't National Board Certified Teacher, I probably wouldn't really want you to come in and talk to me. I would have thought "Oh! They are going to find out how bad a teacher I really am." As I feel more confident as a teacher, I feel less threatened by someone coming in and watching me. (Jennifer, Interview, May 12, 2005)

NBC improved the confidence of Jennifer into her teaching of science tremendously. Accomplishing her advanced teaching certificate in her first attempt was an extra motivation for Jennifer to develop a sharpened confidence in her way of teaching:

I think I am a good teacher. I think I am a real good teacher. I think that I deserved to have my National Board Certificate. I think that you can be a good teacher and not pass it. And that is hard on teachers. I am real glad that I passed it at the first time. So I think I am a good teacher. (Jennifer, Interview, May 12, 2005)

In the interview excerpt above, it was possible to see the reflections of Jennifer's elevated confidence as a result of her successful completion of NBC assessment procedure.

Becoming a NBCST brought more respect and recognition to Jennifer from her colleagues and school administration. Although she did not teach any different than before, her achievement of NBC increased her recognition among her colleagues:

Well, I feel better, yeah! I mean it has done a lot for my self-confidence. And it is something that I can say that other people look at and say "Oh! Look! She is Board Certified!" and I think I don't really teach any different than I did before when I was not Board Certified. But somehow now, I have this halo above my head and people think "Oh! Look! She is Board Certified!" and it just means I

worked hard for one year to show somebody that is what I do. (Jennifer, Interview, May 12, 2005)

Jennifer liked the attention but she did not know what to feel exactly because she wanted people to know that she was not teaching any different before her experience of NBC process. She did not want to give the wrong impression that NBC was a magical touch that changed everything in a positive way in a second.

Patricia

Patricia considered NBC process as an important professional development step in her teaching career. Undergoing the assessment process of NBC allowed her to reconsider her stated teaching habits developed through many years of teaching experience. However, Patricia knew that NBC process was an assessment procedure for experienced teachers to present their best teaching practices rather than their everyday teaching practices of science. In order to make sure that Patricia was capturing the best representation of her teaching with her students, she needed to videotape her teaching practice several times because something went wrong each time: "You want to present your best foot. One time, some of the students were off task. One time we got picture but no sound. Another time there was a fire in the middle of our taping" (Patricia, Interview, May 12, 2005). However, Patricia still found videotapes as more reliable evidence of quality teaching than the actual written explanations of the teaching scenario. She thought that videotapes were providing the concrete evidence about the interactions of the teachers with their students. When I asked Patricia if NBC assessment process was a fair way of deciding the accomplished teachers with quality teaching practices, her response came as follows:

The videotaping when it is done with whole class, when it is done properly, you really see how a teacher interacts. And that is a way to determine accomplished teachers. I mean you can write up your teaching and not be anything how you are in the classroom but the videotape is the evidence to support that you are doing well. (Patricia, Interview, May 12, 2005)

For Patricia, her advanced teaching certificate meant proving that she was a professional teacher. She noted, "I think it is another step towards proving that I am in fact a professional teacher" (Patricia, Interview, May 12, 2005). Like Jennifer, Patricia

saw the place of NBC in her teaching professional development as an affirmation that her teaching practices of science were quality enough to pass the rigorous assessment procedure of NBC: “I learned that some of the stuff that I have been doing was really the right stuff. It was an affirmation of what I am doing is the correct stuff” (Patricia, Interview, May 12, 2005). In her experience with NBC assessment process, she realized that she was already performing her role as a science teacher in her classrooms with great success.

Patricia did not expect to pass her NBC assessment in her first attempt. She was able to achieve her advanced teaching certificate in her first try without having to resubmit any part of her teaching portfolio for another evaluation. When Patricia thought back about her experience with NBC portfolio assessment process, she felt that having a passing score for the evaluation of her teaching portfolio intensified her sense of affirmation that her teaching was accomplished and aligned with the top teaching standards of the nation. Furthermore, accomplishing her advanced certificate in her first attempt taught Patricia that she was a better teacher than she thought she was: “I learned that I am a better teacher than I thought I was” (Patricia, Interview, May 12, 2005). Achieving her advanced teaching certificate with NBC in her first attempt before other teachers in her middle school gave additional confidence to Patricia:

I have passed first time out and other teachers that I consider to be better than me took two or three times to get through it. And it made me feel good because I got it in my first try. Because there are other teachers that I respected their teaching of biology and it took them longer to get through it. It has made me feel really good. (Patricia, Interview, May 12, 2005)

In Patricia's case, not only passing NBC performance assessment procedure but also passing it earlier than other teachers in her middle school played an important role in enhancing her confidence into her teaching practices of science.

NBC process acted as an outside confirmation of good teaching rather than creating long-lasting new accommodations in Patricia's teaching of science. In other words, Patricia thought that undergoing the NBC process would not necessarily help teachers in their professional growth as a teacher. To Patricia, by its nature, the assessment procedure of NBC was an evaluation process in which teachers presented

their best teaching performances in their classrooms. Therefore, NBC assessment process did not necessarily uncover the daily teaching practices of science teachers but rather their highest capabilities of performing their teaching tasks in compliance with the rigorous standards of NBC. In that respect, Patricia claimed that many teachers who underwent NBC process adopted innovative teaching strategies momentarily to satisfy the advanced teaching standards of NBC. Yet, they did not keep using those strategies consistently with their students: "There are teachers who will do something just to satisfy that part [of NBC standards] but then they don't actually ever use it again in their classroom. That is the reality of it" (Patricia, Interview, May 12, 2005). Although Patricia pointed out teachers' tendency in employing some teaching strategies in order to satisfy the requirements of NBC portfolio assessment procedure, she supported that the level of the professional growth of the teachers depended on their intentions with going through NBC process. She felt that the professional growth of teachers with their experiences in NBC performance assessment procedure were contingent upon their willingness to learn and to become better science teachers:

There are people who get NBC just because they want the money. There are some people who get NBC because they really want to be a better teacher. And those who really want to be a better teacher will go and get out of it as a better teacher. They will use more inquiry and they will use more reflective teaching techniques. (Patricia, Interview, May 12, 2005)

From Patricia's approach to NBC as a professional development, it would not be wrong to suggest that she thought that any long term effects of NBC on teachers would be very much dependent on their willingness to learn for their professional growth. Otherwise, their involvement with the certification process wouldn't go beyond satisfying the standards of NBC for the purpose of passing the rigorous assessment procedure of NBC.

Martha

Martha and Mary decided to undergo NBC process together after they attended a presentation made by a National Board Certified art teacher in their middle school. However, they were not able to find satisfactory answers for their questions on this specific day due to the fact that the presenter had a limited knowledge about the

requirements of NBC for science teachers. They decided to pursue it by supporting each other. At the time, Martha did not have much confidence if she could accomplish her advanced certification with NBC. She complained about the lack of appropriate scoring guidelines for teachers to lead them in their effort to complete their portfolios:

I just didn't have a lot of confidence because I had nothing to base it on. I didn't have a rubric or anything to determine how they were going to score me. So I had no idea. Now, they do give out rubrics and they give out scoring guide. And you get to see all that before handed but not while we were doing it. We were the guinea pigs for the science. (Martha, May 26, 2005)

Martha had a chance to review the NBC portfolio of a science teacher in order to get an idea about the structure and the content of science teacher portfolios. However, this experience was everything but helpful for her. That was because Martha found this teacher's NBC portfolio highly sophisticated with several artifacts in it like published books and papers. Comparing herself with this teacher with a PhD degree, Martha did not feel good about her chances of passing the assessment procedure of NBC. Despite such hurdles at the time, Martha accomplished her advanced teaching certificate in her first attempt. However, she was not so sure how she made it through in her first try because she believed that she did not spend as much time on her portfolio as she thought she should have done:

I passed it in my first try. I don't know how because I did not spend as much time on it as I should have. I guess I am kind of a last minute person and I kind of procrastinate it. So I think the only thing that really helped me get by the exam, I am pretty good writer. I think that helped me get by it. And also choosing the right activities for the portfolio entries, I think, really helped. (Martha, May 26, 2005)

Martha attributed the major factor in her success to her good writing skills and her choice of good activities to include into her portfolio.

Martha considered NBC as an important step in her professional teaching career: "For me, it was just another step. It was a kind of a way to become more of a professional" (Martha, Interview, May 26, 2005). However, as it was the case with Jennifer and Patricia, Martha also interpreted her successful involvement in NBC process as an affirmation of good teaching skills. She felt that her teaching practices

found an endorsement in a nationally recognized prestigious group of educators. In Martha's case, her sense of gaining an affirmation from NBC to her teaching practices of science outweighed any of her new learning experiences:

For me, I think it really kind of affirmed what I thought about teaching. And I did learn some new things but I really think that it affirmed what I already knew and things that I was already doing. It wasn't such a big stretch for me because I felt like I was doing a lot of those things. (Martha, Interview, May 26, 2005)

From Martha's expressions above, we might infer that the process of NBC was more of documenting her good teaching skills rather than struggling with new ideas. Passing NBC assessment procedure in her first attempt played a big role in gaining a sense of affirmation for her quality teaching practices of science.

Whereas Martha did not consider her involvement of NBC process as a transformative experience in her teaching of science, she supported that undergoing the process of NBC would be very influential for some teachers with limited teaching abilities:

I think it helps some teachers more than others. We had some teachers here that I thought they should go through the process. I didn't know if they are going to make it but I thought the process would be good for them to go through. (Martha, May 26, 2005)

Martha felt that the process would help teachers who followed traditional ways of teaching science more even if they failed to pass NBC assessment process. Because Martha did not place her teaching of science into the traditional spectrum of teaching techniques and she felt that she had already been following most of the NBC standards in her teaching, she excluded herself from those teachers who would benefit more from their experiences with NBC process. She explained her reasoning for believing that the process would be better for some teachers than the others as follows:

I think some teachers are already doing some of the things. But for some other teachers, they don't. Maybe some of these skills aren't coming as naturally to them. Or maybe they have been teaching in a certain way for so long that they really don't look into other options. I know a lot of teachers I run into will say things like "Oh! My kids can't handle activities. They can't handle hands-on

things.” So they don’t do them. They really haven’t given it a good try. (Martha, Interview, May 26, 2005)

According to Martha’s experiences with NBC, the benefit of the process for teachers was inversely proportional to the traditional nature of their teaching. In other words, Martha asserted that those teachers whose teaching styles deviated more from the advanced teaching standards promoted by NBPTS might experience more transformation in their philosophy and way of teaching than those of the teachers whose teaching had already been closer to the teaching vision of NBPTS. However, Martha thought that the professional growth of teachers from NBC assessment process depended primarily on their intentions for pursuing their advanced teaching certificates with NBC. Like Patricia, Martha also thought that those of the teachers who would consider engaging in NBC assessment procedure for the purpose of obtaining the bonus incentives with no intentions for growing professionally would benefit in a limited way from their experiences with NBC process. Martha attributed the ultimate success of NBC as a professional development experience on the willingness of teachers to grow professionally:

It just really depends on the person. If it is somebody that really wants to improve, change and do better, it might help. If it is somebody that just wants the bonus, s/he probably won’t pass it. S/he probably just goes back to do what s/he always does. It just depends on the person really. If they want to grow, if they want to push themselves so little bit, I think they can get something out of it. They decided that all teachers should go through this but I don’t know if that would be a good thing. (Martha, Interview, May 26, 2005)

As can be noticed from Martha’s statements above, she did not necessarily consider experiencing NBC process as a sufficient sign of professional growth on the side of teachers without examining the underpinning reasons of those teachers in deciding to undergo NBC assessment procedure. In Martha’s case, other than starting her NBC experience primarily with monetary motivations, her initial sense of finding her teaching already closer to the vision of NBC teaching standards played a considerable role in her limited benefit from her NBC experiences.

As it was the case with Jennifer and Patricia, the end result of NBC as a professional development activity for Martha turned into a sense of affirmation of her high teaching capabilities. This eventually resulted in gaining an enhanced confidence into her teaching abilities. The confidence originated from her inside world synchronized on the outside with the recognition and respect given by school administration and her colleagues. In the following excerpt from Martha's interview response, the confidence and recognition blended together into her talk could easily be detected:

You know, I feel pretty confident that I could go to almost any school and they would take me although they may not know me because I am a National Board Certified Teacher. The principal of [nearby high school] was asking a former teacher of ours teaching over there, he said, "Don't you have a NBCST over at your previous school?" And she responded, "Yes! We have two!" And he said, "How can we get them over here?" So for the schools, it is a nice little thing for them to say that they have this many National Board Certified Teachers in their school. (Martha, Interview, May 26, 2005)

Although Martha did not find her involvement of NBC process as a big learning experience overall, she still enjoyed the respect and the recognition that her advanced teaching certificate brought to her.

Mary

Starting the journey of NBC assessment process was a collective decision that Mary and Martha made together. It was just the second year that NBC was being offered and there were not a lot of examples around yet for Mary and Martha to make a better sense of the specific requirements of NBC process. However, Mary and Martha had the biggest support from each other throughout the certification process. When the results were announced, Mary was the one who missed the passing score with a couple of points. Martha was able to make it through in her first attempt but it was a very big disappointment for Mary not to make enough score for passing the portfolio assessment. Although her classroom neighbor Martha continued her support and encouragement for Mary, the following days brought Mary the feeling of the sense of failure intensified with her awareness that everybody in her school already knew the commitment she made in going through NBC performance assessment process: "I think

there is always that sense of you might not be good enough to get the certification. So there is a sense of failure in that” (Mary, Interview, May 5, 2005). The 40 percent of passing rate was a relieving fact to know for Mary to recover from the disappointment of failing NBC assessment procedure in her first attempt. Even if teachers knew the low passing rate of NBC assessment process, Mary still found it difficult for teachers to overcome the sense of failure where everybody in her school knew her intentions with NBC process. From Mary’s case, it would not be difficult to make an inference that experiencing a failure in NBC assessment process might also lead other teachers to feel insecure about their teaching abilities due to the pressure that they felt regarding the awareness of their colleagues about their failure situation.

Although Mary’s first unsuccessful attempt hurt her confidence deeply, it still did not keep her from going through NBC process again the second year. Through the support of her colleague Martha, Mary decided to give it another shot with the feeling that those teachers who passed NBC performance assessment were not any better than her in their performances of teaching science. Although Mary found sufficient strength in her depth to revise her portfolio entries for the second year NBC evaluation, she was not sure what to do because NBC scoring sheet did not include any specific feedback other than some numerical scores assigned for each particular section of the portfolio. Mary made a relatively lower score on one of the portfolio entries but those numbers on the scoring paper did not say much about the specific reasons behind the low score given to the particular portfolio entry:

There was one of those areas that I scored lower on that. I still wish I could have feedback. They never give you feedback but I would love to see that entry and see what was it that was lacking because they never tell you. You just get your score. And in those early days, we were one of the first groups to go through NBC process. So they had not worked it out yet because we did not even have a scoring rubric. You get that now upfront, you get it before you start. We did not have any of that. (Mary, Interview, May 5, 2005)

Like Martha, Mary was also critical about the insufficient scoring guidelines in the early days of NBC assessment process. In addition to that, Mary was not happy about the fact that there were lack of guiding feedbacks for teachers who did not make it in their

first attempt other than numbers. To Mary, this was a limiting factor for teachers in their professional growth with NBC portfolio assessment process.

Mary saw NBC process as another step in becoming a better science teacher: “It is like that next step as becoming a better teacher or master teacher whatever kind of label you would like to put on it” (Mary, Interview, May 5, 2005). Mary considered NBC as a big contribution to the efforts of enhancing the professionalism in teaching. She believed that teaching profession was treated for a long time as something that any people with some education background could do with great success. Mary felt that NBPTS had the potential to bring the professional respect to the teachers that they deserved:

Something that always bugs me about the teaching profession is the professionalism. For many years, teachers were not respected. You will have parents who think they actually know more about teaching than you do just because they happen to be educated. They hand you the curriculum and say “Here! Teach this...” but not “what do you think you should teach?” You know, if they take away our professionalism in so many ways by telling us what to do, this is a way of bringing some of that back. (Mary, Interview, May 5, 2005)

Becoming a NBCST for Mary meant joining to a prestigious group of teachers with accomplished teaching practices of science. Like her husband's professional geologist license, obtaining her advanced teaching certificate ensured that she had the potential to perform her job with the maximum capabilities. In that sense, NBC was a validation for her good teaching capabilities of science:

I mean more validation. I knew I was doing good things. I knew my students were pretty happy and they enjoyed my classes. On the professional level, this was a pretty prestigious group and I guess I looked at it sort of like my husband. He is a geologist. And when he decided to get his professional geologist license, it is a validation. It says, “Yes! You know how to do this. Yes! You are good at it.” I kind of looked at it that way. (Mary, Interview, May 5, 2005)

Mary felt pretty confident about her teaching abilities before obtaining her advanced teaching certificate but she was not comfortable enough to believe that her teaching of science was good enough to pass NBC assessment procedure. Even if she knew that

many things that she was doing with her students followed the standards of NBC, she still considered her National Board Certificate as a formal documentation of her good teaching skills.

Mary overall found the assessment procedure of NBC rigorous enough to determine accomplished teachers. Although Mary felt that deciding the quality level of teachers' classroom practices without visiting and observing their classes was not an accurate way of assessing teachers, she still considered NBC performance assessment procedure more robust than any teacher assessment tests based primarily on multiple choice questions:

I think it is hard for anybody to make an assessment of what some teachers are doing in their classrooms unless you just go and watch them for a period of time. But that is not practical. People cannot come and stay for a month and see how you do things. So I guess this [NBC] is the best right now. It is certainly more rigorous than taking a multiple choice test, which if you are a good tester, you might get lucky. Through the teacher reflections in this whole process and planning and those kinds of things, they get a better sense of what kind of teacher you are. I certainly think it is probably the best. Is it perfect? No, probably not. But it was pretty tough to get all that stuff done. (Mary, Interview, May 5, 2005)

Mary regarded NBC as a successful assessment procedure to determine who was an accomplished teacher. However, when it came to its contribution to the professional development of science teachers, Mary felt that completing her master's degree in science education was more influential than pursuing her advanced teaching certificate with NBC. However, she described undergoing NBC process as a better experience than attending in-service professional development workshops. Mary did not feel positive about her experiences with the professional development workshops that she previously attended because those workshops didn't produce any products that she considered to be meaningful for her professional growth:

I remember being very surprised at the first in-service workshop I went to. They didn't require me to take a test. I went and I was done. I had to do a survey to make sure that whoever taught it did their job for the county. In a professional

development program, you have to have a product when you are done with it. Now, that trend has gone away. Now, the in-service that we are doing is very much you have to have a product. You have to show how it would impact student learning. (Mary, Interview, May 5, 2005)

Since NBC required teachers to exemplify their teaching and their students' learning through presenting the supporting evidences in their portfolios, Mary regarded NBC process as a better professional development experience than those one-time in-service professional development workshops. However, Mary did not feel the same way when it came to her professional development experience in her master's degree. She particularly found the master's thesis that she had to complete in order to receive her master's degree more challenging and rewarding than her professional development journey with NBC assessment process. She appreciated the enlightening and guiding feedbacks that she received from her major professor throughout her thesis project. However, the feedback that she acquired from NBPTS was purely limited to the numerical scores on each individual portfolio section. Thus, Mary shaped her own understanding of portfolio assessment process mostly through her own judgments.

Although Mary regarded NBC assessment process as a rigorous professional development experience, she attributed the success of NBC experience in the professional growth of teachers to their tendency to acknowledge the innovative teaching strategies promoted in science education reform movements. In a sense, Mary argued that science teachers who considered the reform ideas inferior to their conventional notions of teaching science would not benefit as much from their NBC experiences:

I think professionally if you don't buy into hands-on teaching, inquiry-based learning, and helping kids make connections about their world, and if you are in science teaching for other reasons, I think this isn't for you. I just don't. I think if you want to teach from a book, then you are in a different league, you are in a different direction. (Mary, Interview, May 5, 2005)

As can be noticed from Mary's argument above, like Jennifer and Patricia, she also underlined the essential importance of teachers' willingness to improve themselves professionally in order for them to benefit from their NBC experiences. Unlike Martha,

Mary did not necessarily think that NBC assessment process would impact teachers with traditional teaching philosophies more if those teachers started their NBC journey without quitting their preexisting conventional notions of teaching science and embracing the vision of national standards. Such approach to NBC process pointed out its limited potential on teachers' transformation of traditional teaching practices to more reform-oriented teaching forms unless they already started their NBC experiences with the acknowledgement of the betterness of reform ideas: "I think you have to embrace the standards. And if you don't embrace the standards, then this is not a process for you" (Mary, Interview, May 5, 2005).

For Mary, accomplishing her advanced teaching certificate was something to be proud of because she put a lot of effort into it. And reaching to a satisfaction level with her success was the natural end result of overcoming a challenging assessment process like NBC:

I was proud that I achieved it because it was hard. It was just like anytime how it was in your thesis. You put so many hours into it. You really pour yourself into it. And it feels good when you get it. That is that satisfaction there. (Mary, Interview, May 5, 2005)

Other than a validation of being a professional teacher, Mary enjoyed the professional respect that her advanced teaching certificate brought into her teaching career. She appreciated education administrators in the county in which her school located for the value that they gave to NBCSTs. Especially she was honored with the letter that she received from the governor to congratulate her for her accomplished teaching. Mary felt that the fact that passing the performance assessment of NBC was acknowledged to be a big challenge for many teachers enhanced the professional value of her achievement with NBC assessment process. She thought that it would not be the same if NBC assessment process was not as rigorous as it was:

If it were not as rigorous as it was, if it was just like a multiple choice test, it might not be professionally as worthy as it is. But I think that since it is very rigorous and it has a portfolio aspect to it and it is not for everyone and not everyone passes it, it does tend to bring a little bit more professional respect because it is not just something that everybody can get. (Mary, Interview, May 5, 2005)

For Mary, becoming the recipient of more professional respect for her accomplished teaching performances was deeply meaningful because it made her feel unique about herself as an experienced science teacher.

Comparative Overview

The cases of the teachers presented in this section indicated that they were all in agreement with the affirmational role of NBC portfolio assessment process in their professional development. As an overall reflection of their NBC experiences as a professional development activity, they brought the affirmational role of NBC to the fore in several instances. What they meant by affirmational role of NBC in their professional science teaching careers was that their successful completion of NBC process proved that their science teaching practices were in fact accomplished and aligned with the nationally recognized teaching standards of NBC. Therefore, such affirmation of accomplished science teaching skills by NBC accomplishment strengthened participant teachers' existing notions and practices of science teaching but did little for directing them to transforming some aspects of their teaching into more compatible forms with the science education reform ideas.

With my preceding argument, I need to make a clarification that I do not place each individual teacher on the same teaching scale with respect to their philosophies and ways of teaching science. For instance, Jennifer represented a more conventional way of teaching science whereas Martha tended to support more innovative teaching ideas. However, both teachers passed their NBC assessment and came out of their NBC portfolio assessment experiences with a sharpened confidence into their individual styles of teaching science. Their exposure to NBC assessment process turned out to be a medium where they found support for their existing ideas in teaching of science. After NBC experience, Jennifer still identified herself as a traditional teacher and her peculiar experience with NBC assessment procedure did not weaken her traditional notions of science teaching. On the contrary, her accomplishment of advanced teaching certificate with NBC strengthened her sense of the supremacy of her existing ways of teaching science. In Patricia's case, the situation was not quite different. Patricia did not define herself specifically as a traditional teacher but her approach to some central aspects of science education reform ideas particularly to the concept of teaching of science

through inquiry exhibited some level of resistance. Like Jennifer, Patricia felt that her successful completion of NBC portfolio assessment process reinforced her sense of the effectiveness of her way of teaching. Moreover, her accomplishment of advanced teaching certificate with NBC before some of the teachers, whose teaching practices Patricia always admired, passed the portfolio assessment of NBC led her to feel that she was a better science teacher than she thought she was. In a sense, Patricia perceived her first-attempt success with NBC portfolio assessment process as an important recognition of the validity of her existing notions of teaching science. This meant that her pursuance of advanced teaching certificate with NBC did not encourage her to integrate reform ideas into her teaching practices of science. Therefore, assuming that NBC performance assessment procedure always provides accomplished teachers with reform-oriented science teaching ideas and practices would be misleading. Particularly as in the cases of Jennifer and Patricia, teachers who approach science reform ideas with some level of resistance achieve their advanced science teaching certificates with NBC in their first attempts. At this point, I make the argument that NBC portfolio assessment procedure strengthens the existing teaching notions of science teachers with more conventional teaching ideas through affirming their good science teaching abilities. Such affirmation of teaching abilities seems to work to some extent against rather than towards the promotion of reform-oriented science teaching ideals. Therefore, once teachers find an endorsement for the quality of their science teaching practices through their successful involvement with NBC portfolio assessment procedure, they tend to feel more confident about their teaching abilities no matter whether their notions and practices of science teaching station on the traditional spectrum of science teaching or not. And their elevated confidence levels might sharpen their further resistance towards the science reform ideas. At least, it was the case with the teachers who participated in this research study.

In comparison to Jennifer and Patricia, Mary and Martha appeared to be more synchronized with science education reform ideas. When they looked back to their experiences with NBC several years ago, they also pronounced the affirmational role of NBC experience in their professional development. Therefore, the primary role of NBC performance assessment procedure in those teachers' professional careers did not go

much beyond legitimizing their existing notions of teaching science especially of those teachers inclined more towards conventional teaching ideas. From participant teachers' responses, it was hard to suggest that being exposed to NBC portfolio assessment process opened new avenues in their science teaching practices. We know that the advanced teaching standards of NBC were primarily derived from the central tenets of recent education reform efforts. In other words, the science education reform ideas are inherent aspects of the documents of accomplished teaching standards of NBC. However, it seems that those ideas of science education reform movements embedded in the documents of accomplished teaching standards of NBC had a very limited influence on teachers in terms of their consideration of integrating more reform-oriented ideas in their teaching of science.

Explaining the specific factors for the limited influence of those teachers from their NBC experiences is a multi-dimensional endeavor with the possibility of many agents involved in it. I can think of three that could have something to do with 1) teachers' original intentions of pursuing NBC, 2) achieving their advanced teaching certificates with NBC at their first attempt, and 3) starting their NBC journey aligned with the majority of the teaching standards of NBC. First, as it is true for any type of professional development experience, teachers' willingness to grow professionally in professional development allows these learning experiences to be meaningful for them. In regard to the potential contribution of NBC experience to their professional development, teachers in the study acknowledged the critical role of the original intentions of the teachers in undergoing the portfolio assessment process of NBC. Participant teachers did not necessarily decide to pursue their advanced science teaching certificates with NBC to grow professionally. Instead, obtaining monetary incentives and gaining an affirmation of accomplished teaching capabilities constituted the major motives in going through NBC process for these teachers. Therefore, the limited benefit of the participant teachers from their NBC experiences might be attributed to their initial intentions to pursue advanced science teaching certificates with NBC. Secondly, with the exception of Mary, teachers in the study were able to achieve their advanced teaching certificates with NBC in their first attempts. Therefore, their experiences with NBC assessment process functioned more to document their existing

science teaching abilities rather than serving as a forum to struggle with new ideas in their teaching practices of science. This emphasis on documenting what exists might partially uncover the reason behind their perception of the affirmational role of NBC experience in their professional development. It is possible that teachers who spend more effort in aligning their teaching practices of science with the advanced teaching standards of NBC might experience more professional growth in their teaching careers. In some cases, teachers who fail the assessment process of NBC might benefit more from their NBC experiences. Thirdly, although it would be hard to say that all participant teachers were equally open to adopting science education reform ideas, they had managed to work out their own ways of teaching science through many years of teaching experience. And their teaching practices were effective on their own respect even if some built more on the spectrum of conventional teaching techniques. Making “little” arrangements in their science teaching practices was a sufficient move for them to pass the portfolio assessment of NBC process. Accordingly, those “little” arrangements naturally made little impact on them other than strengthening the notions of their existing science teaching practices.

Another thing noticeable with those teachers' experiences with NBC process was that although they felt uncomfortable about their teaching and their chances of passing NBC assessment process before their NBC journey started, the situation was quite the reverse after their successful completion of NBC process. Their level of confidence into their teaching of science grew exponentially with the elevating sense of success in their completion of NBC assessment process. Especially in Jennifer's case, it was visible that she felt less intimidated with the presence of a researcher in her classroom in order to observe her teaching of science. She was also determined to accept an intern science teacher in her classroom the next year due to her sharpened confidence into her science teaching abilities as a result of her accomplishment of advanced teaching certificate with NBC. Participant teachers identified their successful completion of NBC process as an important step in becoming a professional science teacher. For instance, Mary made a relevant connection with her advanced teaching certificate with NBC and her husband's geology license. As the recipient of science teaching certificate with NBC, she considered her certificate letter as the official documentation of her

professionalism in her many years of science teaching experience. Joining a prestigious group of science teachers with accomplished teaching practices brought the professional recognition that teachers had not experienced in their professional teaching careers before. All teachers in the study enjoyed the professional respect that they received from their colleagues, school administrators, and school district officials due to their acknowledged teaching abilities of science. However, Jennifer was cautious not to give the wrong impression that she was teaching any different than it was before receiving her advanced teaching certificate with NBC. In a sense, Jennifer wanted to convey the message to the people that her accomplished teaching practices were not due to her successful completion of NBC portfolio assessment procedure but because of her many years of efforts in bettering her science teaching abilities.

When it came to the assessment quality of NBC process, participant teachers generally agreed that NBC as a teacher assessment procedure was fulfilling what it promised to achieve in terms of certifying teachers who deserved to be recognized for their accomplished teaching practices. Although Jennifer felt more “cynical” about NBC assessment process at the initial days of my visits to her classroom, her negative attitude toward NBC weakened as we talked more about her experiences. She still found NBC unrealistic as a good professional development experience for teachers, yet she considered it successful as a teacher assessment procedure. Jennifer acknowledged the importance of maintaining a mechanism in the education system to reward teachers with advanced teaching skills. And she found NBC process as a fair way of determining accomplished science teachers. Patricia brought the important place of good writing skills in passing NBC portfolio assessment process to the fore. She made the argument that not only having exemplary teaching practices but also expressing them in a powerful way would make a lot of difference in achieving advanced teaching certificate with NBC. However, she underlined the vulnerability of written explanations of the teachers to possible manipulations. That was why she considered the involvement of the teaching videotapes into the assessment process of NBC as complementary to the written explanations of the teachers. Therefore, Patricia found NBC teacher portfolios supported with videotape recordings of the teaching practices of teachers as a robust way of assessing teachers to determine the ones with

accomplished teaching abilities. However, she was careful to say that NBC was not a teacher assessment procedure to uncover the daily teaching practices of teachers but rather their best potentials in their teaching abilities. Martha attributed her successful completion of NBC portfolio assessment process in her first attempt to her good writing skills and choosing the right activities to include into her teaching portfolio. In a sense, Martha also pointed out the considerable weight of writing skills in achieving advanced teaching certificate with NBC other than having strong teaching abilities. Despite the limited capacity of NBC portfolio assessment procedure in assessing the teaching practices of teachers without making any observations in their classes, Mary still considered the assessment process of NBC as a better way of determining teachers with accomplished teaching practices than more conventional teacher tests that relied mostly on multiple choice questions.

Learning Experiences from NBC Assessment Process

In the previous section, I presented the perspectives of the participant teachers about the role of NBC in their professional development as science teachers. In the following section of the dissertation study, I investigate the specific learning experiences of the teachers in NBC assessment process. However, the learning experiences identified by the participant teachers in this study do not reflect their immediate perspectives as they go through the assessment process of NBC. Rather, they represent their insights into NBC years after completing the assessment process. When I started working with those teachers in the study, Martha and Mary had already been certified for 6 years. And Jennifer and Patricia had received their advanced teaching certificate with NBC almost 2 years before. Therefore, their interview responses reflect their afterward thoughts of NBC rather than their immediate learning experiences from NBC process. This suggests that the expressions of teachers in their learning experiences from NBC should be considered in a more general sense. Although the learning experiences of the teachers sounded secondary in comparison to the affirmational role of NBC in their professional science teaching careers, they identified different learning outcomes from NBC process. In Table-8 below, I display the learning experiences of the participant teachers in NBC assessment process.

Table 8 At First Glance: Learning Experiences from NBC	
Jennifer	▪ Grasped the whole picture of her teaching with a better view of her long term goals with her students. ▪ Understood the educational reasoning of her classroom actions better in her reflections. ▪ Recognized the importance of posing more questions to students in order to understand their perspectives better.
Patricia	▪ Saw NBC as a platform on which she reconsidered her staled teaching habits. ▪ Considered NBC as a process to remind her to do the things that she ignored in her teaching rather than a new learning experience. ▪ Noticed the need for using better questioning techniques with her students while watching her teaching practice in the videotape.
Martha	▪ Described NBC as a process of documenting her good teaching abilities rather than new learning experiences. ▪ Developed a higher awareness of the reflective practice in effective teaching of science.
Mary	▪ Explored the strengths and the weaknesses of her teaching in the systematic reflection process of NBC. ▪ Started doing longer term plans for her teaching activities as a result of undergoing the assessment procedure of NBC. ▪ Interacted with the central ideas of NSES again after her graduation from university with a master's degree.

Before proceeding with each teacher's case, I make the assertion in regard to the learning experiences of the participant teachers from NBC assessment process.

Assertion-3: Experiencing the performance assessment of NBC reminded teachers the importance of reflective practice in becoming effective science teachers.

After presenting the assertion above, I now support it with the individual cases of the teachers. At the end of the teacher cases, I make a cross comparison of the teacher cases.

Jennifer

Jennifer found explaining the underpinning reasons in her classroom action challenging because she felt herself insufficient in doing so. Since Jennifer completed her university education on the field of science but not in teacher education, she did not feel herself proficient enough in examining her teaching practices with an educational perspective. Even if she had been a successful chemistry teacher for a long time, she had never verbalized the educational meaning behind the specific actions in her teaching of science with her students:

One of the challenging things was explaining why you do things. And I haven't really given too much thought about why I do things. It is like in my heart I just wanted my kids to learn it. So I was always thinking about the kids and helping them to learn it. But I haven't ever thought "Well! I do this because...This person is like this." I had those reasons but I never had to verbalize them. (Jennifer, Interview, May 12, 2005)

Her involvement into NBC assessment process enforced Jennifer to spend more effort on recognizing the educational implications of her specific actions with her students. Since she did not feel herself strong about this, she asked the help of one of her colleagues who obtained her National Board Certificate on history education in the previous year. Jennifer found her colleague more competent in analyzing the content of her teaching. In addition, the fact that both of them were teaching to the same group of students helped them to make deeper analyses on their students:

She is a history teacher but we have the same students. So it is like if I am working with this kid, maybe I don't know my specific reasons because I am not that kind of a person that verbalize those things. And being a science person, I am not that much into all the reasons why psychologically I do this. But she was more in tune with that so we could talk about it. (Jennifer, Interview, May 12, 2005)

For Jennifer, reflecting on her teaching with an educational perspective was a new experience. She observed that the teachers whom she mentored had the similar tendencies like her that they did not necessarily think deeply enough about the educational connotations of their actions with their students. While mentoring other teachers, Jennifer benefited from her NBC experience in explaining her actions with her students to other teachers with the educational perspective so that they could take the initiative to become reflective teachers. Therefore, Jennifer's deeper analysis of her teaching in her NBC portfolio preparation process equipped her with the specific reasons for doing certain things in her teaching in order to help other teachers to become cognizant about the psychological factors in their teaching of science:

Now I am starting to realize while teaching other teachers that it is good because they don't know why you do things. And for me, it is like "Of course, you do this."

But I have never thought about why I do things so that I can help to explain it to someone else so that they can start becoming like that. (Jennifer, Interview, May 12, 2005)

In her NBC portfolio experience, Jennifer had the chance to reflect on her teaching. Her reflections on her teaching of science made her more aware of her specific reasons in her actions with the students. As Jennifer became more cognizant about the dynamics of her teaching, she felt more confident about uncovering the nuances in her teaching for explaining them to new teachers.

Other than giving the opportunities to her for reflecting on her teaching, NBC portfolio assessment procedure also allowed Jennifer to grasp the whole picture of her teaching of science throughout the year. Being able to look over her teaching of science in a long period of time kept her more aware of her long term goals with her students:

It made me view more my teaching as a whole. It let me get the whole picture of my teaching of the whole year and how things fit together in my classroom rather than as just isolated parts that I was teaching to my students. And I think it helped me to reinforce through the year what I teach because I have a bigger view of what I am trying to accomplish. (Jennifer, Interview, May 12, 2005)

One of the contributions of NBC portfolio assessment procedure to her professional learning came in the form of holding a better view of her teaching of science in a whole year.

Jennifer's involvement into NBC portfolio assessment procedure directed her to pose more questions to her students in order to make a better sense of their thought processes: "It reinforces you to question your students more so that you see what their understanding is" (Jennifer, Interview, May 12, 2006). She realized such necessity for questioning her students more for their understanding of certain information in the process of analyzing her videotapes. She noticed in group discussion that her students did not know the meaning of independent and dependent variables at all. This was one of the shocking moments of her teaching of science for Jennifer because she had always assumed that her students had already understood clearly what independent and dependent variables meant:

The thing that I learned from [NBC process] is that I thought my kids understood what dependent and independent variables were but they didn't. I was amazed! I didn't even realize that until I went back and looked at my films because I just thought that they already understood! And they didn't. So that was the filming and that part of it. (Jennifer, Interview, May 12, 2005)

In fact, Jennifer had never done a small group discussion with her students before. However, she needed to do that this time because one of NBC portfolio entries asked teachers to present the evidence accompanied with a videotape that they were practicing group discussion with their students. After performing of group discussion with her students through sitting in a big circle, it would be hard to say that Jennifer kept practicing group discussion with her students afterwards: "I don't do group discussions but I ask more questions to the kids to see what their thinking is like because I didn't know this is what they were thinking until I asked them more" (Jennifer, Interview, May 12, 2005). Although Jennifer did not continue group discussions with her students, she noticed the importance of investigating the comprehension of her students on some concepts by posing more questions to them.

Patricia

Patricia intuitively knew that not only possessing accomplished teaching abilities but also presenting one's teaching in a good manner played a critical role in achieving one's advanced teaching certificate with NBC. That was why she thought that teachers with good writing skills started their NBC portfolio assessment process with a big advantage. However, Patricia never felt strong about her writing abilities. It was one of the reasons for her to quit her doctoral study in science education long years ago. Since her doctoral degree experience, the reflective analyses of her teaching on which she worked for her NBC portfolio entries were her biggest writing project. In order to make sure that Patricia was presenting her arguments with a clear language, she asked couple of her colleagues to review her reflective writings. She emphasized the important place of written presentation of ideas in accomplishing National Board Certificate as "Yes! Writing is that important. That is why it is important to have other people read your work before you submit it" (Patricia, Interview, May 16, 2005). Other than her challenge with writing the reflective analyses of her teaching, Patricia found analyzing the

videotapes of her teaching of science hard. One of her colleagues watched her videotapes with her and helped her to identify salient facets of her teaching of science with her students.

Patricia started her NBC performance assessment experience with the expectation that her involvement into NBC might open the doors for a new start in her staled teaching habits after many years of teaching experience. Patricia considered undergoing the NBC process as a refreshing experience of her teaching practices. Rather than a new learning experience, Patricia acknowledged the process of NBC as a reminder of the things that she already knew but ignored to integrate into her teaching:

It pointed out things that I should have been doing differently. And I actually knew better to do them differently. But I just wasn't doing them just because of habit or time constraints. When you think about it, you know what to do but in actual practice, you don't do it. After teaching for 20 years, you start getting the bad habits. And it helped me get out of these bad habits. (Patricia, Interview, may 12, 2005)

NBC experience for Patricia turned into a medium where she discovered and faced those undesired habits as a professional science teacher. When I asked Patricia to tell me one example of such bad habits that she mentioned in her interview response, she expressed that she was not necessarily using wait-time appropriately in her questionings of her students. In addition, she had a tendency for calling on same students all the time rather than involving variety of students into the lesson each time. Especially, her videotape analyses were eye opening experience for Patricia due to the fact that those videotapes gave the chances to her to observe herself as she was teaching: "When you see yourself on videotapes, you can look at yourself through new eyes. You know better but it just reminds you of the things that you get into habit of doing" (Patricia, Interview, May 12, 2005). With her experience of NBC assessment process, Patricia recognized that she needed to include some of the questioning techniques into her teaching of science in order to be an effective teacher. In a sense, the videotape analyses of her teaching became a mirror for Patricia to see her bad teaching habits.

During my visits to Patricia's classroom, she always appeared to be running around with a busy schedule. Although an intern student from a local university shared the teaching load of Patricia, the situation was no different. Under such circumstances, Patricia did not have much time and energy to reflect upon her practices of teaching science. Besides, everyday teaching turned into a routine job for Patricia after many years of experience. At this point, NBC assessment process promised a very good opportunity for Patricia to reflect on her teaching: "It forced me to take time to think about what I did because I usually get so busy in doing the things. I don't really take time to think about what I am doing the best that I could" (Patricia, Interview, May 12, 2005). Reflecting on her teaching of science presented a big challenge to Patricia because she spent a lot of effort on "discovering things about what...[she] was doing when reflecting upon it" (Patricia, Interview, May 12, 2005). Although Patricia found reflecting on her teaching helpful, it was hard to say that she enjoyed doing it due to the fact that analyzing her teaching was not an easy process: "It was good but something could be good but you don't like it" (Patricia, Interview, May 12, 2005).

Martha

Other than gaining a sense of affirmation that her teaching practices were deserved to be regarded as exemplary, she felt that her involvement into NBC portfolio assessment process did not make a deep impact on her professional development. Despite her acceptance of the tremendous influence of NBC experience on some teachers, she did not categorize herself as one of those teachers whose teaching practices took a new route as a result of NBC portfolio assessment process:

Well, nothing really stands out like "Oh! I learned that definitely from that process." I didn't have that kind of experience. I know that some teachers do have that kind of experience that they really felt like it helped them grow. But that really wasn't the case for me. (Martha, Interview, May 26, 2005).

When Martha started the preparation of her teaching portfolio, she felt that she was already following most of the teaching standards promoted by NBC: "It wasn't such a big stretch for me because I felt like I was already doing a lot of those things" (Martha, Interview, May 26, 2005). Her experiences in NBC assessment process centered on documenting her good teaching skills rather than experimenting with new avenues in

her teaching practices of science. In addition, Martha's initial consideration of following her advanced teaching certificate with NBC was shaped by incentive motives more than any other intentions. Martha described the visible connection between the intentions of teachers with their participation into any professional development and the degree of their professional growth from their professional development experiences. It was possible that all those factors and possibly some others kept Martha from undergoing more learning experiences in pursuing of her advanced teaching certificate with NBC.

Although Martha identified little learning experiences from her involvement into NBC portfolio assessment procedure, like other teachers in the study, she found NBC process helpful in promoting reflective practice in teaching. Martha believed that reflection was one of the most natural constituents of a successful teaching performance. Before her introduction to NBC assessment process, she still felt the same way but her experience of NBC awakened a higher consciousness in her that she needed to consider reflecting on her teaching of science:

I experienced nothing really specific but I think just the reflection was really good. It was just good because they require you to go back and look at what you have done in your teaching. I think I was doing it before but I think I just started doing it a little bit more afterwards. I don't see how you could not reflect on your teaching anyway. That seems obvious to me. (Martha, Interview, May 26, 2005)

Although Martha specified that reflecting on her teaching was fruitful experience, she also found it deeply challenging process. Especially she spent a lot of time on analyzing her teaching practices on videotapes. However, Martha enjoyed working with her colleagues the most on a common goal of achieving NBC portfolio assessment procedure. She found her mutual interactions with her colleagues as a good learning experience from each other.

Mary

Although Mary felt herself successful in her teaching of science before pursuing NBC, this did not mean that she was completely secure about all aspects of her teaching. She saw NBC portfolio assessment process as a potentially good opportunity to confront with her insecurities in her teaching:

I kind of wanted if I made NBC. It would make me feel like “Ok! Maybe I do okay in the classroom.” I tend to have some little insecurities about that. I guess all teachers do. I mean you have some confidence in a lot of areas of your teaching but when it comes to improving yourself, I can always be better. I think that was one of these ways that I can make myself better. (Mary, Interview, May 5, 2005)

Mary enjoyed trying new things in her teaching. She never imagined herself doing the same stuff with her students all the time. For her, such approach to teaching would close the doors to further development in one’s teaching. Pursuing her advanced teaching certificate with NBC presented an opportunity to Mary through which she could experience new things in her teaching of science.

Mary’s expectations from NBC assessment process was simple enough to formulate with a couple of words. She thought that capturing a grasp of one’s strengths and weaknesses in her/his teaching would make one a better teacher:

What you learn from this process is that if you learn “wow! I really need to do more of this or I am doing this pretty well but I need to plan better”, if you just get that out of this process, then you are a better teacher. (Mary, Interview, May 5, 2005)

Mary started NBC assessment process not with big expectations in terms of her professional growth as a science teacher. She saw NBC as a good platform on which she had the opportunities to examine the strengths and the weaknesses of her teaching practices of science. Especially writing about her teaching and students was something that Mary found powerful in terms of learning more about herself. Although there were times in her professional teaching career that she analyzed her teaching of science, none was as systematic and persistent as she did in her NBC portfolio:

I like the fact that I learned a little bit more about myself. When you actually stop and write down your thoughts about your teaching and when you suddenly look at it for the first time, you get the chance to see your teaching with different eyes. That was interesting to me and I found some areas where I really need to work on and there were some areas “I guess I do that pretty well.” So that was enlightening. (Mary, Interview, May 5, 2005)

Verbalizing her reflections in NBC process involved more effort and deeper analysis than simply touching on some facets of her teaching. In that respect, Mary considered her writing in the process of NBC portfolio assessment process as a powerful mean of taking a closer look at her teaching abilities.

Like other teachers in the study, Mary recognized the reflective practice in the professional growth of teachers. NBC portfolio assessment process encouraged her to reflect on her teaching even at the busiest times. Although it was hard for Mary to do that all the time, the experiences with NBC process arose a higher consciousness of reflecting on her teaching practices: "I got better about reflecting on my teaching because the questions in the portfolio make you focus particular things in your reflections. I think I got a little better at that" (Mary, Interview, May 5, 2005). Although she did not completely quit her habits of moving quickly on to the next stages of her teaching without giving much thought about it, Mary's reflections on her teaching in general let her do more conscious and long term plans in her subsequent teaching activities:

I am more conscious of when I plan although I sometimes find myself slipping back all the habits too: "Let's get the activity! Let's just get it done!" And it is really hard in a school year not to do that because you are being bombarded from all sides. But I think I became a better planner. I am doing more long term planning than I used to. (Mary, Interview, May 5, 2005)

Mary supported the science teaching vision promoted by NSES. However, her familiarity with NSES went back to the years that she pursued her master's degree in science education. Other than that, she did not have too much interaction with NSES. Since Mary thought that NBC teaching standards for science teachers were primarily based on the central tenets of NSES, her engagement with NBC assessment process allowed her to gain more familiarity with NSES. Mary identified her individual experience with NBC portfolio assessment process as the basis of her revival meeting with NSES years after her master's degree.

Comparative Overview

A closer look into the participant teachers' descriptions of their peculiar experiences with NBC portfolio assessment procedure reveals the reality that they

indeed valued undergoing the process of scrutinizing their science teaching practices through NBC despite the many challenges it presented to them. With a science-oriented background and a distance noticeable in her expressions to the academic field of education, Jennifer had not encountered before with the challenge of questioning her specific teaching actions. Throughout her many years of science teaching experience, she was always concerned about her students' learning of chemistry but never gave a serious thought about the specific reasons behind her teaching actions. Delving into her notions and practices of teaching science at the process of preparing her NBC portfolio allowed Jennifer to capture a better glimpse of her teaching as a whole. Her written reflections about her science teaching practices expressed with the specific educational terms helped her develop an emerging enculturation into the academic field of education. While Jennifer was working on one of the videotapes recorded in a group discussion with her students, she noticed her students' lack of understanding of independent-dependent variable concept. The questioning of her students about their understanding of the certain aspects of the topic in the practice of group discussion uncovered their existing misconceptions. After her NBC experience, Jennifer did not continue practicing group discussion with her students but she tended to spend more effort on posing more questions to her students in order to make better sense of their point of views.

Patricia did not start NBC portfolio assessment process with the consideration of her professional growth in her mind but rather she assumed NBC experience as a refreshment opportunity for her stale teaching habits due to her many years of routine teaching work. In other words, Patricia approached to the assessment process of NBC with the mindset that she already knew what she needed to do in order to better her teaching of science but it was not easy to overcome some of the habits that she developed through many years of science teaching experience. In analyses of her teaching videotapes, Patricia recognized a need for developing better questioning techniques in her teaching of science. Watching herself teaching on videotape allowed Patricia to get a better picture of her interactions with her students. Despite challenging, she found videotape analyses of her teaching as a helpful tool for a deeper reflection on her teaching practices. By considering her somewhat busy schedule with her teaching

load, she did not necessarily have the opportunity for taking extra time to reflect on her teaching but videotapes that have the capability of capturing the specific moment of the teaching at the time provided her the flexibility to take the initiative at a later time to reason the effectiveness of her science teaching practices.

For Martha, constructing of her teaching portfolio artifacts for NBC assessment procedure reflected more of an effort for documenting her already existing capabilities of effective science teaching rather than a struggle for developing new variations in her science teaching practices. That was primarily because upon Martha's involvement with the assessment process of NBC, she felt that most of her science teaching practices were closely matching with the rigorous teaching standards of NBC. Due to her sense of proficiency in her teaching of science, which was strengthened with her successful completion of NBC assessment process in her first attempt, Martha acknowledged that she experienced no significant learning from NBC that made her still remember years after receiving her advanced teaching certificate with NBC. However, like other teachers, Martha also highlighted the importance of her exposure to the reflection experience of her teaching as a result of written commentaries about her teaching of science, which constituted the backbone of NBC portfolio.

For Mary, her experience of NBC assessment process constituted the medium where she could recognize the strengths and weaknesses of her teaching of science. Her involvement into NBC portfolio assessment procedure allowed her to make deeper analyses of her teaching practices. She particularly found the reflective writings about her teaching of science in a systematic and persistent manner a powerful way of learning more about herself as a science teacher. As a result of her reflection experience that helped her learn more about her strategy of teaching science during the period of NBC portfolio assessment, Mary tended to make more conscious lesson plans for her teaching practices afterward, which included more of her long term goals with her students. Mary also considered her NBC assessment experience as having the opportunity for refreshing her knowledge about the central tenets of NSES, which was something that she had not experienced since her graduation from the university with a science education master's degree. Whereas Mary admitted the important role of NBC portfolio assessment process in enforcing the teachers to take the initiative to reflect on

their teaching practices, she did not ignore to add that teacher feedbacks coming from NBC assessment center in the form of simple numerical values instead of written explanatory comments constituted a big limiting factor for the further development of teachers.

Based on the brief overview of participant teachers' identification of their learning experiences from the process of NBC portfolio assessment procedure, I conclude that they all agreed that their pursuance of advanced teaching certificate with NBC put them into the situation where they needed to reflect on their teaching of science in the process of preparing NBC portfolio artifacts that exemplified their best capabilities in their teaching. Although all teachers appeared to recognize the essential role of reflective practice for effective science teaching, it would be difficult to suggest that they developed a habitual behavior to maintain a similar type of reflection, which they experienced in the process of NBC portfolio assessment, with a consistent manner in their later teaching practices. In other words, NBC portfolio assessment process seemed to be created an alerted awareness in teachers for the important place of reflection in their daily teaching practices, yet providing a readily available answer to the question of how consistently they adopted reflective practice in their everyday science teaching practices after their NBC experience was beyond the scope of this dissertation study due to the fact that this question was not one of the primary attraction points of this dissertation research study.

CHAPTER 6

IMAGES OF CLASSROOM INQUIRY REPRESENTED IN THE MINDS OF NBCSTs⁸

Introduction

Teaching resides at the heart of formal education. Improving education is destined to the failure without enhancing the quality of teaching in the schools. That is the very reason that recent teacher education reform movements have shifted their attention more from school factors to the quality of teaching and teachers in increasing the achievement of students (Hallinan & Khmelkov, 2001; Schneider, Krajcik, & Blumenfeld, 2005). NBPTS⁹ can be considered as one of such efforts to contribute to the improvement of the quality of teaching in the schools through certifying accomplished teachers. In its advanced teaching standards for teachers, NBPTS described the qualities of teachers with accomplished teaching practices. Although accomplished teachers share the common characteristics of quality teaching in the advanced teaching standards of NBPTS, each individual subject area exhibits a variety of different teaching strategies. Considering the recent trend in science education, we cannot imagine an accomplished science teaching practice apart from engagement of students into inquiry-oriented experiences in their science classrooms. That is why inquiry-based teaching of science occupies an important place in the advanced teaching standards of NBPTS for science teachers. Science teachers who undergo the performance assessment process of NBC are required to demonstrate the abilities of engaging their students in classroom inquiry experiences.

We know that science teachers exemplify their inquiry teaching practices in NBC portfolios through presenting their written reflective explanations supported with videotapes of classroom inquiry performances with their students. However, this does

⁸ I use NBCSTs in the study as the abbreviation of National Board Certified Science Teachers.

⁹ NBPTS refers to National Board for Professional Teaching Standards.

not tell much to us about the meaning of teaching science through inquiry for those experienced science teachers. This is a worthwhile question to pursue for science education community because the ultimate success of science education reform efforts rests on being better informed about the perspectives of teachers, who fulfill their teaching responsibilities in various contexts, on science education reform ideas. Classroom inquiry as one of the central dynamics of science education reform efforts is in particular need of scrutinization because various meanings are attributed to teaching of science through inquiry by teachers (Crawford, 2007; Cuevas, Lee, Hart, & Deaktor, 2005). Those meanings do not necessarily match with the original intentions of the science education reform documents. Uncovering those various meanings is important for developing better strategies in helping teachers develop appropriate understandings of the original intentions of science education reform documents with classroom inquiry. That is what this chapter of the study attempts to shed light on. The chapter articulates inquiry conceptions of four NBCSTs who demonstrated their abilities in enacting inquiry with their students in NBC portfolios.

Inquiry Practiced by Scientists and by Students

Inquiry may be a single word, yet it is difficult to say the same thing for its meaning because the meaning of the word takes various forms depending on the context in which it is used. The meaning exhibits differences from one teacher to another in schools (Crawford, 2007). One needs to keep in mind that inquiry is not a concept that exists in vacuum. The meaning of the word is influenced by a myriad of concepts in the minds of teachers. One concept that has possible associations with classroom inquiry can be thought of scientific inquiry. Examination of recent science education reform documents shows that the description of classroom inquiry in those documents is heavily influenced by scientific inquiry. That is mainly because inquiry in classroom gets its ultimate inspiration from scientists' ways of inquiring their questions to build scientific knowledge (Jones & Eick, 2007). Therefore, it is important to recognize that the views of teachers about scientific inquiry have certain influence on their understanding and practices of classroom inquiry (Lewtwaite, 2007; Lotter, Harwood, & Bonner, 2007). Better understanding of teachers' conceptions of classroom

inquiry involves pursuing their images of scientific inquiry in their minds and the associations of those images with their notions of classroom inquiry. That is the reason that I start this chapter by presenting the views of participant teachers on scientific inquiry. However, the intent of this section of the chapter is not to investigate Nature of Science (NOS) conceptions of the teachers but rather to display any possible parallel between teachers' notions of scientific inquiry and their conceptions of classroom inquiry. Table-9 below summarizes both conceptions of teachers, namely scientific inquiry and classroom inquiry.

Table 9 At First Glance: Inquiry in Science and in Classroom			
	Scientific Inquiry	Similarities and Differences	Classroom Inquiry
Jennifer	- Regarded discussions of scientists as an important part of building scientific knowledge. - Placed a special emphasis on experimentation.	- Found classroom inquiry carefully planned experiences of students to lead them to acquire certain knowledge. - Associated classroom discussions of students more closely with scientific inquiry.	- Classroom inquiry involved conducting experimental activities. - Inquiry activities included a hands-on component.
Patricia	- Considered scientific inquiry as a way of thinking. - Defined scientific inquiry as a hypothetico-deductive process. - Placed hard evidence at the core of scientific knowledge.	- Described both concepts as the ways of solving problems. - Found both processes similar other than the more complex nature of scientific inquiry. - Unlike scientists, teachers knew answers to be reached by their students in their inquiry experiences.	- Perceived classroom inquiry as laboratory experiences of students. - Classroom inquiry required students to support their conclusions with quantifiable data.
Martha	- Scientists followed the scientific method to generate scientific knowledge. - Used the scientific method interchangeably with experimentation. - Stressed the importance of communicating with other scientists.	- Did not see much difference between the two concepts. - Described classroom inquiry as an effort of teaching the scientific method to students. - Scientists generated their own questions to investigate as opposed to given questions to students.	- Conceptualized classroom inquiry as experimental science activities of students. - Students needed to collect data in their experimental experiences.
Mary	Explained the work of scientists with experimenting.	- Questioned the possibility of imitating the exact work of scientists in classroom due to the background limitations of students. - Classroom investigations of students did not necessarily produce new knowledge.	- Emphasized the active nature of classroom inquiry. - Conducting experiments emerged as an essential characteristic of classroom inquiry.

Before proceeding with presenting the perspectives of teachers on scientific inquiry, I make the following assertion in regard to the relationship between teachers' conceptions of scientific inquiry and classroom inquiry. Assertion-4 below is the

combination of sub-assertion-4a and sub-assertion-4b that build on teachers' notions of scientific inquiry and classroom inquiry respectively.

Assertion-4: Teachers' understanding of scientific inquiry centers primarily on empirical investigations. Engaging students into empirical science activities is regarded by teachers as the essence of classroom inquiry.

Starting with the following subsections, I present the notions of those four NBCSTs regarding inquiry in science and in classroom respectively. In "Comparative Overview" section at the end of these subsections, I discuss the perspectives of all teachers in a comparative manner.

Scientific Inquiry

In this subsection, I display each teacher's understanding of scientific inquiry. But before presenting each teacher's case, I make the following sub-assertion as a supporting component to the mainframe of Assertion-1 included at the beginning of the chapter.

Sub-Assertion-4a: Teachers identify scientific inquiry with the empirical investigations of scientists.

In the following paragraphs, starting with the case of Jennifer, I present each teacher's understanding of scientific inquiry revealed through their interview responses and their written reflections in NBC portfolios.

Jennifer

Jennifer described scientific inquiry as the process of generating scientific knowledge through using known scientific facts to understand the unknown phenomena. In her representation of scientific inquiry process, conducting "experiments" played one of the key roles in building the scientific knowledge. Jennifer explained her understanding of scientific inquiry process as follows:

Scientific inquiry in the laboratory is where you use what you know and apply it to the unknown. And it involves a lot of discussion among colleagues. Most of the

time, it involves **experimentation**, or otherwise it is theoretical. But it tries to find out more about what we don't know through applying what we do know to new situations. (Jennifer, Interview, September 20, 2005).

From Jennifer's interview excerpt above, it was possible to observe that she placed special emphasis on laboratory and "experimentation" in her description of scientific inquiry. However, she avoided limiting the generation of scientific knowledge with "experimentation" but also included theoretical studies of scientists.

Jennifer considered modeling of scientific inquiry in the classroom as an integral element of introducing her students to the similar thinking processes of scientists. However, unlike the experiences of scientists in pursuing their scientific questions, she identified most of classroom inquiry experiences of students as artificial situations organized by teachers to lead the students into predetermined educational goals. She provided her perspective on the relationship between scientific inquiry and classroom inquiry as follow:

Inquiry-based science in the classroom is kind of different because I think it is more contrived in the classroom. I feel like we give students small setups where we have a specific goal a lot of times for them to achieve and a lot of inquiry in the real world is not like that. I know that some inquiry-based science is not like that but I think it is a kind of an artificial situation. I think what is similar is a lot of the discussion that goes on. As far as what is different is that we do want them to acquire certain knowledge in the classroom but in the laboratory they may not be after a specific knowledge, or they may be after specific knowledge but not necessarily. (Jennifer, Interview, September 20, 2005)

Based on the interview excerpt above, it was visible that Jennifer built her argument about the dissimilarities between scientific inquiry and classroom inquiry on differentiated goals expected to be achieved by scientists and by teachers in their respective settings. She characterized classroom inquiry experiences of her students as the moments of learning scientifically accepted ideas rather than producing new scientific knowledge. Jennifer found the classroom discussions generated in inquiry activities of students much closer to the true nature of scientific inquiry.

Patricia

Patricia defined scientific inquiry as an effort for learning more about unknowns in natural events through collecting supportive evidence in a systematic manner. In her interview response, she noted, “Scientific inquiry is trying to learn about things in a logical, reasoned manner, stepwise looking for hard evidence to support” (Patricia, Interview, September 13, 2005). Patricia placed empirical evidence at the core of scientific knowledge. She discussed that scientists “derived [their evidences] from observation and experience and that they all work together to help us understand the way things work in our world” (Patricia, Entry 2, NBC portfolio). In her following interview response, Patricia described science in a much broader sense as a way of thinking. Deriving conclusions from data constituted the essence of this special way of thinking. Patricia portrayed her image of science as follows:

In order to do an inquiry-based activity, you have to be able to think. And thinking is looking at data, analyzing data, and drawing conclusions based on the data rather than anything else. That is what science is all about. Science more than anything in my opinion is a way of thinking. Inquiry is a way of thinking. And we have to teach a way of thinking. (Patricia, Interview, May 12, 2005)

Since Patricia identified science as a way of thinking, she supported teaching the same thinking processes of scientists to students through engaging them into classroom inquiry experiences. In scientific way of thinking, she brought the role of hypothetico-deductive approach in solving scientific problems to the forefront in the succeeding passage from her NBC portfolio: “In a scientific way of thinking, you solve problems by hypothesizing an answer and then collecting data to support or disprove the hypothesis” (Patricia, Entry 3, NBC portfolio).

In regard to the similarities of scientific inquiry and classroom inquiry, Patricia discussed both approaches on the common ground of solving problems. She conceptualized both terms as the ways of seeking answers to questions in different contexts. She explained her point of view as follows:

They are both ways to solve problems. They are both ways of looking at problems to seek a solution. One is little more arbitrary and neat, and the other is little more loose form and not so neat. Inquiry-based science in classroom is

neater because we know that there is an answer. (Patricia, Interview, September 13, 2005)

From her interview response above, it was possible to observe that Patricia did not find much difference between scientific inquiry and classroom inquiry other than more complex nature of scientific inquiry in comparison to classroom inquiry experiences of students. When it came to the dissimilarities between scientific inquiry and classroom inquiry, Patricia thought that the correct answers to which students expected to reach in their classroom experiences of inquiry were known by their teachers beforehand. On the other hand, she argued that scientists delved into unexplored scientific questions in order to offer new solutions to the scientific community. Following excerpt from her interview response revealed her thoughts about the differences between scientific inquiry and classroom inquiry:

In most scientific inquiry, you don't know the end answer. And in inquiry-based science in the classroom, many times or most times, you know what the answer is going to be, at least as the teacher you do. The students may not know it yet but you know where the answer is going. (Patricia, Interview, September 13, 2005)

Patricia implied that classroom inquiry experiences of students were carefully planned settings where students were led to learning scientifically accepted ideas rather than developing new body of scientific information.

Martha

Martha's definition of scientific inquiry centered on "scientific method" through which scientists found solutions to their questions. Her definition came in a simple format: "Using scientific method to answer a question" (Martha, Interview, September 6, 2005). However, it appeared that Martha used "experimentation" and "scientific method" interchangeably in her definition of scientific inquiry because she employed the word "experiment" in lieu of scientific method in a rephrased form of the same definition later in her interview. Following sentence was the new phrase that she preferred to use this time in her definition of scientific inquiry: "Scientific inquiry means that you start off some kind of a question that you are going to **experiment** to find the answer" (Martha, Interview, September 6, 2005). Such tendency of equating "scientific method" with

“experimentation” emerged more clearly from her following statement because she separated both terms in her sentence with a slash: “I think that allowing students to gain a scientific understanding of a concept through using scientific method/**experimenting** is important” (Martha, Written communication, September 19, 2005). One can easily notice that she placed “experimentation” at the foundation of scientific inquiry.

Martha considered experiencing the similar thinking processes of scientists as an essential part of her students’ learning of science. She felt that her students could build a better understanding of the scientific process in science fair projects. In their science fair experiences, she desired her students to experience the possible challenges that scientists encountered in designing their scientific investigations and to understand the importance of communicating with other scientists in the process of scientific work. She noted:

The main thing I want my students to learn is the scientific process. You can’t do that just by saying “you do a hypothesis” because just telling them is not going to work. They know what a hypothesis is but actually going through and doing the project gives them real experiences like “all my plants died.” That happens in science. It happens in the real world. Having to produce the report and then share it with the whole class, they need to know that because that is what scientists do. (Martha, Interview, May 26, 2005).

In her preceding interview response, Martha addressed the essential place of scientists’ communication with other scientists in their effort for generating scientific knowledge. She found science fair projects as useful settings for her students to experience the authentic nature of scientific inquiry process.

Martha did not see big difference between inquiry practiced by scientists in their scientific research projects and inquiry performed by students in their science classes. She described classroom inquiry as an effort for introducing students to the scientific investigation process. The succeeding interview response unveiled Martha’s close association of scientific inquiry with classroom inquiry: “I think inquiry-based science is just a way of teaching that same process, in that, students solve or answer questions through using the scientific method” (Martha, Interview, September 6, 2005). However, Martha differentiated the classroom inquiry experiences of students from the efforts of

scientists in producing solutions to the scientific problems on the basis of the levels of autonomy possessed by scientists and by students in their respective investigations:

Scientists choose their own questions to inquire. In inquiry-based science, the options that students have are sometimes different. Sometimes we give them questions and sometimes we don't let them choose it. We want them do the investigation. I think inquiry-based science can be both of those things; choosing their questions or not choosing them. (Martha, Interview, September 6, 2005)

In her interview response above, Martha indicated that questions to be inquired by students in their classroom inquiry experiences were not necessarily decided by themselves in contrast to the scientific questions to be investigated by scientists were determined by themselves.

Mary

In her definition of scientific inquiry, Mary placed much emphasis on “experimentation” through which scientists found answers to their questions. In response to the interview question regarding her description of scientific inquiry, Mary told:

Scientific inquiry, to me, is investigating scientific topics through **experimenting**. Scientists come up with questions and follow through them by **experimentation**. This leads them to more questions, and reaching more answers set the entire process that we go through or scientists go through. So that is what it means to me. (Mary, Interview, September 22, 2005)

As it was noticeable from her interview remark above, Mary equated inquiry performed by students in their science classes with inquiry practiced by scientists in their scientific investigations. Her description covered both terms, namely scientific inquiry and classroom inquiry, at the same time without separating them.

Although Mary believed that classroom inquiry was an effort to imitate the process of scientific inquiry in classroom conditions, she was still cautious to say that it was possible to follow exactly the same processes of science in the classroom due to the restrictions of students' background knowledge in science. In the following excerpt from her interview, Mary mentioned the limitations existing in classroom conditions: “I think you cannot do all of those different things in the classroom because you have

limitations with student background knowledge, where they come from, and what they already know” (Mary, Interview, September 22, 2005). Mary attributed the failure of classroom inquiry in introducing students to the same process of science in classroom to their lack of background information. However, she added that there existed some science classrooms in which students acted exactly as scientists:

Although we do not offer something new to the scientific community, I think there are science classrooms that do that. That takes part in meteorology projects or NASA offers a lot of that stuff but it is not what I am working on right now. (Mary, Interview, September 22, 2005)

Based on Mary’s argument, we might conclude that she distinguished scientists’ performances of scientific inquiry from many of classroom inquiry experiences of students on the basis of generating new scientific knowledge. She acknowledged that most of inquiry practiced in the classroom did not aim to produce new scientific knowledge.

Summary

Except Patricia, teachers in the study expressed their understanding of scientific inquiry with the word “experimentation.” There is a common tendency among science teachers to equate scientific inquiry with “experimentation” (McComas, 1998; NBPTS, 2003c). Like many of their colleagues, the teachers in this study did not necessarily use the word “experimentation” with a proper meaning of it as testing scientific ideas by manipulating the conditions and controlling the variables. Their use of the word “experimentation” worked as an umbrella term that included the controlled experiment but not necessarily confined to it. Teachers verbalized their understanding of scientific inquiry with the word “experimentation” to refer to a broader term “empirical investigations” of scientists to explain natural events. This broader term might be explained as the activities of scientists “in which evidence is gathered through observation and experiment to explain and predict natural phenomena” (Helms & Carlone, 1999, p.236). In contrast to other teachers in the study, empirical foundations of scientific inquiry were more easily noticeable in Patricia’s case. For Patricia, scientists’ conclusions supported with “hard evidence” constituted the essence of scientific knowledge.

Similar to the cases of the teachers in this study, the word “experimentation” is used commonly with a loose meaning in schools. McComas (1998) explained such representation of the word “experimentation” in school context as follows:

Throughout their school science careers, students are encouraged to associate science with experimentation. Virtually all hands-on experiences that students have in science class are called experiments even if they would more accurately be labeled as technical procedures, explorations or activities. (p.64)

Improper use of the terms like “experimentation” in schools might be explained with teachers’ naïve understanding of the scientific inquiry process. The practice of science is portrayed in current school science as the experimental activities of scientists (Windschitl, Dvornich, Ryken, Tudor, & Koehler, 2007). The experimental approach in school science developed as a result of the dominance of physics research at the time of “the development of paradigms of inquiry for school science” (Windschitl et al., 2007, p.382). Current school science culture promotes a naïve notion that scientific knowledge is constructed through the experimental investigations of scientists (Windschitl & Thompson, 2006). Teachers in the study did not necessarily reduce the meaning of practicing science to the controlled experiments of scientists, yet their notions of scientific inquiry were still influenced by the representation of science as an “experimental” enterprise. Although the empirical investigation of scientists does not represent “a complete picture of how science is done, it remains a central aspect of reform-based instruction” (Helms & Carlone, 1999, p.237).

In the previous subsection of the chapter, I presented these teachers’ images of scientific inquiry in their minds. In the following subsection of the chapter, I will do the same with the teachers’ notions of classroom inquiry. As more informed we become about these accomplished teachers’ conceptions of inquiry in science and in classroom, the more easily we can observe any parallelism in the meanings attributed to both terms by teachers.

Classroom Inquiry

In this subsection of the chapter, I provide each teacher’s views of classroom inquiry. Before starting the presentation of teachers’ notions of classroom inquiry, I

make the succeeding sub-assertion regarding participant teachers' understanding of inquiry in classroom.

Sub-Assertion-4b: Teachers conceive classroom inquiry as the experiences of students with empirical science activities.

In order to support the sub-assertion that I made above, I present each teacher's case in the following paragraphs. I start with Jennifer first.

Jennifer

In several instances, Jennifer pronounced "experimental" activities as one of the major themes in her definition of classroom inquiry. For example, she depicted the meaning of inquiry in classroom as learning experiences of students in science with the involvement of conducting "experimental" activities. In her following statement, it was possible to see the crucial role of experiments in her notion of classroom inquiry: "To teach science through inquiry to me is doing an **experimental** activity, being in an **experimental** situation" (Jennifer, Interview, September 20, 2005). In her following interview response, although Jennifer put somewhat more emphasis on the active nature of inquiry in classroom, she still associated classroom inquiry with the word "experimental." She stated, "I feel like inquiry-based to me means **experimental** that they [students] are doing something" (Jennifer, Interview, September 20, 2005). Jennifer's preceding expression suggested that she used the word "experimental" in its broadest sense to refer to laboratory-based experiences of her students but not necessarily the act of conducting an investigation through controlling variables. The succeeding excerpt from one of Jennifer's interview responses can be given as another example to denote the place of experiments in Jennifer's conception of classroom inquiry: "I very often have inquiry be an **experimental** portion. The rest of it, I don't really make learning science concepts as an inquiry" (Jennifer, Interview, May 12, 2005). Based on Jennifer's preceding expressions, we might infer that she saw "experimental" activities as the major tool in introducing her students into the similar activities of scientists. Jennifer in her NBC portfolio also promoted experiments as the intrinsic element of students' classroom inquiry experiences. She discussed that

“students need opportunities to use scientific inquiry, to ask questions, plan and conduct **experiments**, to creatively solve problems, and use appropriate tools and techniques to gather data” (Jennifer, Entry 3, NBC portfolio). From various expressions of Jennifer presented in this section, we could conclude that “experimentation” constituted an inseparable figure in Jennifer’s image of classroom inquiry in her mind.

Patricia

Patricia did not utilize the word “experiments” in her definition of classroom inquiry but instead, she emphasized the importance of students building their conclusions on actual “quantifiable data” collected in their inquiry activities. The following excerpt from her interview reflected the place of quantifiable data in shaping students’ answers in their classroom inquiry experiences:

In a real inquiry lesson, you need to have quantifiable data to actually draw a conclusion. It is not just “Oh! We are having fun! This is what I think we have.” You are going to actually prove what you did, which is what science is all about. (Patricia, Interview, May 12, 2005)

Patricia’s use of quantifiable data in her description of classroom inquiry implied the crucial role of empirical evidence in students’ practices of inquiry in their classroom. This ultimately suggested that Patricia’s notion of classroom inquiry involved students performing measurements and observations in building their conclusions.

Patricia’s expressions supported her general notion of classroom inquiry that involved collecting some type of quantifiable data in drawing conclusions. Patricia built her description of classroom inquiry on laboratory experiences of students, which meant engaging them into activities that included some type of data collection. She explained her perspective on classroom inquiry as follows:

Inquiry-based science at the middle school would be a lab. You start out with like say magnetism. You start and let your students play with magnets. And then you control it, you put parameters on it a little bit more. They play with it a little bit to get used to what they are doing. And then they actually collect some data with it. And then they draw their conclusions from that data. And that is a real inquiry lesson. (Patricia, Interview, May 12, 2005)

In her interview response above, Patricia underlined the importance of direct experiences of students with the scientific phenomenon in their learning of science. In students' experiences of science in the inquiry lessons, she believed the need for students to justify their conclusions with the involvement of actual evidence.

Martha

Like Jennifer, Martha included the word “experimentation” in her description of classroom inquiry. For example, in the following excerpt from her interview response, conducting “experiments” as her students experienced an inquiry-based laboratory activity constituted one of the central aspects of her image of classroom inquiry. She articulated her image of inquiry in classroom as follows:

I think helping students gain scientific understanding of a concept through **experimenting** is important. That is one thing that I try to do in my labs. I just try to get them start off with their questions, do some kind of **experiment** and collect data that they have to go back, look at, and then figure out what does that data mean? Could there be errors in it? We did a pendulum lab. Some of the kids said, “Wait! I have this data and it doesn’t look like what others have” and I said, “Well! You would need to do more **experimentation**. You have inconclusive data. You can’t do anything with that.” (Martha, Interview, September 6, 2005)

As can easily be noticed in her preceding interview response, Martha’s notion of classroom inquiry involved students making sense of scientific ideas through conducting “experiments” and analyzing data. In the following comments from one of her other interview responses, the important place of “experimentation” in Martha’s understanding of classroom inquiry was observable more clearly. She stated that “an inquiry activity has got to have a question, a good question that the students can do **experimentation** on” (Martha, Interview, September 6, 2005). In Martha’s preceding interview response while emphasizing heavily the value of having good questions in order classroom inquiry process to take a start, Martha added the importance of the questions to be investigable through empirical procedures. As a response to another interview question, Martha expressed similar thoughts about the essential place of “experiments” in her enactment of classroom inquiry with her students. She replied that “that is another reason I like science because the kids get to design their **experiment** and find out about

something that they are interested in” (Martha, Interview, May 26, 2005). From all of Martha’s responses presented in this section, it was possible to infer that her notion of classroom inquiry built on “experimentation” through which students developed an understanding of the scientific inquiry process.

Mary

Like Jennifer and Martha, Mary also associated inquiry in classroom with “experiments” that allowed her students to be active participants of learning rather than passive recipients of information. It was apparent in her description of classroom inquiry that conducting “experiments” was an inseparable aspect of learning science through inquiry. The following description of inquiry that she provided in her interview response could be given as an example to exhibit the importance of “experimenting” in Mary’s understanding of classroom inquiry process:

To teach science through inquiry for me is to have kids actively doing. They need to get some background information first, then getting a chance to use it, running **experiments**, using tools, making measurements, collecting data, and analyzing all that stuff. (Mary, Interview, September 22, 2005)

Although Mary brought the active nature of classroom inquiry experiences to the fore, she still included “experiments” as one of the major components of classroom inquiry. The inherent role of “experimentation” in Mary’s conception of classroom inquiry was more noticeable in the following interview excerpt:

Through inquiry-based science, it is important that kids learn how to think their own. They need to make decisions and develop **experiments** by using what you taught them. But before they get there, they need to have a basic knowledge about how to conduct **experiments**. (Mary, Interview, September 22, 2005)

In her interview response above, Mary saw having the abilities to conduct “experiments” as the prerequisite of their successful engagement into classroom inquiry experiences.

Comparative Overview

“Experimentation” was a recurrent term to appear in these teachers’ notions of inquiry in science and in classroom. Except Patricia, the teachers identified both concepts with the word “experimentation.” In Patricia’s case, she described inquiry practiced by scientists as the empirical investigations supported with “hard evidence.” In

a similar fashion, she conceptualized inquiry performed by students as classroom activities driven by “quantifiable data.” In a sense, Patricia associated both scientific and classroom inquiry with empirical investigations of scientists and students respectively. Although other teachers in the study used the term “experimentation” in their description of scientific and classroom inquiry, they did not necessarily reduce the meaning of it to testing the scientific ideas by controlling the specific variables. Rather, it was an inclusive term to include the controlled experiments but not limited to it. The broad term “experimentation” embraced the empirical investigations conducted through supporting the conclusions with actual evidence, whether observational or experimental. The term “experimentation” is used in school context with a broad meaning (McComas, 1998). For example, teachers tend to name hands-on science activities of their students as experiments (McComas, 1998). NBPTS (2003c) acknowledged that “the experimental approach” (p.40) is typically equated with “scientific inquiry” (p.40) in schools. According to NBPTS (2003c), the typical meaning of “the experimental approach” concept embraces not only the controlled experiments but also the empirical investigations of students. Likewise, the specific cases of the teachers in this study indicated that their use of the word “experimentation” corresponded to the investigations that involved collecting empirical data to support conclusions. Therefore, it is reasonable to state that the teachers in the study visualized the practice of inquiry in science and in classroom as the empirical investigations supported with actual evidence.

In order to see the associations of the meaning of some key words in teachers’ subconscious minds, I asked them to give me their immediate responses with different words as soon as they heard the words “science, scientific research, inquiry-based science, scientist.” The immediate answers provided by teachers in response to the key words can be seen at Table-10 below. The word “lab” was pronounced by teachers except Mary as a first response to the terms “scientific research and inquiry-based science.” Whereas Jennifer and Patricia associated inquiry-based science with labs, Martha did the same with scientific research. Those teachers’ usage of the word “lab” in their immediate responses can be thought as a supportive evidence that empirical activities occupied an important place in their conceptions of inquiry in science and in classroom. The activities performed by scientists and students in laboratory conditions

usually involve collecting some type of empirical data in order to support the conclusions. In that respect, it is reasonable to suggest that those teachers' immediate responses uncovered their notions of classroom inquiry, which was portrayed as the experiences of students in empirically driven laboratory activities.

Table 10 Immediate Teacher Responses

	Jennifer	Martha	Patricia	Mary
Science	why or how things work	curiosity	fun	the world
Scientific Research	investigations	labs	boring papers	in depth learning about the world
Inquiry-based Science	labs	a classroom of students doing something	playing around in the lab	questions
Scientist	researcher	university	smart cool dudes and girls but mostly dudes	people who do the work

Many science teachers hold naïve ideas about the practice of science (Akerson & Hanuscin, 2007; Hodson, 1998; McComas, 1998). The representation of science in popular media sources as well as in many textbooks perpetuates teachers' unsophisticated perceptions of science and scientists (Hodson, 1998). "The experimental method" (Hodson, 1998, p.193) is portrayed in many popular sources as "universally essential to science" (p.193). The situation is no different in school science. The experimental approach is widely used by teachers in their efforts for introducing their students to the reasoning patterns and the actions of practicing scientists (Grandy & Duschl, 2007). Windschitl et al. (2007) described the usual practice of the experimental approach in school science as follows:

In this form of inquiry, students begin by hypothesizing about links between variables in a system....What follows then is the design of an experiment, what

many teachers call a “fair test,” comparing two conditions that differ only on a single variable....Students would identify a responding or dependent variable..., the manipulated or independent variable..., and a set of controlled variables to assure that no other influence could reasonably affect the responding variable...Students then compare...[the changes occurring] under these controlled conditions and draw the appropriate conclusions. (p.383)

However, this experimental model of classroom inquiry is not necessarily an accurate portrayal of the practices of scientists (Grandy & Duschl, 2007; Windschitl et al., 2007). Moreover, reducing the meaning of classroom inquiry to the empirical investigations of students does not serve to the intentions of the reform documents. That is because NRC (1996) encourages teachers to shift their emphasis in their classrooms from “science as exploration and experiment” to “science as argument and explanation.” However, the narrower understanding of classroom inquiry as empirical investigations by the teachers in this study indicated that they were not able to make this shift in their notions of classroom inquiry. Teachers need to recognize that classroom inquiry is not limited to the experiences of the students with empirical investigations (Flick, 1997; Hodson, 1999; NRC, 2000). They need to develop broader operational definitions of classroom inquiry other than the empirical model (Windschitl, 2004). However, this seems to be connected to developing more sophisticated understanding of inquiry practiced by scientists. If teachers develop a better understanding of the role of “the experimentation” and the theory in science, they might interpret the inquiry experiences of students in their classrooms with a broader perspective.

Teachers in the study conceptualized classroom inquiry experiences of their students as the actual modeling of the activities of practicing scientists. These teachers in the study found inquiry performances of students in their classrooms very close to the actual practices of scientists. By stating this, I don’t mean to say that they did not specify any dissimilarity between scientific inquiry and classroom inquiry. One difference between scientific inquiry and classroom inquiry pronounced by Jennifer, Patricia, and Mary was the different goals intended to be achieved by scientists and by students in their respective inquiry settings. They argued that the purpose of classroom inquiry included learning the existing scientific ideas rather than generating new scientific

knowledge as opposed to the scientific research studies conducted by scientists (Izquierdo-Aymerich & Aduriz-Bravo, 2003). Patricia noted that most of the time the teachers knew the answers that their students would reach in their classroom inquiry experiences. As opposed to the higher levels of autonomy owned by scientists in choosing their questions to investigate in their scientific research endeavors, Martha felt that students were given the questions to inquire by their teachers in their classroom investigations (Izquierdo-Aymerich & Aduriz-Bravo, 2003). Teachers' conception of classroom inquiry as the actual modeling of scientific inquiry restricts their ability to create alternative definitions of classroom inquiry. They need to develop a better understanding of the different epistemological assumptions of real science and school science (Chinn & Malhotra, 2002; Izquierdo-Aymerich & Aduriz-Bravo, 2003). Understanding the limitations of school science in comparison to real science helps teachers make better decisions about the relative values of the inquiry investigations of students in experiencing the similar thinking processes of practicing scientists. Although representing the reasoning patterns and the actions of practicing scientists in classroom is one of the ideals of science education reform efforts, achieving this ideal is not possible without engaging students into the authentic inquiry experiences in their classrooms.

In the following section of the chapter, I discuss another essential concept, namely scientific method, which has important influence on teachers' understanding of classroom inquiry.

Scientific Method and Classroom Inquiry

In the preceding section of the chapter, empirical investigations of scientists emerged as a crucial concept to affect teachers' understanding of both scientific inquiry and classroom inquiry. An analysis of teachers' notions of classroom inquiry would be partial without scrutinizing the place of scientific method in practicing inquiry for teachers with their students. In this section of the chapter, I present the opinions of the teachers about the method of science and its place in enacting inquiry in classroom. Table-11 below summarizes the perspectives of participant teachers on scientific method.

Table 11 At First Glance: Views of Scientific Method	
Jennifer	▪ Considered the traditional version of the scientific method as a legitimate way of conducting science. ▪ Avoided confining the works of all scientists to the scientific method.
Patricia	▪ Opposed to the conventional representation of the scientific method as a linear stepwise process. ▪ Conceptualized scientific method as a way of thinking and problem solving.
Martha	▪ Identified the steps of the scientific method as universal entities followed by all scientists in their practice of science. ▪ Classroom inquiry allowed students to experience the scientific method.
Mary	▪ Equated the works of scientists with the practice of conventional form of the scientific method. ▪ Students used the same method of scientists in their classroom investigations.

Before starting a broad discussion of teachers' approaches to scientific method in their teaching performances of classroom inquiry with their students, I make the following assertion regarding the function of scientific method in teachers' understanding of classroom inquiry.

Assertion-5: The conventional representation of scientific method as a linear stepwise process shaped teachers' notions and practices of inquiry in classroom.

I present each individual teacher's perspectives on scientific method below. The chapter ends with a comparative discussion of teachers' views on "scientific method."

Jennifer

Jennifer believed that the scientific inquiry process could be taught to students in classroom conditions. Her description of a typical way of teaching the scientific inquiry in classroom exhibited the characteristics of popularly held image of the scientific method with consisting of some well-known steps. But Jennifer did not necessarily think that this was the only way through which science was practiced. She explicated her views about the typical way of teaching the scientific method in classroom as follows:

We can teach scientific method in classroom conditions. The process of scientific method is typically taught as you make a question, you hypothesize an answer, you do an experiment, you analyze your results, and then you adjust your hypothesis or perhaps make a new hypothesis and retest it. Not all science is

done through that scientific method. So if you think that the scientific method is purely this, then you are wrong. (Jennifer, Interview, September 20, 2005)

Jennifer was cognizant that the scientific method that she described in her interview response did not represent all the fields of science. However, despite her awareness of that, her model of teaching scientific method to her students followed the footsteps of traditional representation of the scientific method as a linear process with prescribed steps in it.

In one of the written reflections from her NBC portfolio, Jennifer asked her students to follow similar orderly steps that she described above in designing their experimental investigations. According to a rubric that she delivered to her students for their investigations, she expected them to go through the phases in the order specified in the rubric. I extracted the following passage from Jennifer's NBC portfolio:

The day prior to this group discussion lesson, I passed out a rubric that stated the requirements of a successfully designed experiment (to pose a question, make an hypothesis and explain it, identify the dependent and independent variables, design a method for the control of other variables and the collection of sufficient, relevant data, state materials and equipment). I used an overhead projector with a copy of the rubric on a transparency, and briefly discussed these parts of an experiment. (Jennifer, Entry 3, NBC portfolio)

In the excerpt above, the steps given to students to follow in their experimental activities reflected the stepwise nature of popular scientific method included in many science textbooks. In the rubric that she delivered to her students, she expected students to follow the steps of the scientific method to investigate their questions. Jennifer particularly found science fair projects as suitable media for her students to employ the scientific method in finding answers to their scientific questions. Students in their science fair projects obtained the opportunities to practice all steps of the scientific method from posing an investigable question to devising a suitable method for answering the question to interpreting the experimental results.

Patricia

Patricia described scientific method as the way of inquiry followed by scientists in the process of generating scientific knowledge. In her interview response below, Patricia verbalized her conception of scientific method as follows:

It [scientific method] is a part of inquiry. It is a method of inquiry. That is not necessarily seven or eleven steps, which is how scientific method is usually taught especially in this age level. It is learning to think. I can't say that I actually agree with the scientific method because lots of times it is not as orderly as, it is not neat little steps. (Patricia, Interview, September 13, 2005)

In the remarks in her interview response above, Patricia did not promote the popular image of scientific method included in many textbooks as a linearly progressing stepwise process. On the contrary, she identified scientific method as a special way of thinking that dictated no orderly simple steps to be followed by scientists in their practices of science.

In one of her written NBC portfolio reflections presented below, Patricia revealed her similar thoughts about scientific method. She promoted the idea that there existed not one single scientific method for all scientists to follow in their scientific endeavors. She verbalized her views about scientific method in her NBC portfolio as follows:

In this entry, I have chosen to focus on the concepts of measurement, data collection and analysis as part of the introduction to physical science unit. Some may call this concept the scientific method. I am opposed to using that terminology as there is really no such thing as the scientific method but rather a way of problem solving and thinking that can result in several "scientific methods" based on sound scientific practices. (Patricia, Entry 1, NBC portfolio)

As explicitly stated in her comments above, Patricia developed a more sophisticated understanding of scientific method. She avoided reducing the activities of scientists into a simple entity used by all scientists in their efforts for generating scientific knowledge. However, she still considered some of the science process skills that her students needed to learn in their science classes as the essential components of modeling the scientists' ways of thinking in their practice of science.

Although Patricia opposed the popular representation of scientific method as a linear stepwise process, the following interview response denoted that she did not ostracize the traditional steps of the scientific method completely from her teaching of science:

Scientific inquiry is trying to learn about things in a logical, reasoned manner, stepwise looking for hard evidence to support. That is what scientific inquiry is. You can begin to try to teach them the scientific method. You can certainly teach them all those little steps. But really the scientific method is a way of thinking. It is an approach to problem solving. (Patricia, Interview, September 13, 2005)

Patricia tended to see scientific method as the model for students to imitate the scientific inquiry process in classroom. She thought that the well-known steps that involved in the scientific method could be taught to students in their science classes. Although Patricia was knowledgeable about the nonexistence of a universal scientific method followed by all scientists in their scientific research projects, she was not able to devise an alternative model of scientific method, which represented the work of scientists, in her teaching of science other than presenting the little steps of the scientific method. This suggested that having a broader understanding of scientific method did not automatically mean that teachers developed an alternative model of scientific method to exclude the linear stepwise nature of it in their science teaching practices.

Martha

Martha defined scientific method simply as the “process used to answer a question” (Martha, Interview, September 6, 2005). In her following interview response, it was very clear that she conceptualized scientific method as a special way to be followed by students to answer their questions in their classroom inquiry experiences. She noted that “I think inquiry-based science is just a way of teaching that same process to me. Students solve or answer questions through using the scientific method” (Martha, Interview, September 6, 2005). Martha saw inquiry experiences of her students as the opportunities for them to learn the practice of the scientific method.

Martha promoted the naïve idea that the scientific method was a universal entity employed by all scientists in their scientific work. That was why Martha wanted her

students to learn those universal steps involved in the scientific method in their inquiry-based science experiences. She stated, "I want them [students] to understand that there is a method that is universal. Science process is universal and what those steps are" (Martha, Interview, September 6, 2005). In her preceding statements, Martha implied that classroom inquiry activities of students served as a platform where students experienced the central tenets of the scientific method. In order to demonstrate the simplistic representation of scientific method with linear steps in Martha's mind, another excerpt from her interview response could be given as "When we were just going through the steps, I was just showing them [students] how to come up with questions, kind of walking through the [scientific] process" (Martha, Interview, September 6, 2005). The steps that Martha asked her students to follow in their inquiry experiences were nothing but the popular steps of the scientific method illustrated in many science textbooks.

Martha was pretty confident that she could teach her students the process of scientific method in their science classes. In order to do that, she felt that students needed to be engaged into the appropriate activities that modeled the scientific method in classroom. However, she found experiencing the different parts of the scientific method at a time more practical to accomplish in classroom conditions rather than following all of the steps in the scientific method at once. Martha explicated her perspective of modeling different components of the scientific method in different classes as follows:

You can teach students the process of scientific method. You do a lot of modeling of the process [scientific method]. You may not do the whole thing at once. Focusing on different parts of the method, I think, is important and various activities focus on that. A lot of my activities focus on identifying that independent-dependent variable and it is really important because they need to know that and it is on FCAT. They are not going to have a thorough understanding of it like somebody who is doing science everyday but at least they understand that there is that process of science. (Martha, Interview, September 6, 2005)

From Martha's previous expressions, it was possible to infer that she considered scientific method both as a body of knowledge to be learned by students in their science classes and a stepwise process to be followed by students in their inquiry activities.

Mary

Mary felt that scientific method occupied a very important place in her students' everyday lives. In the following interview excerpt, the example that she gave to her students in order to denote the hidden connections of the scientific method with their daily lives unveiled her conception of scientific method as a process to be consisted of clearly defined linear steps:

When I teach the scientific process, I tell my students: "Ok! Let's say that you have a crying baby. You have a little sister and she is in your room and she is really, really crying. You go through the scientific method whether you realize or not because you go through **step by step** trying to find out why your sister is crying because you want her to stop. And you don't think it as if the scientific process but you go through the problem solving method. You do it naturally. It is the part of what you do all the time with something like that or in other places, scientists do it in just different context." (Mary, Interview, May 5, 2005)

In the real life example above that Mary used in her teaching, she identified method of science as the problem solving process of scientists. However, her simplistic portrayal of the problem solving process of scientists matched with popular image of the scientific method promoted by many science textbooks as a linear stepwise process. Mary's tendency of equating the activities of scientists with this simplistic notion of the scientific method indicated the unsophisticated nature of her understanding of scientific inquiry process.

Mary was confident that she could make her students experience the scientific inquiry process in their science classes. In order to achieve that, she engaged her students into classroom investigations. Students followed the steps of scientific method in their efforts for solving their questions. The steps in traditional representation of the scientific method were observable in the following interview excerpt:

I am teaching scientific method right now. Today we did an entire experiment with guinea pigs. We went through the entire scientific process of starting with

the question, doing some background research about what we knew, doing an experimental design with hypothesis. We run the experiment, got our data, and analyzed it. We are going to do a little bit more tomorrow. And then we are going to come up with some conclusions like what did we learn? What further study could we do? What are the some things that went wrong? Did they affect our data? I think that is exactly what scientists do. And I think that is what we did too.
(Mary, Interview, September 22, 2005)

As can be noticed from Mary's interview response above, her teaching of scientific method to her students followed a linear path with certain steps in it. She considered this linear stepwise process that her students followed in their science activities as the actual modeling of scientific inquiry process.

Based on Mary's interview responses, it would not be wrong to suggest that stepwise structure of the scientific method dominated her understanding of the scientific investigation process. In one of my visits to Mary's classroom, I observed her enactment of a microscope activity with her students. In our talk later about this activity, she refrained from pronouncing this activity as an inquiry-based one because she thought that the activity lacked the critical steps of the scientific method. In her clarification for the missing component of the activity that kept her from calling it as inquiry, she stated, "I don't think I asked them [students] to actually solve something with steps in critical thinking. I just asked them to go through a procedure and learn how to manipulate things" (Mary, Interview, May 26, 2005). Mary's preceding expressions indicated that she could not imagine classroom inquiry separate from the scientific method. Hence, she conceptualized scientific method as the tool to lead students to reach their conclusions in their classroom inquiry experiences.

Comparative Overview

Without any doubt, science as one of the ways of knowing is one of the most important innovations in the history of mankind. Beyond being a body of knowledge, science represents a unique way of thinking in approaching to the events (Johnston, 2000). Recent science education reform documents stress the importance of students developing an understanding of scientists' ways of thinking in their science classes (AAAS, 1993; NRC, 1996). However, this presents a challenge for teachers to

accomplish with their students because science is a complex process with no prescribed method (Ramalay, 2003). Many science teachers employ the conventional representation of the scientific method, which consist of well-known linear steps, in their teaching in order to engage their students into the similar thinking processes and activities of practicing scientists. McComas (1998) presented the prominent steps of the traditional scientific method included in many school textbooks as: “a) defining the problem, b) gathering background information, c) forming a hypothesis, d) making observations, e) testing the hypothesis and f) drawing conclusions” (p. 57). However, this conventional presentation of the scientific method is acknowledged by many scholars as a myth rather than an actual portrayal of the practices of scientists (e.g. Finley & Pocovi, 2000; Grandy & Duschl, 2007; Hodson, 1998; Jenkins, 2007; Llewellyn, 2002; McComas, 1998, Rowbottom & Aiston, 2006; Settlage, 2007; Windschitl, 2004). Scientists in their efforts for investigating their questions do not follow a specific path in a linear manner. Many times, the sequential presentation of the results in scientific research papers gives the impression that scientists conduct their scientific investigations through following a linear pathway (McComas, 1998; Reiff, 2004). Scientists “approach and solve problems with imagination, creativity, prior knowledge and perseverance” (McComas, 1998, p.58) rather than following a single method of science recognized universally by all scientists. In fact, scientists who work in different fields of science use different methods in answering their scientific questions (Hodson, 1998; Sandoval, 2005; Windschitl et al., 2007). Despite being heavily criticized in the education literature, “somehow the myth of the scientific method lives on and not only within the realm of the science classroom” (Settlage, 2007, p.462). Many science teachers continue to introduce their students to the practice of science by implementing the scientific method in their classrooms.

The teachers in the study were no different than many of their colleagues who considered “the scientific method” as the actual practices of scientists. Their enactment of inquiry with their students involved using this simplistic representation of the scientific method. In other words, the teachers conceptualized scientific method as a specific way to be followed by students in their classroom inquiry experiences. Of course, teachers’ understanding of “scientific method” exhibited variations from one to another. Not all

teachers in the study developed equally sophisticated understandings of scientific method. Martha and Mary, in particular, held a more naïve image of scientific method in their minds. For instance, Martha portrayed the scientific method as a universal entity employed by scientists from all areas of science in their scientific investigations. Both Martha and Mary depicted the scientific method as a process with predetermined steps for scientists to follow in conducting their scientific research studies. This linear stepwise representation of scientific method was in coherence with the popular image of the concept included in many science textbooks. Mary naively equated the activities of practicing scientists with this simplistic version of scientific method. She wanted her students to notice that they were already using those well-known steps of the scientific method in their daily lives without realizing that they were applying the scientific method to their everyday problems. In a sense, Mary introduced the steps of the scientific method to her students as a natural part of their lives. Patricia opposed to the usage of the terminology scientific method completely because she knew that there existed no single scientific method to be employed by all scientists in their research studies. Like Patricia, Jennifer also avoided confining the practice of science with one general method of science. Although Jennifer and Patricia held a more sophisticated image of scientific method in their minds, their description of the practice of inquiry with their students was not free from this simplistic representation of scientific method. Having more sophisticated understanding of “scientific method” did not necessarily lead Jennifer and Patricia to create an alternative model of scientific method to use in their teaching practices of science. The linear and stepwise structure of the traditional representation of scientific method still placed a heavy influence on these teachers’ performances of inquiry with their students.

Participant teachers’ unsophisticated understanding of the scientific inquiry process might be attributed partly to their lack of real science research experiences. None of them had a prior science research experience in their teaching careers. Having real science research experiences is promoted in the education literature as one of the ways of giving a better understanding of the scientific inquiry process to teachers (Brown & Melear, 2006; Windschitl, 2004). Placing teachers into real science research

experiences might be a solution for overcoming the dominance of the traditional scientific method in the classrooms of many science teachers.

Student Inquiry in Classroom

In the previous two sections of the chapter, teachers' conceptions of classroom inquiry were driven primarily by scientific rationales, which involved engaging students into the similar thinking processes and activities of scientists. In this section of the chapter, constructivist rationales, which involved allowing students to build their own understandings of scientific ideas, played the major role in shaping their notions of inquiry in classroom. Table-12 below displays the ideas of teachers in a brief way.

Table 12 At First Glance: Conceptions of Student Inquiry	
Jennifer	- Promoted student autonomy in deciding methods for solving questions as one of the most important characteristics of classroom inquiry. - Expected from students to take control of their learning in collaboration with one another.
Patricia	- Considered student questioning as one of the central dynamics of classroom inquiry. - Students needed to be given the autonomy in developing their own ways for solving their questions. - The answers were required to be supported with actual data.
Martha	- Conceptualized student questioning as a key element of practicing inquiry. - Identified classroom discussions as an essential component of classroom inquiry experiences of students.
Mary	- Classroom inquiry included a hands-on component for students to investigate their questions actively. - Accepted student autonomy and student questioning as the crucial elements of classroom inquiry.

Before starting a broad discussion of teachers' description of inquiry, I make the following assertion.

Assertion-6: Teachers think that student autonomy and student questioning are the two most important characteristics of classroom inquiry.

In the following part of this section of the chapter, I present each teacher's description of student inquiry in classroom. The section ends with a comparative overview of teachers' notions of classroom inquiry.

Jennifer

Following two elements emerged as the essential characteristics of Jennifer's image of classroom inquiry: students to be allowed to devise their own methods and students to be required to find their own answers. In her following interview response, it was possible to observe these two elements of inquiry:

Inquiry-based is where I don't give students the answer. I don't tell them what to do. Well, I have two kinds of lab activities. Some are kind of cookbook that they do and some are like I just ask them to figure something out. (Jennifer, Interview, May 12, 2005)

Based on Jennifer's interview response above, we might infer that she considered student autonomy as an inherent aspect of classroom inquiry. In the following interview response, Jennifer emphasized the importance of giving students autonomy in their classroom inquiry experiences:

A successfully implemented inquiry activity would be that the students work through whatever process they are doing themselves without me. They work together to brainstorm and discuss and solve their own problems. And they would be able to interpret and evaluate their results adequately within the knowledge that they should have already achieved. (Jennifer, Interview, September 20, 2005)

In the interview excerpt above, Jennifer placed student autonomy at the center of her depiction of classroom inquiry. In her description of a classroom atmosphere dominated by inquiry teaching strategies, she expected from students to take control of their own learning rather than to act as passive recipients of knowledge.

Jennifer considered the following three ingredients to be present in a science teacher's inquiry practice: 1) The activity allowed students to follow different methods to reach their conclusions, 2) Students were not provided direct answers to their questions, 3) The teacher discussed students' conclusions through helping them clarify their thought processes at the end of the inquiry investigation. In the following interview response, Jennifer provided her thoughts about the important aspects of a teacher's lesson to be considered as inquiry:

The lesson would be something that it does not just have one answer or one method. When kids ask her [teacher] something, she asks them a question back to get them to think instead of telling them the answer. And then when they are finished, she questions them to help them evaluate it and draw out the thought process. (Jennifer, Interview, September 20, 2005)

Jennifer distinguished inquiry-based experiences of students from their experiences with confirmatory type of activities planned to lead all students to one correct answer through following the same method. Her conceptualization of classroom inquiry involved students having some options in choosing their own ways to find solutions to their questions. In order to promote students' thinking on producing solutions to their problems, Jennifer felt that the teacher needed to avoid providing direct answers to her/his students' questions. This suggested that Jennifer expected science teachers who were considered to be practicing inquiry in their classrooms to encourage their students' thinking on their scientific questions. Jennifer found communications of teachers with their students at the end of their inquiry experiences to help them develop better understanding of scientific topics as one of the essential elements of classroom inquiry. In other words, Jennifer argued the need for ending the inquiry experiences of students with holding a discussion session to clarify the ideas of students better.

Patricia

Patricia promoted questioning as an important component of student inquiry in classroom because she acknowledged questions generated by students as a good sign of thinking on the side of students. She noted, "I think that 'what if questions' are also considered as part of inquiry because students are thinking. And anytime we are checking work, anytime we are going over assignments, those questions come up" (Patricia, Interview, May 12, 2005). Because questions stimulated students' thinking skills, Patricia used questioning strategies with her students as a part of teaching her students science through inquiry. However, she led her students to investigate some questions further but not all to find an answer. Which question to inquire usually depended on nonexistence of a readily available answer to a student-generated question and the worth of the question to investigate further. In the following interview

response, Patricia verbalized her thoughts about the important place of questioning in inquiry-based teaching of science:

I do most of my inquiry in questions. I encourage my students to pose “what if questions.” And to me, that is an inquiry because it is a student-generated question. They would like to know the answer. And if the question is something that the students care enough about, we set up an investigation to see what we can do about it. Inquiry is getting the students to think about what they are doing and what could happen. Sometimes the “what if” is enough to satisfy their curiosity. (Patricia, Interview, May 12, 2005)

Patricia introduced classroom inquiry experiences of students as the instances in which students sought answers to their questions in order to satisfy their curiosity. Since the questions originated from students’ curiosity served as a good indication of their mental activities, Patricia in many instances found the mere process of questioning as a satisfactory experience for students in their learning of science through inquiry.

I wanted Patricia to assume that she was given a task to observe a teacher’s practice in order to see if the teacher was using any inquiry teaching strategies in her/his classroom. I asked her to tell me the three most important characteristics that she would be looking for in this teacher’s practice to see the evidence whether s/he was teaching science through inquiry. Patricia’s response included the following inquiry characteristics to be present in a teacher’s lesson: 1) the activity to have directed questions, 2) the teacher not to tell students the answers and the methods other than providing some suggestions, 3) the students to communicate with each other instead of relying on their teacher in order to reach correct conclusions, and 4) the answers given to the questions to be supported by collected data. Patricia’s response to the imaginary scenario was as follows:

I would look for directed question. I would look for her [teacher] not telling the students what to do but giving suggestions like “Could you try this? What do you think about that? We have got all these stuff what do you think you can use?” If the student asks the question, the teacher turns the question around. I would look for students looking to each other rather than the teacher for affirmation that they are doing it correctly. I would also look for students generating their

conclusions in a way supportable with their data. (Patricia, Interview, September 13, 2005)

In Patricia's interview response above, the level of student autonomy and evidence-based nature of conclusions constituted the main structure of inquiry in classroom. The central focus of the lesson shifted from teacher to students. In her depiction of practicing inquiry in classroom, she assigned more active roles to students in their learning of science.

Martha

Martha placed much emphasis on questions in classroom inquiry process. She accepted questions as the key to ignite student investigations. She stated, "Questions are key to that. You start with a question. It is not inquiry if there is no question" (Martha, Interview, September 6, 2005). In the previous statements of Martha from her interview, she was very definitive about the status of questions in classroom inquiry, in that, she acknowledged the presence of questions as a requirement for student activities to be considered as inquiry. In response to my interview question about observing the teaching performance of a teacher in an imaginary situation in order to see whether the teacher was using any inquiry strategies in her/his classroom, Martha solely based her attention on questions posed by the teacher and the students in this teacher's classroom. More than the active process of answering questions, Martha thought that the presence of open-ended questions in the environment was a better sign that inquiry was being performed in this teacher's classroom. She told:

I think I would be looking at the questions that they were posing to the students and the questions that the students were asking. If they are asking students the questions a little bit open-ended with not just one yes or no answer, that forces students to think more. Students are asking questions and the teacher is giving them some other questions to get them to think about it. That is I think the real inquiry is going on. It is not so much with doing, what the process is up here.

(Martha, Interview, May 26, 2005)

In the interview excerpt above, Martha pronounced questions as one of the most essential ingredients of inquiry performed in classroom. She particularly considered the open nature of questions as a good strategy to lead students to activate their mental

capabilities. Martha valued thinking opportunities offered to students in their inquiry experiences more than students' active involvement into inquiry activities in their classrooms. Because questions promoted students' active thinking in their investigation process, Martha gave special emphasis to the presence of many questions in inquiry environments.

Another important component of classroom inquiry promoted by Martha in her interview response was communication. Because Martha found ongoing discussions among scientists as one of the most crucial elements in the construction of scientific knowledge, she expected to see similar communication processes among students in their classroom inquiry experiences. Following interview excerpt exhibited the role of communication in the process of generating scientific knowledge:

A huge part of the scientific process is sharing what you have learned. Science is very universal. The scientists from Cuba may still talk to the scientists from the US with nothing to do with politics. It has to be shared as no point in doing your experiment and finding this if you are not going to share them with other scientists. So that is why I think communication in classroom is important.

(Martha, Interview, September 6, 2005)

In her statements above, Martha stressed the collective effort of scientists in building scientific knowledge. Although scientists used different languages in their respective countries, Martha felt that they could still communicate their ideas with each other through the universal language of science. The inherent place of communication in the scientific process was the primary motivation behind Martha's promotion of student discussions at the end of their inquiry experiences. Regarding the importance of having discussions at the end of classroom inquiry process, Martha stated:

I think just starting off a good question is important. Doing the experimentation is important. And some kind of discussion with the data is important. We need to have a classroom discussion, some kind of discussion about what we did and what we found. And the kids always bring up stuff that I don't even think about.

So I am always amazed by that. (Martha, Interview, September 6, 2005)

In Martha's comments above, student discussions as the modeling of the actual practices of scientists in sharing their scientific ideas with each other emerged as one of

the crucial elements of classroom inquiry experiences of students. This suggested that Martha refrained from calling an activity, which missed student discussion from its general format, as inquiry.

Mary

Mary's enactment of inquiry in her science classes usually involved students actively doing something. Mary's notion of inquiry in classroom as an active process driven through hands-on activities was apparent in her following statement: "A lot of times, they [hands-on science and inquiry-based science] go hand in hand. A lot of times, they are together because inquiry-based usually, at least mine anyway, consist of doing something" (Mary, Interview, May 5, 2005). However, Mary avoided equating hands-on activities with inquiry experiences of students. She identified questions to be investigated by students through using their own methods as the missing component from hands-on activities that kept her from categorizing them as inquiry experiences. She verbalized her comparative perspective of hands-on activities and inquiry-based science as follows:

To me, I don't think hands-on activities are inquiry-based. I think they are close but they are not the same thing. To me, in my mind, if you are doing inquiry, you are posing a question that kids have to come to consensus or their own way to solve it. I can do a hands-on lab or activity, and that doesn't really pose a question. And there is really no problem solving along with it. (Mary, Interview, May 5, 2005)

As it was easily observable from Mary's interview response above, problem solving and student autonomy were the key terms to form the skeleton of Mary's definition of inquiry in classroom. For Mary, the degree of an activity to be considered as inquiry-oriented was inversely proportional with predetermined nature of methods to be followed by students in solving their questions. In the following interview excerpt, Mary promoted student autonomy in determining the proper methods to produce solutions to investigation questions:

Inquiry-based to me means that they [students] are questioning through it and problem solving as they go. You don't give them the activity from A to B and "by the time you get here, you will have this." I don't use inquiry-based for everything

that I do but that is what it is. It says having the kids do thinking instead of you doing it for them and writing it out for them. So that is what it means to me and that is how I view it. (Mary, Interview, May 5, 2005)

In Mary's interview response above, student autonomy emerged as the driving force of student thinking. In other words, in lieu of following predetermined ways, inquiry practiced by students in classroom encouraged them to think alternative methods to find solutions to their scientific problems. Therefore, Mary saw inquiry as an active thinking process of students rather than a passive process with low levels of mental activity.

I wanted Mary to put herself into the place of a classroom observer, who visited the classroom of a science teacher in order to see whether the teacher was using any inquiry strategies in her/his teaching of science. I asked her to tell me any specific elements that she would expect to observe in a science classroom driven with inquiry teaching strategies. She replied that she would expect to see the following elements in this teacher's classroom to decide whether the inquiry was being practiced by her/him: 1) students to be in action in their cooperative groups, 2) students to have chances to interact with each other, 3) students to do a lot of questioning in their activities, and 4) students to be exposed to hands-on activities. Mary's response to my interview question came as follows:

I would look for if the teacher were giving her students chances to interact with each other. And also I would want to see lots of questioning in the classroom. That is important because kids need to answer and learn how to think that way. I would want to see hands-on activities going on in the classroom. I would like not seeing the kids with the books open, and reading. I would hope they were working in groups too because science isn't done by itself. (Mary, Interview, September 22, 2005)

In the interview excerpt above, Mary visualized a classroom atmosphere in which students had higher levels of interactions with each other. This suggested that her conception of classroom inquiry placed students into an active learning environment in which hands-on activities dominated students' learning of science. In other words, Mary brought the active nature of classroom inquiry experiences of students to the fore.

Comparative Overview

Teachers found inquiry experiences of students valuable to activate their thinking abilities. Student autonomy and student questioning played critical roles in promoting the mental engagement of students in their classroom inquiry experiences. Student autonomy was promoted by Jennifer, Patricia and Mary as one of the most important elements of classroom inquiry. Teachers expected from students to take control of their learning in their inquiry experiences. In an inquiry-oriented classroom environment, they imagined students in interaction with one another. They considered inquiry activities as the experiences of students to find their answers through following their own methods. That was why they expected from teachers to refrain from providing direct answers to their students in their inquiry practices. Another aspect of student inquiry emphasized by teachers was questions. Patricia, Martha and Mary discussed the important place of student questions in inquiry activities because questions posed by students were a good indicator of their mental engagements with the topic. Patricia considered student questioning as a valuable inquiry experience for students even if they did not investigate their questions. Martha acknowledged the presence of open-ended questions in a classroom environment as a good indication of the inquiry nature of the science lesson. Martha and Jennifer underlined the necessity of having a discussion session at the end of inquiry experiences of students. In summary, student autonomy, student questioning and communicating emerged as the most important components of successfully implemented inquiry lesson.

As participant teachers specified, student autonomy constitutes one of the most important aspects of classroom inquiry. However, the autonomy given to students varies depending on the level of inquiry teaching practiced by teachers (Colburn, 2000; NRC, 1996; Windschitl, 2003). Classroom inquiry experiences of students with higher levels of structure help them understand the accepted science concepts better (Keys, 1997; Llewellyn, 2002). In inquiry investigations with higher levels of student autonomy, students develop the problem solving abilities by conducting their investigations with their own ways (Llewellyn, 2002; Lynch & Zenchak, 2002). However, associating inquiry with the higher levels of student autonomy might inhibit a wider acceptance of inquiry by teachers in their teaching practices of science. For a long time, science education

community promoted the enactment of open inquiry by teachers in their classrooms. However, this ideal did not go beyond a myth. Settlage (2007) noted, “Holding open inquiry as the purest form of classroom inquiry and suggesting it is an ideal for which science teachers should strive is a myth” (p.464). Teachers need to recognize that practicing inquiry does not necessarily mean to engage students into classroom investigations with high levels of student autonomy. Depending on the educational goals to be achieved with students and the abilities of the students, teachers might use the different forms of inquiry from structured inquiry to open inquiry effectively in their classrooms. This brings the crucial role of developing a good understanding of the inquiry continuum by teachers to the fore.

Confirmatory Science versus Inquiry Science

In order to develop a better understanding of teachers’ conceptions of classroom inquiry, it is sometimes good to approach the concept of inquiry from the opposite side. In other words, in lieu of pursuing what inquiry is for teachers, going after what inquiry is not might be more helpful to make a better sense of teachers’ images of classroom inquiry in their minds. “Cookbook science” as treated in many ways to be the contrary of inquiry science can serve to that purpose satisfactorily. Investigating teachers’ perspectives on “cookbook science” in comparison to inquiry science helps better uncovering the various meanings attributed to inquiry by teachers. That is the very reason that I explore those teachers’ notions of “cookbook science” in connection with inquiry science in this section of the chapter. Table-13 below summarizes participant teachers’ perceptions of confirmatory and inquiry science.

Table 13 At First Glance: Perspectives on Confirmatory and Inquiry Science

Jennifer	▪ Distinguished both concepts on the basis of methods given by teachers or chosen by students. ▪ Considered confirmatory science as the initial steps to be taken by students for developing certain laboratory skills. ▪ Found classroom inquiry powerful for activating students' mental capabilities.
Patricia	▪ Acknowledged confirmatory science activities as inquiry experiences for students because they did not know the correct answers beforehand. ▪ In true nature of classroom inquiry, neither teacher nor students knew the answers beforehand. ▪ Found confirmatory science activities effective in learning scientific ideas whereas practicing inquiry helped students experience the thinking processes of scientists.
Martha	▪ Having the options for choosing different methods in solving questions differentiated inquiry from confirmatory science. ▪ Visualized confirmatory science activities as a good platform for learning science concepts. ▪ Promoted inquiry science as a fertile environment for experiencing the scientific method.
Mary	▪ Methods to be determined by students constituted the essence of classroom inquiry. ▪ Valued confirmatory science activities of students for helping them learn certain laboratory techniques and procedures. ▪ Found inquiry experiences crucial for students to develop independent thinking abilities.

Before presenting each individual teacher's case, I make the succeeding assertion on teachers' understanding of confirmatory and inquiry science.

Assertion-7: Teachers hold a dualistic image of confirmatory and inquiry science experiences of students.

In the following subsections, I present each participant teacher's views on confirmatory and inquiry science.

Jennifer

Jennifer differentiated “cookbook” science experiences of students from inquiry-based ones on the basis of prescribed nature of instructions given to students in their cookbook science activities. In contrast to confirmatory nature of science activities, she argued that inquiry-oriented experiences of students involved devising their own ways for solving their questions rather than following predetermined methods given by their teachers. Jennifer expressed her understanding of cookbook and inquiry science as follows:

What is different is that one tells you exactly what to do, and typically you just collect data and do calculations with it and interpret it. That is the cookbook science. For inquiry-based science, students don't have a method given to them

so they have to figure out their method themselves. Sometimes they may have to come up with their own hypothesis or maybe their own questions. (Jennifer, Interview, September 20, 2005)

In Jennifer's argument above, open nature of methods to be decided by students emerged as the single most important factor in determining inquiry-oriented nature of classroom experiences of students. In other words, Jennifer conceptualized the flexibility given to students in determining their methods for investigating questions as the minimum condition to be met by teachers who considered to be practicing inquiry with their students. Although the nature of questions to be investigated by students appeared as one of other important characteristics of inquiry, the methods determined by students still constituted the bottom line of classroom inquiry.

Jennifer found none of the teaching strategies, namely confirmatory science and inquiry science, superior to one another. On the contrary, she considered both teaching strategies as equally important for students' learning of science because she felt that each had different strengths on their own respect. In the following interview excerpt, Jennifer discussed the essentiality of cookbook science activities in teaching students certain laboratory procedures and techniques:

I think that they are both equally important. The strength of cookbook science is that it teaches methodology that the students have to have in order to use or in order to be able to do inquiry-based science. If they don't know techniques, if they don't know how to use equipment, their ability to really do inquiry-based science is limited to very elementary levels. And they have to have done some of these techniques. (Jennifer, Interview, September 20, 2005)

In her interview response above, Jennifer introduced confirmatory science as classroom experiences of students to acquire prerequisite abilities for conducting their inquiry activities effectively. In other words, "cookbook" science activities constituted basic steps to be taken by students in order to develop certain abilities necessary for performing inquiry in their classrooms. In addition to helping students build prerequisite abilities for their classroom inquiry practices, Jennifer thought that cookbook science activities created opportunities for students to experience the application of scientific ideas in order for them to enhance their understanding of science concepts. She

continued her comments on the strengths of cookbook science as “another advantage of cookbook science is that it allows students to apply things that they learn, which comes out of the books specifically to examples to enhance it. And they can interpret or evaluate the method, and draw conclusions” (Jennifer, Interview, September 20, 2005). When it came to the strengths of inquiry science, Jennifer found classroom inquiry experiences of students crucial in promoting their thinking skills. Following interview excerpt revealed her perspective on the strengths of inquiry science:

Inquiry-based science can be something where students have to think through the techniques that they know in order to perhaps figure out a method. They have to be able to understand the natural limitations of an experiment and apply it so they have to try many more concepts into it. And it keeps the kids from being lazy mentally. (Jennifer, Interview, September 20, 2005)

Jennifer brought constructivist nature of inquiry practiced by students in their classrooms to the fore because she argued that students needed to generate their own thinking in devising their own methods rather than to accept predetermined methods without spending any thinking effort. She placed special emphasis on the strength of classroom inquiry experiences in stimulating mental engagement of students.

Patricia

Patricia argued that teachers already knew specific answers beforehand to be reached by their students in most of their classroom inquiry practices. She felt that this did not represent the true nature of inquiry in classroom. To Patricia, true practice of inquiry would only take place in a student investigation in which neither teacher nor students knew the answer beforehand for a question being inquired by students. As a natural consequence of this, both teacher and students would investigate the question at the same time to reach unknown conclusions. In the following interview response, it was possible to see Jennifer’s view of true inquiry in classroom: “If it is truly inquiry-based where the teacher doesn’t know the answer, and we are all going after it together, it is too easy for the students to develop misconceptions” (Patricia, Interview, September 13, 2005). Jennifer’s notion of true nature of classroom inquiry developed parallel to her conception of scientific inquiry practiced by scientists. Due to the fact that scientists started their scientific investigation journeys without knowing answers to their

questions, Patricia imagined the same process of scientists to be true for classroom inquiry experiences of students. In other words, the exact imitation of the activities of practicing scientists constituted the true nature of classroom inquiry. In her subconscious mind, Patricia had a tendency to associate classroom inquiry with open-ended activities. In the following interview excerpt, Patricia mentioned about the open nature of inquiry that dominated the image of classroom inquiry that she held in her subconscious mind:

When I think of inquiry, it is maybe my prejudice but when somebody mentions to me inquiry-based learning, I think of completely open-ended stuff. And I don't think that works very often. I think that children need more guidance than that. Students need more background knowledge to be able to understand what they are seeing. You can have elements of full inquiry lab but you can't have it all because the students are just as curious but they don't know how to recognize what they are seeing. (Patricia, Interview, May 12, 2005)

Patricia's association of classroom inquiry with open-ended activities in her mind might have something to do with the general portrayal of classroom inquiry as an open process in a couple of inquiry workshops for teachers to which Patricia attended. In those workshops, Patricia witnessed that the practice of inquiry in classroom was usually exemplified with unrealistic open-ended activities for actual classroom conditions. However, Patricia believed that students needed more guidance in their classroom inquiry experiences to be able to give appropriate meanings to their experiences.

Interestingly, Patricia approached to confirmatory science both with the perspectives of teachers and students. Patricia argued that confirmatory and inquiry science activities were the same thing from the perspectives of students because they had no previous experience with either one of them. Those activities could be considered as cookbook science only for teachers because teachers already knew correct answers beforehand for cookbook science experiences of students. In the following interview response, Patricia expressed her perspective on cookbook and inquiry science:

From the standpoint of students, cookbook and inquiry is the same thing because they have never seen the cookbook before. It is only cookbook for us because we know that there is an answer but for students, it is still inquiry. (Patricia, Interview, September 13, 2005)

Patricia's comments in her interview response above indicated that she based the meaning of cookbook science on answers known by students beforehand. However, she felt that since students did not know correct answers in their cookbook science experiences in advance, those activities acted as inquiry experiences for students.

For Patricia, the distinction between teaching science through cookbook science and inquiry science centered on teachers' approach to helping students solve their questions. Because teachers did not know the correct answers beforehand in true nature of inquiry, they would play the role of experienced learners to facilitate their students' problem solving process by giving helpful suggestions to them. In cookbook science, teachers would provide more concrete support to their students by directing them to the exact problem to be fixed. Following interview excerpt unveiled Patricia's notion of cookbook and inquiry science:

In inquiry-based science, the teacher doesn't know the answer so you can't give hints, even with facial expression or something. You can only give "What about this? What about that." In cookbook science, especially with the student who is struggling, it is very easy to go "No! This is the problem, right here. Go fix this." It is too easy for the teacher to point out where they need to fix something rather than the students figuring out where it is. (Patricia, Interview, September 13, 2005)

Patricia in her interview response above supported the idea that teachers knew correct answers in their teaching of science through cookbook activities in contrast to their practices of inquiry in classroom. She discussed that unknown answers by teachers put them automatically into a position in which they investigated the question together with their students. In the following interview excerpt, Patricia found practicing inquiry more challenging for teachers due to the fact that teachers felt less comfortable in their teaching of science without knowing the correct answers beforehand:

Cookbook science is safer for the teacher. There are some teachers who just won't teach straight inquiry because they don't want to look foolish in front of the students. They don't want the students to see that they don't know the answer.

And that is very difficult. (Patricia, Interview, September 13, 2005)

As it was noticeable in Patricia's arguments above, she identified unknown answers by teachers and students as the key element of true nature of inquiry practiced in classroom.

Patricia thought that both "cookbook" and inquiry science had their special places in classroom because students would learn something different from each respective teaching strategy. She argued that cookbook science was more effective in teaching scientific ideas to students. And she found inquiry experiences of students more powerful in learning scientists' ways of thinking in their efforts for generating scientific knowledge. Following interview excerpt displayed Patricia's perspective on the strengths of cookbook and inquiry science:

I think they are both important. Cookbook science will get you to a principle faster and easier. So students can see a principle if it turns out right, if they do the experiment right. So they can understand why a principle or a law is the way it is. Inquiry is better for understanding how to think like scientists. (Patricia, Interview, September 13, 2005)

Based on Patricia's argument in the interview response above, we could say that she conceptualized classroom inquiry as the major teaching strategy for engaging students into the similar thinking processes of scientists. Patricia did not consider practicing inquiry in classroom as an effective way of teaching science concepts to students.

Martha

Martha distinguished inquiry science from confirmatory science on the basis of the nature of the activities to present choices to students in their efforts to solve questions. In contrast to "cookbook" science, Martha found inquiry-based learning of science as more student-centered due to students having higher degrees of freedom in inquiry activities to make their own decisions. Regarding student choices in inquiry science, Martha told:

I think inquiry-based science is more student-driven. I try to give my students more chances to make their choices even when I do give them the question of work and writing procedures. That is a painful process because they really are not strong with that. Cookbook science just has it all laid out form. And I think a combination of both is good. (Martha, Interview, September 6, 2005)

In her argument above, Martha underlined the inherent place of student autonomy in inquiry-oriented science activities. Even if students did not have a chance to determine their own questions, Martha expected them to make their own decisions in choosing their specific methods to investigate given questions. In comparison to some choices made by students in their classroom inquiry experiences, she discussed that cookbook science activities clearly defined every step to be taken by students without allowing them to spend some effort to decide on their ways for solving questions.

Martha thought that both confirmatory and inquiry science activities included a discussion part for students on their respective learning experiences at the end of their investigation experiences. However, she argued that the questions to initiate student investigations in classroom inquiry were not the norm for cookbook type of science activities. Martha articulated her perception of inquiry and cookbook science in the following interview response:

You see I do that part [discussion] both for the cookbook science and the inquiry-based science. There is always going to be that component. Well, we are always going to talk about what we learned and share what we found out. As far as it being inquiry-based, I think you have to start with a question because that is how the whole method [scientific method] starts. So if you don't start off with a question, then that is hard. I have taken cookbook science type of labs and turned them into a question so that there is a question there and the students are trying to find an answer. (Martha, Interview, September 6, 2005)

In Martha's comments in the interview response above, she was very definitive about the role of questions to be investigated by students in their science learning experiences. She avoided categorizing activities that missed a specific question for students to investigate as an inquiry experience.

Martha found both cookbook and inquiry science experiences necessary for students' learning of science. However, she attributed different strengths to each respective teaching strategy. She considered cookbook science as a more appropriate teaching strategy when her instructional goal involved teaching a specific science concept to her students. Inquiry science came to the scene when her goal became engaging her students into the process of scientific method in investigating scientific questions. Martha put her perspective on the strengths of each teaching strategy into words as follows:

I think students can learn things from both teaching strategy. If you use the combination of both, I think that is ideal. I think the cookbook strategy is when you are looking for a specific concept, your students are not going to be able to generate a question, or they are not going to be able to generate the procedure themselves. You do cookbook type of science when you want to show them something that you already know what the answer is, you know what it is. The inquiry-based science is definitely when you want to focus on teaching that method [scientific method] and giving them some choices whether it is a very small choice or the big one. (Martha, Interview, September 6, 2005)

Like Patricia, Martha pronounced that teachers already knew the correct answers to be reached by students in their cookbook science experiences. However, teachers did not necessarily know the solutions to be generated by students in their scientific investigations. This implied that inquiry experiences of students had the potential to yield variety of answers depending on the specific methods decided by students to follow in solving their questions. On the other hand, cookbook science activities led all students to a certain answer predetermined by teachers.

Mary

Mary built the distinction of confirmatory and inquiry science on the nature of the methods to be employed by students in solving their questions. In other words, whether students were given or not the specific methods to follow in their activities emerged as one of the most important determinant factors to judge the inquiry nature of classroom experiences of students. In the following interview excerpt, Mary identified student

investigations that failed to give any chances to students in choosing their own ways for solving questions as “cookbook” science:

In cookbook science, you are basically telling the kids what you want them to do. But in inquiry-based science, the students are making those decisions. So you give them a question and the kids come up with a way to try to answer it, or to test their hypothesis, or whatever it is they are doing. (Mary, Interview, September 22, 2005)

In Mary’s perspective on classroom inquiry, students were given a question to investigate by their teachers, yet specific methods to inquire the question were solely decided by students.

Like Martha, Mary considered the presence of an investigable question at the beginning of student investigations as an important sign for deciding the inquiry orientation of the experiences of students. In one of my visits to Mary’s classroom, she conducted a microscope activity with her students. In this activity, she asked her students to investigate different type of cells under the microscope. When I asked her later about this microscope activity, she categorized it as a hands-on activity rather than an inquiry-based one because she thought that the activity was missing a specific question to be investigated by students. Mary responded my question as “I think I would call that [microscope activity] more hands-on but not really inquiry. I didn’t really give them [students] a question and tell them to solve it” (Mary, Interview, May 26, 2005). As Mary’s interview response indicated, she visualized inquiry as a student investigation process starting with a question.

Mary considered both “cookbook” and inquiry science as valuable experiences for students because she thought that each teaching strategy had something different to offer to students. In the following interview extract, she introduced cookbook science as a good strategy for teaching necessary procedures and techniques to students to be used in their laboratory activities:

If it is cookbook science, you are giving your students an activity to do. And I don’t want to say that there is no value in that, there is! Because you teach procedures, techniques, and lots of things but that is not inquiry-based science. (Mary, Interview, September 22, 2005)

Mary gave major credit to classroom inquiry experiences of students in helping students develop independent thinking skills. She elaborated her point of view regarding the strength of inquiry science as follows:

I think kids who do inquiry-based science activities get a chance to think on their feet. You know, they get a chance to see what then, and apply their knowledge to something. If you have a cookbook kind of thing, they might be learning how to use tools, follow procedures, and things like that but they miss that thinking outside the box kind of thing or how can I make this work in a different way.

(Mary, Interview, September 22, 2005)

In the interview excerpt above, Mary stressed the constructivist nature of students' classroom inquiry experiences because students needed to be active thinkers in the process of developing their investigations.

Comparative Overview

Every single day, science teachers in schools all over the nation enact variety of science activities with their students. Those various activities display a broad range of characteristics. It is possible to represent those activities on a continuum from confirmatory science to open inquiry (Colburn, 2000; Llewellyn, 2004; NWREL, 1997; Wenning, 2005). In other words, the two extreme ends of the inquiry continuum scale are occupied by confirmatory science and open inquiry experiences of students. This representation of inquiry continuum scale is commonly used by science education community. In this model of inquiry continuum scale, structured inquiry acts as the bridge in transitioning from confirmatory science to guided inquiry teaching approach. In structured inquiry approach, students are given procedures to be employed in their investigations but expected to reach their own conclusions (Llewellyn, 2002; Wenning, 2005). However, structured inquiry that bridges confirmatory science to guided inquiry has foggy borders, which sometimes make it difficult to distinguish from cookbook experiences of students. That is primarily because students are provided the methods to use in both types of activities. Colburn (2000) found structured inquiry investigations of students "similar to those known as cookbook activities, although a cookbook activity generally include...[d] more direction than a structured inquiry activity about what students are to observe and which data they are to collect" (p. 42). In Colburn's

description of structured inquiry, relatively lower levels of directions given to students in investigating questions determined inquiry nature of activities. NRC (2000) suggested teachers to make confirmatory science activities more compatible with inquiry science by “resequencing them to come before the readings or lectures” (p.138). NRC (2000) promoted changing the sequence of confirmatory science activities in order to allow students to “explore in a concrete way before learning the concepts and terms” (p. 138). As can be seen from those examples, the distinctions between confirmatory science and structured inquiry are not easily distinguishable. Teachers in the study developed a dualistic understanding of confirmatory and inquiry science. In comparison to the continuum model, the transition from cookbook science to inquiry science in teachers’ dualistic model occurred in a sharper manner. In other words, teachers’ dualistic conception of inquiry created a broader gap between cookbook and inquiry science. It appeared that structured inquiry was dismissed from teachers’ notions of inquiry in classroom. This resulted in the emergence of a dualistic representation of student investigations conducted through employing methods given by teachers or derived by students. In those teachers’ notions of classroom inquiry, methods to be decided by students in their investigations emerged as the minimum requirement to be met by teachers in their enactment of inquiry. This meant that teachers categorized classroom activities in which students were given methods to follow in their investigations automatically as cookbook science. However, this approach of teachers excluded structured inquiry completely from the scene. In its most widely accepted definition in science education community, structured inquiry is regarded as classroom investigations of students to propose scientific explanations to questions by following given methods. When structured inquiry as a medium between confirmatory science and guided inquiry is not recognized by teachers, the following duality arises: on the one hand, classroom investigations performed by students through following given methods, and on the other hand, classroom investigations conducted by students through using their own methods.

Other than open nature of methods, teachers considered questions to initiate student investigations as an important indicator of inquiry nature of classroom experiences of students. Both Martha and Mary placed questions at the heart of

classroom inquiry process. Rather than the origin of the questions, they stressed the importance of the presence of questions, whether proposed by teachers or posed by students, to be explored by students in their classroom investigations. They identified questions as the missing component from cookbook science activities, which kept them from pronouncing those activities as inquiry science. Interestingly, Patricia evaluated cookbook science activities both in reference to teachers and students. From the standpoint of students, she argued that cookbook and inquiry science are not regarded as different experiences from one another because students had no prior experience with either one of them. So students were unaware of correct answers beforehand in each case of their respective investigation experiences. However, those activities acted as cookbook experience for teachers because teachers already knew the correct answers beforehand in their students' cookbook science activities. Patricia and Martha argued that teachers did not know correct answers to be reached by their students beforehand in a true nature of classroom inquiry.

Teachers in the study found both "cookbook" and inquiry science equally important for their students' learning of science. Therefore, they believed the need for keeping a good balance on their teaching practices driven by "cookbook" and inquiry science. Jennifer and Mary stressed the important place of cookbook science activities for students' learning of essential laboratory procedures and techniques. In that sense, they found cookbook science experiences of students as preliminary steps needed to be taken by students in order to develop necessary skills to conduct their science investigations. Patricia and Martha placed more emphasis on students' learning of science concepts and experiencing of the applications of scientific ideas in their cookbook science experiences. Teachers valued inquiry experiences of students due to their promotion of students' thinking skills. Jennifer highlighted active thinking maintained by students in their classroom inquiry experiences. Patricia saw inquiry experiences of students as the opportunities for experiencing the thinking processes of scientists. Mary considered engagement of students into inquiry activities as vital experiences for developing independent thinking abilities. Martha characterized inquiry practices of students as suitable platforms for learning to perform the scientific method to investigate their questions.

In order to use inquiry effectively with their students, teachers need to develop a better understanding of the different forms of inquiry. A dualistic understanding of confirmatory and inquiry science might put classroom inquiry into a position in their eyes as an ineffective strategy for teaching science concepts. As discussed in previous section, participant teachers had a tendency to associate classroom inquiry with high levels of student autonomy. That is one of the misconceptions shared by many teachers. Many science teachers consider open inquiry as the best representative of classroom inquiry because they feel that it reflects the actual works of practicing scientists more accurately (Biological Sciences Curriculum Study, 2005). However, this perception of inquiry held by the teachers might discourage them to use it in a wider sense in their classrooms. Brown, Abell, Demir and Schmidt (2006) noted, "The full and open view of inquiry-based instruction is an incomplete view that constrains college science faculty members from considering inquiry-based approaches in their teaching" (p.799). This implies the critical importance of teachers' understanding of the different forms of classroom inquiry. Teachers in this study found confirmatory science experiences of students more powerful in their learning of scientific principles. Without developing a proper understanding of structured inquiry, teachers might not consider using inquiry in teaching science concepts to their students.

CHAPTER 7

INTENTIONS AND CHALLENGES OF NBCSTs WITH PRACTICING INQUIRY

Introduction

In previous chapter of the dissertation study, I presented NBCSTs' conceptions of classroom inquiry. In this chapter of the dissertation, I exhibit participant teachers' intentions and challenges with using inquiry in their classrooms.

Educational Goals with Practicing Inquiry

Schooling is a purposeful act of educating students. Like any other purposeful institutions, school system is driven by educational goals to be achieved by students in their classrooms. However, educational goals for students are not stable but rather dynamic entities. That is because they display changes from one time period to the other. Periodically, fresh waves of reform movements carry new goals to the shore of education land. In the early 80s, those waves arrived to science education territory. With the emergence of new reform efforts, science education community redefined the goals to be accomplished by students in their science classes. In the reform documents, scientific literacy was promoted as "the overarching goal of science education reform" (Eisenhart, Finkel, & Marion, 1996, p. 262). Scientific literacy is an attractive yet a challenging goal for science education community. It is attractive because it is presented as a successful formula for transforming the citizens of a democratic society into highly conscious individuals, who can give more informed decisions on critical issues for the future of society, in order to better the functioning of the democratic system. It is challenging as well because it is a vague term with no consensus reached on its ingredients and feasibility by science education community. This makes it unreachable shiny star in the universe of science education reform, at least for now.

However, the light of the shiny star enlightens the general directions of contemporary science education reform movements.

Science is not only a body of knowledge to be learned by students in their classes but also a systematic process of inquiry for learning about the natural world (Wee, Shepardson, Fast, & Harbor, 2007). Therefore, the educational goals proposed in science education reform documents to be accomplished by students embrace both the content and the processes of science. Hodson (1998) pronounced the following three actions of students in their science classes as the major elements of science education: learning science, learning about science, and doing science. Learning science refers to developing a knowledge base of important scientific ideas. Learning about science stands for gaining an understanding of nature and historical development of science. Doing science represents obtaining the abilities to conduct scientific investigations. Inquiry performed by students in their science classes plays one of the key roles in achieving those major elements of science education. NRC (1996) encouraged science teachers to use more inquiry teaching strategies in their everyday classroom practices. Due to the fact that teachers' intentions are the major driving force of their classroom actions, they need to develop an appropriate understanding of educational goals promoted by contemporary science education standards.

In previous chapter, I presented participant teachers' conceptions of classroom inquiry. In this section of this chapter, I do the same with their goals in their enactments of inquiry in their science classes. Understanding of teachers' intentions in practicing inquiry with their students is as much necessary as their notions of classroom inquiry because the goals adopted by teachers in their inquiry teaching practices unveil their general approaches to science education reform ideas. Due to the fact that teachers are the sole stakeholder for the administration of reform ideas at the classroom level (Johnson, 2007), the compatibility of teachers' intentions with the goals supported by science education reform documents are vital for the future success of science education reform ideas. And especially if those teachers are NBCSTs like the ones in this study, articulating their intentions in practicing inquiry with their students is more important because they have the potential to influence inexperienced teachers in their schools (NBPTS, 2006). Table-14 below summarizes teachers' goals with practicing

inquiry with their students and their understanding of scientific literacy as the ultimate goal of science education.

Table 14 At First Glance: Intentions with Inquiry and Description of Scientific Literacy		
	Intentions with Inquiry	Scientific Literacy
Jennifer	- Intended to improve the thinking abilities of students by inquiry activities. - Introduced students to the thinking processes and activities of scientists. - Avoided teaching science concepts with inquiry.	- Having a solid foundation of scientific facts and knowing the applications of scientific knowledge. - Giving students a strong science education with the knowledge of scientific facts was required for scientific literacy.
Patricia	- Saw inquiry as a good platform for experiencing the scientific way of thinking. - Not necessarily thought that this form of thinking fitted to every student equally well. - Did not consider inquiry as an effective way of teaching scientific principles.	- Knowing fundamental scientific principles and approaching to events with evidentiary perspective. - In depth learning of scientific topics was needed for scientific literacy.
Martha	- Valued inquiry for promoting higher order thinking and questioning skills of students. - Used inquiry for introducing students to scientific investigation process, but not for teaching science concepts. - Wanted students to realize that science could be done in their classrooms.	- Having the knowledge of basic scientific principles and an understanding of scientific process. - Exposing students to as much science as around them was needed to educate them as scientifically literate individuals.
Mary	- Engaged students in the practice of science by inquiry activities. - Promoted inquiry as a medium for learning the application of scientific knowledge. - Expected from students to learn science content in their inquiry experiences.	- Having a strong knowledge base of scientific concepts and critical thinking capabilities. - Teaching popular science topics to students was needed for helping them become scientifically literate individuals.

Before presenting participant teachers' goals in their inquiry practices, I make the following assertion.

Assertion-8: There is a tension between teachers' understanding of educating scientifically literate students and embracing more inquiry teaching strategies.

In the following subsection of the chapter, I present participant teachers' intentions with their inquiry teaching practices in their classrooms. The next subsection displays those teachers' perspectives on scientific literacy. The section ends with the comparison of teachers' views.

Teachers' Intentions with Practicing Inquiry

Participant teachers demonstrated the capabilities of engaging their students into inquiry experiences in NBC portfolios. However, having the capabilities of enacting inquiry does not automatically mean that teachers employ inquiry teaching strategies regularly in their science teaching practices. Then, the following question becomes the central attraction point of this subsection: What purposes motivate those accomplished science teachers to use their inquiry capabilities with their students? This question helps uncovering the intentions of teachers in their practices of inquiry. The succeeding sub-assertion displays teachers' general intentions to accomplish with their students in their inquiry practices.

Sub-Assertion-8a: Teachers employ inquiry for introducing students to scientific way of thinking but not for teaching science concepts.

Starting with Jennifer, I present participant teachers' intentions in practicing inquiry with their students in the following paragraphs.

Jennifer

Jennifer saw classroom inquiry as a powerful way for enhancing the thinking capabilities of students because it encouraged students to come up with their own methods to solve their questions rather than following predetermined procedures. She stated:

I know that there is more emphasis on inquiry-based teaching because people want kids to think more and this is a good way to help them think. And actually the brightest kids really enjoy it. They want some freedom to do what they would like to do. (Jennifer, Interview, September 20, 2005)

Based on Jennifer's preceding interview response, it would be possible to state that generating student thinking was one of her intentions with practicing inquiry.

Other than promoting student thinking, Jennifer considered classroom inquiry as a good platform for experiencing the reasoning processes of scientists. She expressed her intention in the following NBC portfolio reflection:

I didn't want to simply tell them what to do, but I wanted...[students] to model the thinking processes of scientists in critically analyzing procedures, which is an important part of student inquiry. (Jennifer, Entry 2, NBC portfolio)

In addition to gaining an understanding of the reasoning patterns of scientists, Jennifer wanted her students to experience that scientists might approach scientific questions with different methods. She used cooking analogy in order to exemplify this:

One of my goals is for my students to understand that there is not one way that science is done. To me, it is like cooking. When people go into kitchen and get pots and pans out, not everybody cooks the same. And people in the world use methods that they are very different but they still come up with good food. In the same way with science, there might be a typical way to follow, but it is not like this is the only method and this is the right method. I think inquiry-based science sets students free to think of, and not being afraid to try new things with the science. (Jennifer, Interview, September 20, 2005)

Reaching solutions by using different methods in their inquiry activities promoted students' understanding of the different ways of solving scientifically-oriented questions.

Although Jennifer acknowledged inquiry as a good teaching strategy for introducing students to the thinking processes and activities of practicing scientists, same thing was not true for scientific concepts. She avoided using inquiry to teach science concepts to her students: "I very often have inquiry be an experimental portion. The rest of it, I don't really make learning science concepts as an inquiry" (Jennifer, Interview, May 12, 2005). Her reluctance for employing inquiry strategies for teaching science concepts resulted partly from time limitations. She explained her view as follows:

When you teach content, inquiry takes a long time. You can't say "Ok! Fifteen minutes of inquiry today" but you can do that with content. You can say "We are going to learn this concept today", teach it, do an activity, do a lab on it, and you are done. But with inquiry, you have to allow kids to find their own pace somewhat. If you have certain things that you want to accomplish within a year, it limits how much inquiry you can do. (Jennifer, Interview, September 20, 2005)

Inquiry involved giving autonomy to students in their classroom investigations. However, Jennifer saw the autonomy given to students in their inquiry activities as a time consuming process. Following interview excerpt indicated that she found starting a new topic with inquiry activities inefficient for learning science concepts:

I don't think it is good to give inquiry activities to introduce a concept. That is why a lot of my concrete things are demonstrations, where I show it, we explain it, then we apply it. To me, it is the blind leading the blind if it is just totally inquiry-based and you have to have some foundation. (Jennifer, Interview, September 20, 2005)

In her interview response above, Jennifer was not in favor of using inquiry teaching strategies to introduce her students to a new science concept.

Patricia

Patricia supported using inquiry teaching strategies because she thought that inquiry promoted student thinking:

I try to teach my students to think. I want them to think in a manner that they can support their conclusions. That is what I want them to do. I want to teach them to think. That is why I do inquiry. I want them to think. (Patricia, Interview, September 13, 2005)

As can be seen from Patricia's expressions in her interview excerpt, she thought that inquiry activated the mental capabilities of students. She also underlined the importance of students being able to support their thoughts with the help of actual evidence. In the following excerpt from her NBC portfolio, this was more noticeable:

I wanted students to be able to concentrate on the actual experimentation and data collected. I wanted their responses to be based on actual data not just on what they believed to be true or assumed to be true based on prior knowledge. To accomplish this goal, I use questioning techniques to constantly focus students' attention and thoughts on being able to support their results based on their data. (Patricia, Entry 3, NBC portfolio)

Patricia saw classroom inquiry as crucial experiences for students to learn the scientific way of thinking. However, she was doubtful whether such mode of thinking could fit

every student. She articulated her views about the exclusive nature of the scientific way of thinking as follows:

You can expose your students to the scientific method and the scientific way of thinking in inquiry. That does not mean that they are going to get it because like some people are right-handed and some people are left-handed, that modality of thinking will not fit and they are just different people. Should we require every child to be able to do that? Probably not. (Patricia, Interview, September 13, 2005)

In her preceding interview response, Patricia argued that scientific way of thinking suited children who brought natural abilities from their birth. Therefore, she questioned the idea of exposing every child to this mode of thinking.

Like Jennifer, Patricia did not find inquiry-based teaching of science as an efficient way of teaching scientific principles. She felt that recent trend towards standardized testing in the US education system would keep teachers from using more inquiry strategies in their classrooms:

The most efficient way to get across scientific facts is not inquiry-based teaching. That is why I am pretty concerned about No Child Left Behind and yearly adequate growth measurements can result in funding for inquiry science to go down the tubes or at least to be severely cut back because it is not the most efficient way to get material across the student. The goal now, the bottom line goal is to pass the test. (Patricia, Interview, September 13, 2005)

Likewise, Patricia felt that learning basic scientific principles in inquiry science activities of students would take extended time. That was why Patricia thought that it was better to teach basic information needed to be known through didactic teaching strategies before engaging in inquiry activities. She presented her thoughts as follows:

You can't let somebody explore basic information without it taking way too long in lots of cases. A lot of times, you have to tell it to them anything in lecture kind of format, and then have them experiment with it so they can see how you said applied to something else. (Patricia, Interview, May 12, 2005)

Based on Patricia's statements in her interview response above, we could infer that she preferred to use inquiry with her students in order to show them the application of

scientific ideas rather than learning scientific concepts directly from their inquiry experiences.

Martha

For Martha, helping her students develop good thinking skills in their science classes constituted an important goal to achieve with inquiry-based teaching of science. Regarding the role of inquiry, Martha stated that “I think the students have to really be working through it in their brains. They have to be thinking through whatever topic they are working on if they are doing inquiry” (Martha, Interview, May 26, 2005). Martha conceptualized inquiry in classroom as a good medium through which her students developed higher order thinking skills. She noted:

Inquiry-based science is a way of teaching that engages the students and gets them to problem solve and use the higher order thinking skills that they need to be using. And it is hard at our school because you see so many holes in students’ learning and you think how I am going to get them up here when they are way down here. Getting them up to that level is tough. I think what is good with inquiry-based learning is that they have to really think, problem solve, and synthesize. They have to use those higher order thinking skills. (Martha, Interview, May 26, 2005)

As Martha specified in her preceding interview response, she emphasized the importance of inquiry in promoting the higher order thinking skills. Solving questions in inquiry activities required students to increase their mental activities. Martha saw inquiry as a good platform for introducing students to the scientific investigation process. Students followed the scientific method in their classroom inquiry experiences in order to produce solutions to their problems. In response to my interview question regarding her goals with her teaching science through inquiry, she said, “My goal with doing inquiry is probably more process than science content or anything. The process of using the scientific method, problem solving process basically” (Martha, Interview, September 6, 2005). As Martha stated in her interview response, she used inquiry for giving experiences to her students with scientific inquiry process. However, she did not prefer inquiry in her teaching of science content.

Martha placed special emphasis on questions in the process of classroom inquiry because she felt that students needed to have a good question in order to start their investigations. Therefore, Martha gave special emphasis on enhancing her students' questioning skills. Engaging her students into inquiry experiences created opportunities to do that. In order to exemplify how she stimulated her students' curiosity and encouraged them to ask investigable questions, she provided the following mockingbird scenario with her students:

I do an example with the kids. I put a picture of mockingbird on the projector. I asked students "Do you know mockingbird? It is a kind of grey brown bird. You see them all around. They are usually on the grass. They do some odd behaviors. One of the things that they do is called wing flashing. They do this odd behavior with their wings. And I see that more than one of these birds do this behavior. So what could that be? Why is he doing that? There must be some purpose behind it. He is not just doing that for no reason. He is not going to waste his energy doing that." So then I started getting come up with hypothesis. I tried to get them understand that you see things and you automatically ask questions about it in your mind. (Martha, Interview, September 6, 2005)

In mockingbird example, Martha indicated her intentions for improving the questioning abilities of her students. She expected students to ask curious questions about the objects on their surrounding.

By giving opportunities to her students to conduct their investigations in their science classes, Martha wanted to denote them that science was not the property of a chosen elite group. Martha verbalized her objective of allowing her students to practice science in classroom conditions as follows:

I want my students understand that science can be done to anyone because everyone has access to information. It is not just male-female or a specific race but everyone has access to the information if they can take some initiative. And there are a lot of different places that science is done. (Martha, Interview, September 6, 2005)

In her interview excerpt, Martha desired her students to experience that the practice of science could be done even in their science classes. Classroom inquiry experiences of students exemplified the practice of science in the classroom.

Mary

Mary promoted inquiry-based teaching of science as a good way of helping her students apply what they learned in their science classes. Mary emphasized the importance of students having the abilities to use the science knowledge in their daily lives in her following statement: “You can know a lot of science content but to be able to apply is the key” (Mary, Interview, May 5, 2005). By applying their knowledge of science to concrete activities in classroom inquiry experiences, she thought that her students would make the relevant connections with the real life. Another intention of Mary with inquiry-based teaching of science was to uncover some of the misconceptions that her students brought into the classroom together with them. She phrased her intentions with practicing inquiry as follows:

There are several. One would be hopefully to apply some things that we have learned already. Another goal would be to find misconceptions as students are doing things. You know, we all come with the misconceptions about things and catching those misconceptions is important. If they are doing inquiry-based [activities], you can usually catch them because kids are talking to each other and they are communicating with you. Hopefully they learn some content if they are answering a question. (Mary, Interview, September 22, 2005)

Due to high levels of interactions taking place between students and teacher in inquiry-oriented classroom environment, Martha felt that it was easier to detect any possible misconceptions that students had about a science concept. Unlike other three teachers in the study who did not specify learning science concepts among their goals to achieve with their teaching of science through inquiry, Mary expected her students to develop an understanding of science concepts in their classroom inquiry experiences.

Another important intention of Martha with practicing inquiry was to introduce her students to the process of conducting scientific investigations. In the following excerpt from her NBC portfolios, she expected her students to develop the necessary skills to be able to perform a scientific investigation from beginning to the end:

The students have a pretty sound understanding of how to navigate effectively through a scientific investigation but they are not as thorough as I feel they should be before they go off to high school. I wanted the students to demonstrate one final time what the proper and efficient procedures are for conducting a successful scientific investigation from the beginning to the end. (Mary, Entry 3, NBC portfolio)

Mary conceptualized inquiry as a good opportunity for students to learn conducting scientific investigations.

Summary

Teachers in the study considered using inquiry teaching strategies exclusively for engaging students into the thinking processes and the actions of practicing scientists. When it came to teaching science concepts, inquiry was regarded as the last resort. In other words, teachers avoided teaching scientific principles with inquiry approach because they felt that inquiry promised little for students' learning of science content. Such attitude of teachers can be displayed as one of the major barriers to be overcome by science education community in order for inquiry to be acknowledged as the central strategy of teaching science by science teachers. As can be seen from following statement, NRC (1996) did not limit the function of inquiry in classroom with students' experiences of scientific process: "Inquiry...refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). Developing knowledge of science concepts was also promoted as one of the major outcomes of inquiry-based teaching of science.

After the first interviews, I determined seven key terms pronounced by teachers in their definition of classroom inquiry. As shown in the bar graph below, I asked teachers to distribute the total of 20 points among those seven key terms by assigning more points to the terms of which they found more significant in representing the true nature of inquiry-based science. On the basis of general pattern in the bar graph below, it was noticeable that teachers placed the highest points to the term "thinking" whereas the term "solving" was given the lowest points. Based on that pattern, we could suggest that teachers in the study highly valued thinking of their students in their classroom

inquiry experiences. And, their assignment of the lowest points to the term “solving” can be interpreted as an indication of relatively less importance of reaching correct solutions by students in their scientific investigations. Of course, other than this noticeable pattern in teachers’ responses, each individual teacher placed more emphasis on different aspects of classroom inquiry.

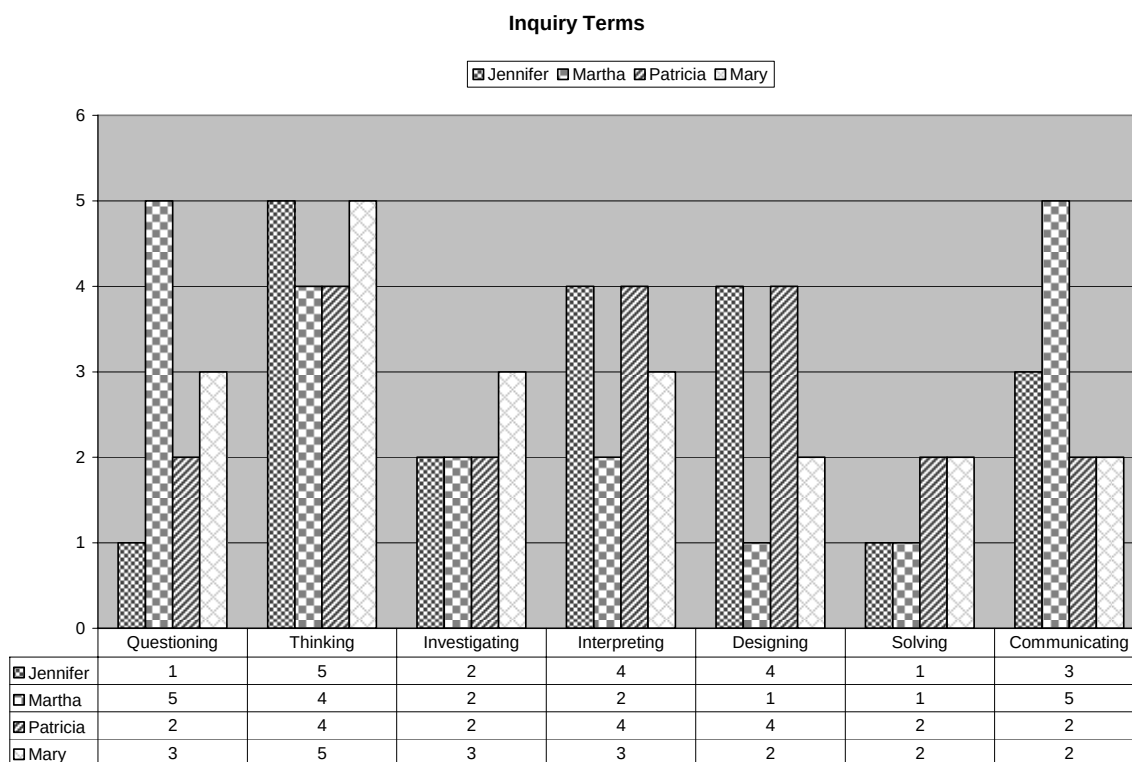


Figure 6 Representative Terms of Classroom Inquiry

After presenting those teachers’ intentions with practicing inquiry, I will discuss those teachers’ approach to the concept of scientific literacy in the following subsection. This is important to inquire because educating scientifically literate students is the biggest goal of science education community.

Educating Scientifically Literate Students

Scientific literacy is one of the most prominent terms in contemporary science education reform documents (Laugksch, 2000; Parsons, Matson, & Quintanar, 2002). It is because the term scientific literacy finds itself a secure place in all of the latest science education reform movements. Science education reform documents promote scientific literacy as the ultimate goal of science education to be achieved with students

(Eisenhart, Finkel & Marion, 1996). However, this goal exhibits major difficulties to be overcome by science education community. One of the primary challenges arises from its definition because scientific literacy is an ambiguous term. The ambiguity of the term results mainly from nonexistence of a consensus on its meaning by the members of science education community (Deboer, 2000; Parsons, Matson, & Quintanar, 2002). In other words, the qualifications of scientifically literate people and the specific ways for educating individuals with those qualifications are still open to debate in science education community. Despite the ambiguity of the term scientific literacy, there is no doubt that it is one of the central dynamics of contemporary science education reform efforts. Likewise, NBPTS acknowledges the important place of scientific literacy in the outcomes of students' education in science. In its advanced teaching standards for Early Adolescence Science Teachers, NBPTS (2003c) noted, "Accomplished science educators' primary goal is to develop scientifically literate students by teaching them to think like scientists, both in science class and in their everyday lives" (p. 1).

NBCSTs in the study pronounced scientific literacy as one of the goals to achieve with their students. Teachers' recognition of this important goal of science education indicated their awareness of the broad goals adopted by science education community. However, this does not end the debate but rather creates new questions like the following ones: What do those accomplished science teachers mean by scientific literacy? How do their intentions with inquiry teaching strategies relate to their understanding of scientific literacy? In this subsection of the chapter, I present teachers' views about scientific literacy. However, providing an in-depth account of teachers' scientific literacy conceptions is neither the focus nor the purpose of this dissertation study. Scientific literacy in this sub-section of the chapter represents the ultimate goal of science education reform efforts and discussed within the context of teachers' intentions with inquiry teaching practices. And at any time, a discussion of goals in science education brings scientific literacy naturally to the surface. Before starting the presentation of teachers' conception of scientific literacy, I make the following sub-assertion. Although this sub-assertion stands independently, it is also a sub-component of Assertion-5.

Sub-Assertion-8b: The nature of scientific literacy revealed by teachers is more content-driven than process-oriented.

Following is the views of teachers on scientific literacy. Jennifer comes first in the order of my presentation of teachers' perspectives.

Jennifer

Having a strong basis on scientific facts emerged as the primary element of scientific literacy from Jennifer's description of a scientifically literate person. Jennifer articulated her visualization of a scientifically literate person as follows:

They [scientifically literate people] are solidly grounded in known scientific concepts. To be literate, I think they need to be aware of applications in the real world. They are open-minded in the sense that they understand that there is not always one way of explaining things. (Jennifer, Interview, September 20, 2005)

Jennifer not only expected from a scientifically literate person to possess sound foundation of scientific principles but also be aware of the real life applications of those scientific principles. She finally pronounced open-mindedness as another important component of scientific literacy. She used the term open-mindedness with a meaning that scientifically literate people would not accept one explanation blindly but instead take into account the possibility of the existence of alternative explanations to the events.

For educating scientifically literate students, Jennifer thought that students needed to be given a quality science education with a limited exposure to classroom inquiry experiences in order for them to learn the essential scientific facts, which constituted the backbone of the scientific literacy. In the following interview excerpt, she verbalized her perspective of educating scientifically literate students:

You need to give students a real solid science education that you don't just do so much inquiry that they don't learn any scientific facts. They have to get that solid science foundation. Otherwise, they don't know facts enough. And I know facts are almost the word that is not really acceptable but facts, or ideas, or theories, or concepts, whatever they need to know about science. They have to have something to base it on. (Jennifer, Interview, September 20, 2005)

When it came to giving her students experiences about real life applications of science, Jennifer thought that inviting guest speakers to talk about current issues in science and reading interesting articles in the classroom about recent scientific research efforts would be practical ways to allow her students to make the necessary connections between what they learned in their science classes and what scientists were currently studying on. She put her insights about teaching her students the real life aspects of science into words in the following comment: “I think how we can equip our students to know more about the real world is that you could have guest speakers, you could have brought up topics of interests for discussion in the classroom” (Jennifer, Interview, September 20, 2005).

Patricia

Patricia identified a scientifically literate person with two major characteristics: having a basic understanding of scientific principles and approaching events with an evidentiary perspective. Patricia included scientific literacy as an important element to achieve with her students in their science classes. In her following remarks, she tended to associate scientific literacy with knowing fundamental scientific facts:

They [students] need to learn to think and evaluate evidence in order not to take everything given to them. Now on top of that, they need to be scientifically literate. They need to know basic scientific principles like if I drop something on the world with mass, it is going to fall. That magic is science unexplained.

(Patricia, Interview, May 12, 2005)

Patricia thought that scientifically literate people needed to know basic science principles in order to be able to make sense of scientific writings. She expressed her view in the following interview response:

In order to be a scientifically literate person, there are some basic things in science that you have to know in order to understand what you are reading. By the same purpose, a person can't do algebra until s/he can add and subtract. You have to understand what a number is before you can do mathematics. Same is true for science too. (Patricia, Interview, September 19, 2005)

As it was noticeable from Patricia's statements in her preceding interview excerpt, knowing basic science principle played a crucial role in Patricia's understanding of scientific literacy.

Other than being knowledgeable about basic science principles, Patricia also thought that scientifically literate people were expected to build their decision mechanism on evidences. She expressed her views about scientific literacy as follows:

A scientifically literate person is a person who looks at problems from a logical, evidentiary perspective. You look at the evidence and you look at what is said. And sometimes it is hard to do that because in the real world, sometimes it is real hard to get the real evidence. And if they hold an opinion and other evidence comes up, they are not married to their opinion. They are willing to change it if other evidences come up. That is what I think the scientifically literate person is. You look at things logically, realistically, and with supporting evidence not because somebody said so. (Patricia, Interview, September 19, 2005)

Patricia thought that posing her students "why" questions consistently in order to let them present their evidences for their scientific thoughts would help students consider approaching the issues with evidential perspective.

To Patricia, educating scientifically literate students involved providing opportunities to them for developing in-depth understanding of scientific concepts. She provided her prescription for educating scientifically literate students as follows:

Just do a lot of science teaching. You have to teach a lot of subject or better maybe not so many subjects but they [students] take the subjects that you do teach in greater depth. Don't just hit the highlights. When a child gets hold of a concept, they want to know more about the concept. They don't want to know the top of this and the top of this and the top of that. They do want to know more than that. Once you get interested in the subject, you want to know all various aspects that you can handle about that subject. That is the teacher's job to know how much the child can intellectually handle. Give them as much as you can with the best demonstrations or laboratory experiences. You go with videos, you go with lecture, you go with drawing, you go with whatever they will get it. And let the child go as far as s/he can go. (Patricia, Interview, May 12, 2005)

Patricia recognized the importance of developing a deeper understanding of science concepts to become a scientifically literate person. A careful examination of Patricia's view of educating scientifically literate students would yield that she brought the content understanding of science to the fore.

Martha

Martha built her description of scientific literacy around two major components: knowing of science basics and understanding of scientific process. She noted, "They [scientifically literate people] should have some kind of knowledge of basics, I call them just the basics and the ability to follow the process" (Martha, Interview, September 6, 2005). In her following argument, Martha promoted the knowledge of scientific ideas as the most inherent element of scientific literacy:

I think you have to have some kind of a background and I think a lot of people don't have much of a scientific background. Yeah, I don't think there is a whole bunch of people I would consider scientifically literate. I may have to explain things to my husband. He went to college but do I consider him scientifically literate? No! I don't know if I would consider myself scientifically literate on some science topics. I don't know. I am not quite sure. (Martha, Interview, September 6, 2005)

In Martha's preceding description of scientific literacy, it was possible to observe that she centered her understanding of scientific literacy on the content of science. She did not consider herself scientifically literate on some science topics. In her following interview response, she expected from scientifically literate people to have broad scope of information on scientific ideas: "[A scientifically literate person is] somebody who can read something on the internet or on the paper and not automatically say 'that is true'. You know about some kind of scientific information so you can ask questions about it" (Martha, Interview, September 6, 2005).

Although Martha indicated the importance of having strong background knowledge of science content, she did not limit her understanding of scientific literacy with the knowledge of science concepts. In the following interview response, she also underlined the need for developing an understanding of scientific inquiry process:

I think they need to have just some idea that there is that process that scientists follow. And I think they also need to be aware of data that can be skewed or misinterpreted to fit them in. They need to know some scientists have agendas and not all science is good sound science. (Martha, Interview, September 6, 2005)

In her interview excerpt above, Martha highlighted the importance of having the appropriate knowledge about the working mechanism of the scientific inquiry process.

Martha argued that exposing her students to the science around them as much as possible would help them develop necessary qualities of scientifically literate people. She provided her point of view about how to educate students with the necessary elements of scientific literacy as follows:

I think if we can expose them [students] to all the science around them or a lot of the science around them, I think that helps. If I am reading an article on the paper about something, it is important to have background knowledge to say “Yes! That is true” or “No! It is not.” (Martha, Interview, September 6, 2005)

From Mary’s interview response above, it was possible to observe that her image of educating students with the qualities of scientific literacy centered primarily on the content knowledge of science. She expected students to have background knowledge on various science topics in order for them to decide the accuracy of the information presented in the media resources.

Mary

Mary argued that scientifically literate people were expected to develop a strong knowledge base in science. She especially thought that scientifically literate people needed to have a good understanding of the popular science topics that had the potential to affect the world. She revealed her perspective in the following interview response:

I think scientifically literate people have a pretty good knowledge base on a lot of scientific things that affect the world and their lives. I think they are that person that can probably sit and watch a science show on TV and get more information out of it because they have some background knowledge already and they have been exposed to it before. (Mary, Interview, September 22, 2005)

Mary expected from scientifically literate people to improve their knowledge of popular science topics by following the media resources.

Although Mary gave a special consideration to building a strong knowledge base of science content knowledge, she did not confine the meaning of scientific literacy to the content of science. In her following interview response, she added the importance of developing critical thinking skills:

I think they [scientifically literate people] are open to accept new theories and things. I think some of these scientifically literate people are broader thinkers. I think they can communicate verbally and in written words with other people about science topics. And I think they can think critically about scientific topics. (Mary, Interview, September 22, 2005)

In the interview excerpt above, Mary discussed the crucial role of critical thinking abilities in order to be able to make good judgments on the accuracy of scientific ideas.

In order to educate scientifically literate students, Mary found exposing students to the popular science topics essential for giving better decisions on sensitive issues to affect their lives. She expressed her view as follows:

Giving our students as much exposure to scientific topics, especially things that mean a lot to them, things that they can relate to, things that they might have to vote on someday. There are going to be real uncomfortable things that you may have to vote on like population control, cloning, DNA research etc. Those are the things that are really going to impact your life. If you don't know anything about them, you are going to let other people make decisions for you. I think it is important that kids hear those things that we talk about current issues. (Mary, Interview, September 22, 2005)

In the argument that Mary made in her interview excerpt above, she considered developing a broad knowledge of popular science topics as a necessary component of scientific literacy. Her discussion of educating scientifically literate students focused more on the content knowledge of science.

Comparative Overview

The educational goals of teachers with inquiry teaching strategies were driven by scientific and constructivist rationales (Furtak, 2006). Participant teachers introduced

their students to the thinking processes and actions of scientists through practicing inquiry in their classrooms. However, Patricia interestingly argued that scientific way of thinking might not be a good fit for all students. She felt this way because she found each child unique in her/his abilities. She discussed that some students came to school with natural abilities for developing scientific thinking habits. On the other hand, some other students lacked those natural capabilities for functioning with such mode of thinking. Like being left-handed or right-handed, Patricia claimed that those capabilities were possessed intrinsically by some students. She thought that exposing students to scientific method in their classrooms would not necessarily help them develop critical thinking skills if they did not have those abilities from their birth. Thus, Patricia questioned the initiative efforts that promoted scientific ways of thinking for all students. The vision imposed by recent science education reform movements for educating all students with the abilities of scientific way of thinking might be interpreted as one of the contributing factors in Patricia's noticeable resistance to the idea of equipping all students with those thinking capabilities. In other words, she criticized reform efforts for treating all students alike in educating them with scientific thinking capabilities. Whereas teachers pronounced engaging students into scientific way of thinking as an essential goal of inquiry performances of students, they were hesitant to include teaching of scientific principles into their list of goals to accomplish with their inquiry teaching practices. Only Mary brought the role of inquiry in students' learning of the subject matter of science to the fore. In contrast to Mary, Jennifer and Patricia made the argument that students benefited little from their classroom inquiry experiences in terms of learning scientific principles. They thought that teaching science concepts to students with inquiry strategies took more time and effort in comparison to more traditional means of teaching science. Whereas teachers questioned the benefit of inquiry in their students' learning of science concepts, they considered classroom inquiry activities as indispensable experience for mental engagement of students. Teachers knew that inquiry encouraged students to generate their own thinking rather than to expect it to be done by their teachers for them. They felt that the methods to be decided by students in their science investigations stimulated their thinking skills. This was the major driving

force for teachers to consider employing inquiry teaching strategies in their science classes.

In addition to the common inquiry goals of teachers discussed in the preceding paragraph, each participant teacher intended different goals to achieve with their students in inquiry teaching practices. For instance, Jennifer expected her students to experience in their classroom inquiry investigations that scientists employed variety of different methods as opposed to one universal method to reach their scientific conclusions. Because of the fact that students were given the autonomy to use different methods from one another in conducting their classroom investigations, inquiry performances of students served to that purpose very well. Patricia stressed the importance of students obtaining the capabilities of supporting their arguments with the help of actual evidence in their inquiry experiences. Martha wanted her students to dismiss the idea that science belonged exclusively to a certain group of people. Students' engagement into scientific investigations helped them realize that they could also practice science in their own classrooms. Mary encouraged her students to possess not only a sound knowledge of scientific concepts but also a good understanding of the application of scientific ideas. She saw classroom inquiry activities as a suitable platform for students to learn the application of scientific principles.

Teachers in the study approached to the concept of scientific literacy primarily with a content-oriented perspective. In other words, having a strong basis on subject matter of science constituted the backbone of scientific literacy for participant teachers. However, this did not mean that they reduced the meaning of scientific literacy merely to science content knowledge. Participant teachers mentioned about the importance of students developing scientific reasoning capabilities in order for them to be able to make rational decisions in their everyday lives. Yet, the holistic image of scientifically literate people held by teachers appeared to be dominated by the knowledge of scientific facts. Based on that, I make the argument that the content-oriented nature of those teachers' perception of scientific literacy might limit their use of more inquiry teaching strategies with their students because they avoided regarding inquiry as an efficient strategy for teaching scientific concepts. In other words, inquiry was perceived by teachers as an incompatible teaching form for equipping students with strong

science subject matter knowledge, which constituted the most important component of scientific literacy for teachers. This bore the potential for keeping teachers from seeking new avenues with inquiry in educating scientifically literate students. That was the main theme promoted in Assertion-5 included at the beginning of this section of the chapter.

Challenges with Enacting Inquiry

Since the emergence of science education reform documents in late 80's, science teachers have been encouraged to adopt new roles compatible with the central tenets of reform ideas in their teaching practices of science. New expectations have meant new challenges to be overcome by teachers in integrating reform ideas into their classroom contexts. This is especially true for teachers' transitions from employing didactic methods to considering more inquiry-oriented strategies in their science teaching practices. Although inquiry-based teaching of science is promoted as one of the most essential dynamics of science education reform efforts, the progress made by science teachers in embracing inquiry teaching strategies in their classrooms throughout the nation has stayed rather limited. This might be explained with various challenges encountered by teachers in practicing inquiry with their students. Lynch (1997) tied the relative success of education reform movements to the following three conditions: teacher beliefs, teacher empowerment issues, and system alignment and transformation. In her representation of those three categories, the first condition can be attributed to internal factors whereas the last two conditions are driven primarily by external factors. I use internal factors as the underpinning causes of the hurdles resulting directly from teachers' own initiatives in integrating reform ideas into their teaching contexts. External factors, on the other hand, refer to other contextual dynamics, not controlled by teachers, for keeping teachers from enacting reform ideas. Teacher beliefs for and understandings of reform ideas play a critical role for the success of science education reform. "Reform is held back by entrenched teacher beliefs incongruent with reform goals" (Lynch, 1997, p.5). Science education reform imposed on teachers by education authorities is subject to fail unless teachers feel empowered to take an important part in the process of reforming the education system (Lynch, 1997). However, focusing solely on teachers is insufficient for creating intended

changes in the education system because science education reform is still destined to failure without systemic changes to take place in the larger education system (Lynch, 1997).

In the preceding section of the chapter, I presented the central motives to encourage teachers to consider using inquiry with their students. In this section of the dissertation study, I do the same with teachers' hurdles that discourage them from adopting inquiry teaching strategies in their classrooms. Those experienced science teachers in the study with advanced teaching certificates displayed the capabilities of engaging their students into inquiry-oriented classroom experiences in their NBC portfolios. However, having the capabilities of enacting inquiry does not automatically mean that those experienced science teachers embrace inquiry as the central strategy for teaching science as promoted by science education standards. Various factors in the education system influence teachers' consideration of using more inquiry teaching strategies with their students. Scrutinizing those factors promises enlightening information for the future success of science education reform efforts. And if those teachers are the experienced ones like in this study with recognized teaching abilities by NBPTS, the factors influencing their decision mechanisms for using inquiry with their students exhibit a more realistic picture of challenges encountered by teachers in practicing inquiry in their classrooms. The true feasibility of inquiry teaching in school context might be understood better with the perspectives of those accomplished teachers because the expertise that they developed through many years of teaching experience helps them to look at the place of classroom inquiry in the education system with bigger perspectives than inexperienced teachers who still struggles with other distractions in the school system. Table-15 below summarizes the challenges of participant teachers in enacting inquiry with their students.

Table 15 At First Glance: Hurdles with Practicing Inquiry	
Jennifer	▪ Considered certain class structures and student background characteristics as important obstacles in practicing inquiry. ▪ Claimed that practicing inquiry did not fit well to science subject areas heavy in content. ▪ Criticized inquiry workshops for their unrealistic portrayal of inquiry in classroom.
Patricia	▪ Saw content standards and standardized tests as big hurdles for enacting inquiry. ▪ Believed that practicing inquiry required having high levels of classroom management abilities. ▪ Questioned inquiry workshops for modeling inquiry in an unrealistic way for teachers.
Martha	▪ Described certain student characteristics and lack of classroom materials as the barriers for implementing inquiry. ▪ Identified content standards and standardized tests as important hurdles for practicing inquiry. ▪ Complained about unrealistic representation of inquiry in short-term workshops.
Mary	▪ Specified content standards and standardized tests as a limiting factor for teaching of science through inquiry. ▪ Emphasized the importance of having strong science content knowledge to master inquiry successfully. ▪ Found practicing inquiry with abstract science topics more challenging.

The following assertion comes before proceeding to exhibit those accomplished teachers' perceptions on the challenges presented by inquiry.

Assertion-9: Teachers attribute the hurdles that discourage them to adopt inquiry teaching strategies to external factors.

In the following subsections, I display each teacher's perspectives on the challenges presented by inquiry in their teaching practices of science.

Jennifer

Jennifer felt that some of the physical characteristics of classes prevented effective implementation of inquiry activities. She thought that teaching of science through inquiry turned into a big challenge in a classroom with higher number of students. She expressed her perspective as follows: "The larger the class is, the less you can really do inquiry-based science. With small classes, you have time to spend with the students but with large classes, you just can't let the kids do that much" (Jennifer, Interview, September 20, 2005). Jennifer felt more comfortable practicing inquiry in smaller classes because she could respond to the needs of each student more effectively. Another hurdle that Jennifer identified with practicing inquiry was the short period of classes. She responded, "It would be better to have flexible schedules because so often they [students] are limited to their 50 minutes. It is very hard to work

that way to do what they want to do” (Jennifer, Interview, September 20, 2005). Jennifer found longer period of classes necessary for students to spend enough time on their classroom investigations.

Other than the obstacles caused by physical structure of classes, Jennifer saw certain student characteristics as a hurdle for enacting inquiry. In her following interview response, she brought the role of student capabilities to the fore in teaching of science through inquiry:

The kids are not quite as capable this year. And when they are not as capable, you know what you think you can go through in one period may take two. It is just harder on my classes because they are so much larger. It is very hard to do some of those things [inquiry activities] with huge classes. (Jennifer, Interview, May 12, 2005)

In her interview excerpt above, Jennifer implied that practicing inquiry fitted to students better with higher capabilities. In most of the cases, students were not used to being taught with inquiry strategies. Since practicing inquiry required students to find their answers by devising their own methods, Jennifer avoided giving direct answers to her students. However, this created higher levels of student frustration as described in her following interview excerpt:

The kids like to be told what to do. It is frustrating when you don't tell them what to do. When I first started teaching here and I did that activity with them, they were mad at me for three days. They were trying to badger me to tell them what to do but I wouldn't tell them. Finally they did it. Since then, I haven't had quite as that reaction. (Jennifer, Interview, May 12, 2005)

Based on Jennifer's interview response, it was not difficult to see that taking control of their learning was not an easy task for students, who were used to acquiring knowledge directly from their teacher.

In addition to certain student characteristics, Jennifer interestingly attributed some of the hurdles in practicing inquiry to science subject characteristics. She felt that science subject areas like environmental science availed themselves to inquiry-based teaching of science more easily. She argued her point of view as follows:

Typically when you go to these things [inquiry workshops], they focus on biology or environmental science because they are much easier to do inquiry-based science. When you are in chemistry, there is not much there. And I get tired of hearing about biology and environmental science inquiry-based activities.

(Jennifer, Interview, September 20, 2005)

Jennifer found certain subject areas like environmental science more inquiry friendly because she thought that science content to be taught in those areas of science was not as intense as the content in subject areas like chemistry. She explained her perspective in her following interview excerpt:

Every time when I talk to chemistry teachers, they all just say “Chemistry is different.” They say that because of the content. It is so heavy in content. And you can’t just have the kids discover like in environmental [science]. They are learning the techniques of studying the ecology of a system. Well, they go and do an open-ended question about the ecology of a system. But it just doesn’t work like that in chemistry. Inquiry-based, open-ended, think of your own question, it is a lot harder to fit in with what I am doing. And content is heavy in chemistry.

(Jennifer, Interview, September 20, 2005)

As Jennifer’s arguments in her preceding interview response suggested, she conceptualized inquiry as a teaching strategy exclusively for science subject areas with lighter content. In her classroom context with heavy chemistry content, Jennifer saw practicing inquiry as an unpractical way of teaching science. She was critical about short-term workshops which tended to portray inquiry in the context of science subject areas with lighter content. In a sense, she questioned the unrealistic representation of inquiry in workshops for actual classroom conditions.

Patricia

Patricia attributed some of her challenges with practicing inquiry to classroom characteristics. She thought that teachers needed to spend more efforts in order to respond to the needs of students in their classroom inquiry experiences. However, this presented a big challenge to teachers due to the higher number of students in classrooms. Following interview excerpt displayed Patricia’s views:

You need additional people in the classroom because inquiry-based labs with children requires multiple sets of us to make sure that they are staying safe and you can get to their questions faster because when kids are turned on the science and really into it, their questions are like enlightening. And they want to know the answer and they want to know it yesterday, they want to know it at least right now. You can't do that with 30 people on one person. That is why when you are really doing inquiry lab, you need to have more than one person in the lab.

(Patricia, Interview, May 12, 2005)

In her interview response above, Patricia argued that higher number of students made the enactment of inquiry more challenging for teachers. That was why she emphasized the need for additional help in the classroom.

Other than challenges presented by classroom characteristics, Patricia saw content standards as an important obstacle to keep teachers from using more inquiry strategies in their teaching practices of science. In the following interview response, she discussed the role of content standards in teachers' reluctance to embrace inquiry in their teaching practices:

I can't spend as much time on inquiry as I would like because I have material that needs to be covered because students are going to be tested on it, and I am going to be held accountable for what they can do on the test. (Patricia, Interview, September 13, 2005).

In her argument, Patricia brought an important dilemma phrased by many science teachers to the fore. Like many teachers, Patricia felt the pressure to prepare her students for standardized tests. However, she found inquiry incompatible for covering the required content standards. Therefore, the high profile of standardized tests in the current education system counteracted to teachers' willingness to adopt inquiry teaching strategies in their classrooms.

Patricia thought that successful practice of inquiry depended on the expertise of teachers. She especially found it more challenging for inexperienced teachers as she expressed in her following interview excerpt:

I wouldn't expect a beginner teacher to do inquiry yet because before you can do inquiry, you have to have mastered classroom management. And until you can

master classroom management, you can't do inquiry because it is too crazy. There is too much possibility of danger. You have to master classroom management before you can do inquiry. I just believe that. (Patricia, Interview, September 13, 2005)

Because students were given higher levels of autonomy in their inquiry experiences, Patricia considered having good classroom management abilities as a crucial factor in enacting inquiry successfully. Gaining the ability to practice inquiry involved spending extra effort for inexperienced science teachers.

Patricia found short-term inquiry workshops unhelpful for teachers to model the practice of inquiry in their classrooms. In her following argument, she criticized the unrealistic modeling of inquiry in workshops:

Their idea of teaching ecology is to write a poem about a tree and then go out and plant or not even plant one but go hug one. And that is so wrong. That is not ecology. Ecology is learning what are the chemicals that are involved in this thing? What environmental conditions will make this plant grow better? It is a lot of hard science. (Patricia, Interview, May 12, 2005)

In her preceding interview response, Patricia implied that inquiry exemplified in short-term workshops offered very little to teachers to transfer into their classroom contexts. Inquiry activities in those workshops were usually chosen from science subject areas with lighter content. Patricia continued her negative comments about inquiry workshops as follows:

Mostly what I learned in those kinds of professional development activities are the stuff that I don't want to do. I have learned what I don't like and what I don't want to do rather than what I want to do. In many instances, they are too open. And I feel the frustration that the children would feel "What do you want me to do with this? What am I supposed to do? Give me a clue if I am headed in the right direction." (Patricia, Interview, September 13, 2005)

Based on Patricia's arguments about inquiry workshops, it would not be wrong to say that unrealistic representation of inquiry in workshops was far from promoting wider usage of inquiry by science teachers. That was primarily because the unrealistic

presentation of inquiry in one-shot workshops conveyed the message that inquiry fitted better to science subject areas with lighter content.

Martha

Like Patricia, Martha thought that she needed extra help in her practice of inquiry because she felt herself insufficient in responding to the needs of her students. The following interview response indicated her challenge with helping her students in their science fair projects:

When I do science fair, I really feel like I am drowning. I feel completely inefficient and completely not helpful to the kids because there are just so many of them and they need so much support but I am just not able to get that to them. That is exactly it, just me in power and the kind of support these kids need. We need more adults for helping students. (Martha, Interview, May 26, 2005)

In her interview excerpt, Martha complained about the extra burden brought by the higher number of students to teachers. She provided giving one-on-one help to students as one of her biggest challenges in practicing inquiry. Other than the need for additional support in enacting inquiry, Martha thought that finding the necessary materials to be used in inquiry-based science activities presented certain challenges to teachers:

I think time to prepare for these types of activities is pretty intense. In order to get some of the materials, you need to write a grant. You just need to get the materials that you use. So that is probably the biggest constraint. And you have to have teachers who are willing to really spend the time on planning because those [activities] require a lot of planning. (Martha, Interview, September 6, 2005)

As Martha discussed in her interview response, engaging students into open-ended inquiry experiences required teachers to do intense planning prior to putting students into action. Such requirement seemed to be a sufficient reason for teachers to hesitate to give open-ended inquiry experiences to their students.

Like other teachers in the study, Martha mentioned the negative effects of standardized tests on teachers' willingness to embrace inquiry in their teaching practices of science. In her following interview response, she displayed the tension between covering the required content standards and using inquiry with students:

One of the downsides of inquiry-based science is sometimes it can be extremely time consuming. And you are under so many constraints of FCAT and what you are supposed to cover. I can't even cover everything I am supposed to cover throughout the year because there are so many standards. I don't know if anybody gets through it all. If they say that they do, they are lying. (Martha, Interview, September 6, 2005)

Based on Martha's comments in her interview excerpt, it would not be difficult to see the dilemma faced by teachers in preparing their students for standardized tests. In order to cover the content standards, Martha had to give up using more inquiry teaching strategies with her students.

Martha was critical about the unrealistic portrayal of classroom inquiry in short-term workshops. In one of the inquiry workshops that she attended, the instructor gave students too much freedom to inquire their questions. Martha did not think that this experience was transferable into her classroom context due to the unrealistic nature of the activity:

They had this classroom in which the students did not have a topic. It was just an open form where the students posted questions. Then the teacher gathered the materials and they did it. To me, I thought I don't think I could function that way. For one thing, we have standards that we have to teach. We have to get through some materials. Especially now with FCAT, you can't just focus only on what the kids are interested in. They come to learn some stuff that they are not so interested in, which is where the teaching part comes in. You have to find a way to make it interesting. That kind of inquiry-based learning is not for me. (Martha, Interview, May 26, 2005)

Martha questioned the feasibility of teaching science in such an open inquiry form because she had many commitments to fulfill with her students. In Martha's case, it was hard to suggest that her inquiry workshop experience encouraged her to use more inquiry teaching strategies with her students. On the contrary, it gave her the impression that inquiry was an impractical teaching strategy for her classroom context.

Mary

Mary considered certain student characteristics as an important constraint for enacting inquiry. Depending on behavioral problems of students, Mary found practicing inquiry in some of her classes more challenging than others. She stated, "In some classes, it is easier to do those activities. Particularly if I have a behaviorally challenging group of students, inquiry with them is really tough" (Mary, Interview, May 5, 2005). In addition to the behavioral problems of students, Mary recognized that performing inquiry with students who lacked some of the science background knowledge involved her spending more effort. Mary expressed the problem with background knowledge of students as follows:

It is very frustrating sometimes because they [students] don't have the background knowledge to make some of these decisions and they get frustrated because they don't know what to do. And of course there is a comfort zone for kids when you tell them what to do and they don't have to think about it. When they have to make their own decisions in their inquiry-based activities, that is uncomfortable sometimes. (Mary, Interview, September 22, 2005)

Practicing inquiry required Mary to avoid providing direct answers to her students. This caused students to get frustrated in their inquiry experiences because they were usually not used to giving their own decisions in their science activities. That was why Mary argued that students needed to have appropriate science background knowledge to manage their classroom inquiry tasks.

Like other teachers in the study, Mary pronounced standardized tests as an important obstacle to discourage science teachers to engage their students into inquiry experiences in their classrooms. That was primarily because teachers needed to make sacrifices from the time that they spent on practicing inquiry for the sake of preparing their students to the standardized tests. In her following interview response, Mary described the influence of standardized tests on her decision mechanism in her science classes:

I am looking at my standards and what I have to teach in a school year, I can't do inquiry more. The FCAT has tied my hands in that regard. Sometimes when I am doing my cloning class, I just have to make a professional decision about what is

more important for my students to learn. Sometimes that [teaching popular science topics] is not possible because we need to go in the direction of benchmarks. (Mary, Interview, May 5, 2005)

In her interview excerpt above, Mary discussed about one of the biggest dilemmas of science teachers: covering required content standards in a school year and engaging students into inquiry experiences. Science teachers felt that inquiry teaching strategies unfitted to prepare their students for standardized tests.

Mary claimed that the challenges experienced by teachers in practicing inquiry depended also on subject areas of science. She thought that inquiry fitted better to the fields of science with lighter content in her following interview excerpt:

Some [areas of science] lend themselves much more easily than others. The environment is a good example. It is easy to practice inquiry there because you can just walk outside and take a plot and say, "Now! If you want to find out, come up with a question here to investigate the organisms that live in this", you know, ten by ten centimeters block. "What do you think you are going to do? How can we design an experiment that would do that?" And then they have to think about it. (Mary, Interview, September 22, 2005)

In her interview response, Mary argued the higher feasibility of inquiry with certain subject areas of science. She felt the same way with concrete science topics. Mary thought that enacting inquiry with abstract science topics presented more challenges to her. She explained the difficulty of implementing inquiry with abstract science topics as follows:

One thing is atoms. I mean I always go back to that. You know, they [students] learn about it. They know that they can recite to you the parts of the atom. They can probably talk to you about the periodic table, atomic mass or whatever but what do you give them inquiry-based that is going to make kids actually able to investigate that. I mean that is really tough. (Mary, Interview, September 22, 2005)

Mary was doubtful about practicing inquiry with abstract science topics. Her doubt resulted largely from her tendency of reducing the meaning of inquiry to the experimental laboratory activities of students.

Mary argued that science teachers needed to possess a strong knowledge base of science in order to be able to master inquiry successfully with their students. She sometimes found her content knowledge of science insufficient for practicing inquiry. Mary noted, "Sometimes it is my own content base. I need to go and research a little bit more. I am looking through journals, getting ideas, taking somebody else's ideas and maybe modifying it and making it work" (Mary, Interview, September 22, 2005). Likewise, in her following statements, Mary made the same point that teaching science through inquiry required teachers to be reasonably well equipped with the science content knowledge in their subject areas: "You have to be able to set up an opportunity for kids to learn what you want them to learn. If you don't have a good content understanding of it, then you wouldn't do that very well (Mary, Interview, September 22, 2005). From Mary's interview responses above, we could say that inquiry required teachers to spend more effort to improve their science content knowledge in order to be able to practice it with their students successfully.

Comparative Overview

Although classroom inquiry has been supported by science education reform documents as the central strategy of teaching science for many decades, this ideal is still waiting to turn into reality (Horizon Research, 2003). Many science teachers approach the idea of teaching science through inquiry reluctantly (Crawford, 2007; Smolleck, Zembal-Saul, & Yoder, 2006; Trumbull, Scarano, & Bonney, 2006). Teachers' reluctance to embrace inquiry in their classrooms is attributed by many scholars to the various barriers that exist in the education system (e.g. Anderson & Helms, 2001; Barrow, 2006; Crawford, 1999; DeBoer, 2002; Edelson, Gordin, & Pea, 1999; Furtak, 2006; Hofstein & Lunetta, 2004). Those barriers that keep teachers from embracing inquiry in their teaching practices of science vary from internal factors to external factors (Anderson, 2002; Horizon Research, 2003; Johnson, 2007). Anderson (2002) used the word "dilemmas" in his description of the problems of teachers in embracing inquiry as the central teaching strategy of science. With his purposeful use of the word "dilemmas", he intended to indicate the need for required changes in internal structures of teachers, which "requires significant changes in...[their] values and beliefs about science education practice (Anderson & Helms, 2001, p.7). Similarly, van Driel, Bijaard

and Verloop (2001) discussed the crucial role of questioning the fundamental beliefs of science teachers about teaching and learning of science in order to start a change in their classroom practices. Anderson (2002) classified the barriers and the dilemmas of science teachers in practicing inquiry with their students in three dimensions: technical, political, and cultural dimension. The technical dimension includes the following factors: teachers' commitment to teaching science from textbooks, inadequate professional development opportunities for teachers, difficulty of embracing the new roles by teachers and students, negative effects of standardized assessments, Insufficient planning time for inquiry teaching, etc (Barrow, 2006; Johnson, 2007). The political dimension consists of the following factors: parental resistance to reform ideas, unresolved conflicts among science teachers, lack of support from school and district administration, and insufficiency of available resources, etc (Barrow, 2006; Johnson, 2007). The cultural dimension is comprised of the following factors: incompatible teacher beliefs about teaching of science, lack of understanding the reform ideas, ideal versus reality of classroom, and preparing students for the next level of schooling, etc (Barrow, 2006; Johnson, 2007). Whereas technical and political dimensions refer to the external barriers for embracing inquiry by science teachers, cultural dimension applies to internal dilemmas of science teachers (Johnson, 2007).

The hurdles identified by the participant teachers in practicing inquiry with their students indicated that they attributed their constraints in enacting inquiry to external factors such as student characteristics, science content standards, insufficient laboratory materials, science subject areas, physical classroom conditions, standardized tests, and time limitations, etc. (Anderson & Helms, 2001; Furtak, 2006; Hofstein & Lunetta, 2004; Horizon Research, 2003). Those external factors that made the consistent practice of inquiry harder for teachers with their students excluded any "dilemmas" that resulted directly from internal factors, namely from teachers themselves. Blaming external factors for failing to embrace more inquiry teaching strategies in their classrooms emerged as the typical reaction for all participant teachers whether they exhibited more or less resistance to science education reform ideas. In only two instances, Patricia and Mary brought the important place of expertise of teachers to the fore in managing inquiry successfully in the classroom. Patricia argued

the need for teachers having advanced classroom management skills to be able to master inquiry with their students in a successful manner (Baker, Lang, & Lawson, 2002). Likewise, Mary discussed the importance of teachers possessing strong science content knowledge to be able to perform inquiry in their science classes without difficulty (Luera, Moyer, & Everett, 2005; NWREL, 1997; Smith et al., 2007). Teachers' tendency to attribute their challenges in practicing inquiry to external factors might be interpreted in a way that they justified their unwillingness to employ more inquiry strategies in their teaching practices of science by exhibiting some of the educational dilemmas experienced by teachers in the larger education system. They meant to say that many factors in the school system failed to support teachers who struggled with integrating reform ideas into their science teaching practices. Teachers' indication of those external factors in preventing them from using more inquiry teaching strategies with their students suggested that teachers' perception of mismatch between classroom inquiry and current education system constituted a major barrier to be overcome by science education community.

As a part of externally driven factors that constrained a wider use of classroom inquiry in science classrooms, teachers in the study perceived inquiry as an exclusive teaching strategy to be employed by teachers for teaching certain science subject areas and topics better to students. Jennifer and Mary particularly argued that practicing inquiry promised little success with science subject areas heavy in content and science topics abstract in nature. Jennifer felt that inquiry teaching strategies fitted better to subjects like environmental science with lighter content because inquiry required teachers to spend more time on science topics than they otherwise did with direct instruction. This did not oppose teachers' general notions of inquiry as an impractical strategy for teaching scientific principles as discussed in the earlier sections of the chapter. Mary promoted the idea that enacting inquiry with concrete science topics presented fewer challenges to teachers in comparison to abstract science subjects because introducing students into classroom inquiry experiences by conducting science activities appeared to be more plausible with concrete science topics. Mary's such approach to inquiry resulted primarily from reducing the meaning of student experiences of classroom inquiry into empirically driven laboratory science activities as articulated in

Assertion-1. That was because Mary sounded less confident in finding inquiry investigations empirical in nature to engage students in abstract topics like atoms. This indicated that Mary equated classroom inquiry experiences of students with empirical investigations conducted by students for developing meaningful understandings of scientific ideas.

In order for science teachers to embrace inquiry strategies in their teaching practices of science, they need to develop a better understanding of inquiry and to see the actual modeling of it in the classroom. For those purposes, teachers are encouraged to attend professional development opportunities offered in their school districts. Participant teachers in the study reported their attendance of short-term inquiry workshops designed for teachers in demonstrating the practice of inquiry in the classroom. However, it was hard to say that teachers found those inquiry workshops helpful for their professional development at all. Especially, Patricia and Martha questioned the unrealistic nature of inquiry activities modeled in those workshops for their own school contexts. They complained about impractical inquiry activities, highly student-centered and open-ended in nature, used in those workshops to be modeled by teacher attendees in their classroom contexts. In addition, Jennifer expressed her frustration of seeing many of the inquiry workshops dominated by biology and environmental science examples. Jennifer felt that those subject areas were prone to availing themselves more easily to the practice of classroom inquiry because science content to be learned by students in those areas of science was not as intense as some other fields of science like physics and chemistry. Jennifer was critical about inquiry workshops for exemplifying the practice of inquiry stereotypically within the borders of subject areas with lighter content. And those inquiry workshops that Jennifer attended failed to address her needs in her specific classroom context with heavy chemistry content. From those participant teachers' portrayal of workshops organized for helping them develop better inquiry teaching abilities, it was possible to infer that they did not meet the professional development needs of teachers as originally intended (Matson & Parsons, 2006; Wee, Shepardson, Fast, & Harbor, 2007). That was primarily because those short-term inquiry workshops promoted an unrealistic representation of classroom inquiry, which ultimately kept teachers from considering more inquiry teaching strategies

in their classrooms. Teachers' critical comments on inquiry workshops indicated the need for giving more realistic experiences to teachers to be transferable into their particular classroom contexts.

CHAPTER 8

INQUIRY-ORIENTED TEACHING PRACTICES OF NBCSTs

Introduction

If we were to seek for a single concept inherent in all of recent science education reform documents, it would be “inquiry.” The concept is almost treated as the potential savior of science education from its current problems. Without changing everyday teaching routines of the teachers, reform efforts in science education are destined to the failure. This strengthens the position of inquiry in science education community because it is promoted as the mainline teaching approach in reform documents. Despite the high-profile of the word in the reform documents, the trend is quite the reverse in the school context. Due to various reasons mentioned in previous chapters, most of the teachers in schools do not embrace this type of approach in their everyday teaching of science (Crawford, 2007; Luera, Moyer, & Everett, 2005). Even if they claim that they do, their enactments of inquiry science with their students may not necessarily match with the original intentions of the reform documents with teaching of science through inquiry because the elastic word inquiry takes several different forms in the world of teachers (Wee, Shepardson, Fast, & Harbor, 2007). Although reform documents draw the general borders for the meaning of the word inquiry at the macro level, each teacher develops a unique understanding of the meaning of the term in her/his own context. That is why turning our attention to the micro level is important in unveiling the different forms of inquiry being performed in various classroom contexts (Keys & Bryan, 2001).

Inquiry occupies an important space in science education standards, as it does in the advanced science teaching standards of NBC. Science teachers who undergo the portfolio assessment process of NBC are required to demonstrate their abilities in engaging their students in inquiry-oriented science investigations. Hence, NBC standards consider having the abilities for enacting classroom inquiry as one of the

integral elements of being an accomplished science teacher. Each NBCST presents her/his enactment of inquiry with her/his students in NBC portfolios, but what forms inquiry teaching take at the hands of those “accomplished” teachers is a question with no readily available answer. In other words, science teachers are required to evidence their practice of inquiry with their students in order to complete the portfolio assessment process of NBC. However, this does not explain any details of their enactment of inquiry in their classrooms. Those details are important to know for science education community because the ultimate success of science education reform efforts rests on a better understanding of teachers’ perceptions and performances of reform ideas at the micro level of their classrooms. In this chapter of the dissertation study, I describe the inquiry teaching practices of four NBCSTs as they exhibited them in their NBC portfolios through their teaching videotapes and their written reflective analyses of inquiry-based teaching performances.

Inquiry Teaching in Action

Before presenting the inquiry-based teaching performances of the participant teachers in their NBC portfolios, it is important to specify that all had developed their own teaching strategies in their specific contexts through many years of teaching experiences. None of them built their teaching of science primarily on textbooks. On the contrary, they used variety of resources and activities with their students. However, they were not equally open to science education reform ideas. Jennifer and Patricia, in particular, appeared to have a tendency for distancing themselves from the reform ideas of science education academia because they felt that theoretical ideas of the educators in many instances proved to be impractical in the context of actual classrooms. Martha and Mary, on the other hand, seemed to exhibit less resistance to the reform initiatives of science education community. Of course, working in different school contexts with different student populations might be considered as one of the many factors in shaping those teachers’ general attitudes towards the reform ideas. The IB programs in which Jennifer and Patricia were teaching were composed of a select student body coming from the families with higher expectations for their children. In Martha and Mary’s integrated science classes, the content requirements were not as intense as it was in IB

classes. Despite functioning in different school contexts with different expectations, all participant teachers successfully demonstrated their enactment of inquiry with their students in their NBC portfolios. Those experienced science teachers with their accomplished teaching abilities endorsed by NBPTS might act as the locomotive of the education reform efforts, particularly in expanding the adoption of inquiry teaching techniques to other teachers in schools because they have the potential to influence many inexperienced teachers that they mentor. Considering such influence on beginner teachers makes it crucial to scrutinize their mentors' inquiry teaching practices in the light of original intentions of science education reform documents because we do not know much about whether NBCSTs developed an understanding of inquiry-based science compatible with current reform ideas in their several years of professional teaching experiences. Before presenting each teacher's performance of inquiry exemplified in NBC portfolio, I make the succeeding assertion with regard to inquiry teaching practices of NBCSTs.

Assertion-10: Teachers built their inquiry teaching performances on science activities with the involvement of scientific and constructivist rationales.

In order to support my assertion, I provide a detailed description of each teacher's enactment of inquiry in the following subsections. Following that, the chapter ends with the comparative overview section, which summarizes inquiry performances of teachers.

Jennifer

In her NBC portfolio, Jennifer used an activity based on the concept of "counting by weighing" in order to exemplify her performance of teaching science through inquiry with her students. She considered this activity very useful for her students to conceptualize the abstract chemistry concept of the mole in a more concrete manner. In a sense, Jennifer intended to use the concept of counting by weighing as a springboard to the relevant topic of atomic mass, which scientists determined through taking the weighted average of the mass of the isotopes of the atoms of a specific element. Jennifer had started doing this activity with her students 4-5 years before. She had

previously introduced this activity to her students after she taught them the concept of mole first. Yet, she changed her routine this time and replaced the order of the activity before her introduction of the mole concept to her students. So as their transition was taking place from experiencing a concrete activity to the abstract concept of mole, she could remind her students the analogy of beans through referring them back to their experiences in this activity in determining the number of beans without counting them, and this would ease their comprehension of the mole concept due to establishing the necessary connections with their concrete experiences. Jennifer conducted this inquiry-based activity with her students as “a prelude to the study of the mole, and atomic and molar mass” (Jennifer, NBC portfolio, Entry 2) followed by the complementary instructional performances like formal lectures about the topic of the mole, reading the textbook, practicing calculations for finding atomic and molar mass, and watching a videotape named “The Mole.” Therefore, Jennifer did not intend the bean activity to be the main scaffolding of her teaching of the mole concept. Rather, her original intention of implementing the bean activity was driven mainly from the motive of exposing her students to a supplementary activity as they move into her rather conventional stages of instruction. In a sense, the bean activity opened the doors for a start on the chemical mole concept but not necessarily constituted the major learning agent of her overall introduction of the topic of chemical mole to her students. The activity served as an analogy for the students to use in making sense of the mole.

Jennifer recorded her videotape of inquiry-based science teaching in her 10th grade pre-IB class with nineteen students. She placed a cup of beans and a digital scale in each of the lab stations for a group of two students to share in conducting their activities collaboratively. She also put extra beans and cups on the table in front of the classroom for her students to use in their struggle to find out the number of beans in a cup without counting them. Jennifer found bean activity very practical due to the fact that it lent itself easily to using with students without any need for “hard to find” extra lab materials. Besides, the activity was efficient to be accomplished in a fifty minute class period. Jennifer planned the activity to be open-ended in nature where each student had a chance to devise her/his own method in pursuing a solution for the specific task in the activity rather than following a prescribed way of reaching to the right answers. Yet, the

materials were prepared for a specific methodology that she wanted the students to use. For example, she did not prepare for alternative ways of finding the answer like using volume rather than mass. Jennifer listed her goals to achieve with her students by giving them the opportunities to engage in the bean activity as follows:

1) Understand the concept of atomic mass by using beans as a model of atoms of an element, 2) Understand the concept of finding the number of beans by weighing them and correlating it to how a scientist indirectly determines the number of particles by weighing, 3) Model the thinking processes of a scientist in that the students participate creatively in figuring out a solution to a problem and design a method, and generate a written description of a procedure and a labeled record of data, 4) Mathematically and critically analyze experimental design and results to determine sources of error and suggest improvements concerning: a) repetition of trials, b) sample size, c) uncertainty in measurements, and d) reliability of data. And last, but not least, 5) Enjoy success. (Jennifer, NBC portfolio, Entry 2)

In order to accomplish the preceding goals with her students, Jennifer refrained from answering their questions directly but rather she wanted them to build their own understandings from out of their interactions with the bean activity.

In her inquiry-oriented teaching videotape, Jennifer stood in front of the classroom and explained to her students some procedures about the bean activity before her students began their investigations. The students listened quietly in their chairs in a traditional format. Jennifer started her enactment of bean activity through introducing her students to some chemical materials on the table. As she showed those bottles of chemical materials in powder form to her students, she questioned them whether they could count the number of atoms in the bottle of chemical samples in her hand. She received the expected answer from her students that the atoms in those chemical materials were too tiny to count and there were so many of them in the bottle. After Jennifer got the confirmation from her students that counting atoms in a bottle of chemical material would almost be impossible, she exhibited her approval for the answers that came from her students through stating that it would last a lifetime to achieve such thing. At this point, she started making the relevant connections with the

necessity for indirect ways of determining the number of atoms or molecules in a sample of chemical material. After demonstrating her students the difficulty of finding the number of atoms by counting, she transitioned to the bean activity that they were about to engage in shortly. Rather than leading her students to the bean activity with an investigation question, she asked her students to find the number of beans in the cups through weighing but without counting them. Her introduction phrase came in the form of “your job today is...” with the connotations that students were given a task to achieve in their activities rather than a question to inquire in order to come up with an answer. The given task left no space for students to be a part of the decision mechanism. The students posed some questions mostly related to the procedures which they needed to follow in their involvement with the bean activity. Jennifer further explained her students that they were not allowed to remove any beans from their cups while working on determining the number of beans in their cups. While holding bean activity sheet in one of her hands, she asked her students to find the percent error in comparison with their weighed and counted results. She also wanted them to explain their specific methods in detail at the designated place on the back of activity sheet. In order to keep her students from revealing their specific methods to follow in their effort to find out the number of beans in their sample cups, Jennifer asked her students couple of times not to mention anything about their specific methods that came into their minds at that time because she wanted to give each group of students the chance to devise their own unique methods without being influenced from other students’ thinking.

When students left their chairs and went to the lab counters located at the back of the classroom for conducting their activities with their peers, they found a cup of beans and a digital scale on the lab counters. Groups of two students started their investigations with the required materials provided for them. As they continue making weight measurements, Jennifer constantly moved around and asked her students some questions without giving them direct answers. That was because she wanted them to make sense of their unique ways to come up with their own answers. The noise level in the classroom increased noticeably as the students began collecting their data and students looked engaged with their tasks. Student interaction usually took place with other group member but not with the members of the other groups. After a while, some

students started shouting enthusiastically that they found weighed number of beans very close to counted number of beans. Jennifer took the opportunity and questioned them whether each of the beans in the cups was identical in terms of their weight. She highlighted the possible problems that might occur due to sampling and measurement errors. She questioned her students whether finding the average weight of more beans would produce more accurate results. However, students had the immediate chance to match their answers with the actual numbers of beans in the cups. This left little room for them to revise their methods when they found a close number of beans based on the weight of one selected bean. In other words, many students did not attempt to improve their methods through involving more beans into their weighted sample of beans once they found a close answer with the help of dividing the weight of beans in the cup by the weight of one “lucky bean.”

After students completed their investigations, they returned back to their chairs in order to make a discussion about their results. Jennifer asked each group the percent error that their results produced and the number of beans that they weighed to reach their conclusions. Some groups chose only one bean to weigh whereas some other groups took the average weight of more than one bean. When Jennifer heard that one of the groups had relatively higher percent error, she asked the class about the possible ways of improving their experimental results. After a couple of students commented about choosing a better bean to improve their results, Jennifer asked her students whether any of the students had included “repetition of trials” into their activity sheet as one of the possible ways of improving experimental results. When nobody was positive about that, she needed to make an explanation that repeating trials were going to improve experimental results. One of the students responded that she did not state this in her activity paper because she assumed that they did not have enough time for more trials. Jennifer replied back through expressing explicitly that scientists in their scientific research repeated the experiments in order to reach more accurate results but due to time limitations in the classroom, many times they did not have sufficient opportunities to go with more trials. This student’s comment suggested that the bean activity did not necessarily teach students the importance of repeated trials in conducting successful experimental research studies.

Patricia

In her NBC portfolio, Patricia used an activity entitled “Observing Multiple Images in Plane Mirrors” from Holt Physical Science Laboratory Investigations in order to demonstrate her enactment of inquiry with her students. Before this activity, Patricia had her inquiry-based teaching videotaped couple of times with different activities but each time she encountered some technical problems with videotapes, which prevented her from including them into her portfolio. Some of her colleagues suggested using the same activities with her students again to produce a better quality videotape but she thought that it would not be an authentic way of exemplifying her inquiry teaching because her students would already know the answers beforehand. In her search for another inquiry-oriented activity to represent her inquiry teaching skills, she came up with this activity, which perfectly fitted to the flow of her teaching of light waves in the bigger picture of electromagnetic waves. The class in which Patricia implemented mirror activity was eighth grade advanced physical science class with 28 students. Students formed groups of two students and rearranged their chairs in an opposite way of facing to each other. Due to the fact that Patricia’s classroom had originally been constructed with partial walls, she wanted her students to stay at their desks as much as possible as a preventative measure of keeping the noise in a desired level in order not to distract other classes on the opposite side of the hallway.

Patricia’s enactment of mirror activity with her students took place after they learned about the properties and parts of waves. Therefore, the mirror activity was one of the supporting agents in the learning process of the larger topic of waves. Patricia used some analogies in order to present some of the fundamental aspects of the waves. For instance, the story “Big foot-Little foot” that she shared with her students associated the wavelength of waves to the shoe size whereas the number of steps taken represented the frequency of waves. She demonstrated to her students the occurrence of constructive and destructive wave interferences through lab activities. The current activity followed the sequence of lessons on electromagnetic waves after Patricia discussed the concepts of reflection and refraction of light waves briefly. The nature of the activity was primarily based on observing the number of images occurring through changing the angle between two adjacent flat mirrors. The activity itself did not

include a specific question for students to investigate but Patricia stimulated the student interest through posing them questions about the working principles of kaleidoscopes. Therefore, the students in a sense investigated the fundamental reflection phenomenon of light waves in the mechanism of kaleidoscopes. The follow-up activity already involved preparing a home-made kaleidoscope.

Patricia considered the mirror activity as a “good hands-on-minds-on activity” (Patricia, NBC portfolio, Entry 3) for both her average and advanced students while helpful for developing an understanding of the basic concept of reflection for the former ones and useful for exploring the topic in a creative way for the latter ones. In her NBC portfolio, she provided her goals in implementing the mirror activity with her students as follows:

- 1) to gain an understanding of the relationship between the angle of adjacent mirrors and the number of images observed, 2) to review our prior knowledge of reflection within the specific context of light, and 3) to practice measurement and observation skills. (Patricia, NBC portfolio, Entry 3)

Students having the ability to base their arguments on the actual data that they collected in their investigations constituted the backbone of Patricia’s enactment of inquiry-based activity with her students. In other words, she valued hard evidence, in this case student observations of number of images on the mirrors, in shaping the students’ ideas more than right conclusions. In order to allow students to base their conclusions on actual evidence, Patricia refrained from giving direct answers to her students. She continued helping her students but just provided suggestions rather than direct answers in the process of data collection. She “facilitated discussion by walking among the groups, helping them collect good data and by never really answering questions, but asking questions about the data to lead students to understand what they were observing” (Patricia, NBC portfolio, Entry 3). At the beginning of the mirror activity, Patricia discussed with her students the procedures they needed to follow and some possible sources of error in their data collection process. The specific methods that students were asked to follow in conducting the mirror activity was described clearly in the activity sheet. However, the general approach of Patricia for her students to collect

“good data” as they performed their measurements left little room for students to learn from their mistakes in the process of data analysis.

The segment of the videotape in Patricia's NBC portfolio mostly captured the interactions of students with the data collection process. The follow-up discussions about the activity were not present in the videotape. The videotape started with Patricia's help to one group of students in placing the mirrors properly. The two girls in the group were not in agreement about the number of images that occurred on the mirrors. Patricia told the girls not to count the actual object in front of the mirrors but just the images of the object that they were seeing on the mirrors. They still insisted that they were observing different number of images, three and four images respectively on the mirrors with a right angle between the adjacent mirrors. Patricia asked them then to note on their papers whatever the number of the images they saw on the mirrors. She did not give any clue to them about the correct number of images that they were expected to see with a right angle between the mirrors but she emphasized one more time that the actual object was not the subject of the count but just the images of the object on the mirrors. Patricia avoided going beyond certain point in her help to her students when the requested help involved providing any specific answers to the questions that students were expected to reach by themselves. In one instance, one of the students complained about finding the inconsistent results on his graph. Patricia suggested him to take new measurements in order to correct the problem. Through her following response, Patricia confirmed the existence of a problem but refrained from giving any specific answer to fix the error: “So something needs to be fixed here, doesn't it? It doesn't look real good there.” Instead of providing a direct answer, she expected him to figure out the solution for fixing the problem by himself.

Patricia continuously circulated in the classroom to help her students. However, the space between student chairs was not sufficient for easy movement. Although the different groups of students were sitting close to each other, there was not much interaction between them. In order to promote student's collaborative work, Patricia asked one of the students to close the gap between her chair and her group member's chair. Throughout the videotape, Patricia moved around constantly to help her students who displayed their need for help by raising their hands. The majority of the questions

that came from students centered on procedural issues clarifying whether they were making the measurements appropriately. For example, some asked about drawing the graph on a normal paper since they did not bring any graph paper on the day. One student wanted to make sure from which side of the mirrors that he needed to make his observations because he was observing different number of images from sides and center of the mirrors. Two girls were unsure about which variables to place on the axis of their graphs. One boy was able to devise a formula to find the number of images in response to the changing angles between the mirrors. Without any involvement of his group partner, he explained his formula to Patricia. She directed him to test his theory with different angles of mirrors whether his theory would predict the observed results correctly. Patricia's enactment of the mirror activity with her students, she appeared to be totally in charge of her students' learning because each student question was directed to her as the ultimate source of knowledge in the classroom. As Patricia was exposed to different questions from the student groups, she usually did not consider sharing them with the rest of the class to involve more students into the process of building the learning responsibility on her students.

Based on what Patricia explained in her portfolio, the discussion about the results took place on the next day. Although not all groups were able to use their collected data to develop a matching relationship with the expected conclusions, some groups did formulated the relationship between the number of images and the value of the angle between adjacent mirrors, 360 divided by the angle between mirrors produced the number of images plus 1 . This was the direction of the activity from which students were expected to formulate the relation. Whereas the mirror activity provided data collection procedures to the students, making the necessary relations between the number of images and the angles of mirrors were left to the students based on the graph that they produced through placing the angles of the mirrors on the x axis and the corresponding number of images plus 1 on the y axis. None of the students questioned the reason for adding 1 to the number of images as they drew their graphs. Students preferred following the given procedures properly rather than applying their reasoning skills into the process of investigation.

Martha

In the inquiry section of her NBC portfolio, Martha used one of the kit-based activities of SEPUP (Science Education for Public Understanding Program). The SEPUP activity that Martha implemented with her students was based on a fictitious story of a town named Fruitvale, whose underwater resources were contaminated with some type of a pesticide. In this problem-based environmental activity, students were asked to investigate the possible sources of water pollutants, the extent of the affected areas, and the possible ways of cleaning the contaminated regions. In order to produce a solution for the pollution problem of Fruitvale town, students were expected to take the active roles of scientists through collecting and analyzing relevant data in the context of a real life situation. The SEPUP kit consisted of twelve modules with all necessary materials to be used by students included into the activity set. In the earlier days before her recording of the teaching videotape, Martha implemented the modules that involved data collection from students' choice of wells located on the numbered areas of the Fruitvale map. In her videotape, she continued implementing other modules that required her students to create boundary plumes of contaminated regions based on the results of their well testings. The 7th grade Integrated Science class in which Martha used Fruitvale activity consisted of 30 students with a range of diverse backgrounds from high level students to low level ones. However, for videotape recording purposes, Martha worked with seven of her students who showed a higher interest and volunteered to be involved in the recorded class. In the earlier modules in which all of Martha's students participated, Martha assigned her students into the groups of four students in conducting their activities. On the other hand, in videotape-recorded activity, Martha and her seven students sat around a laboratory table in the format of a focus group discussion without forming any student groups.

Through engaging her students into the Fruitvale activity, Martha expected from her students to develop both an understanding of science content and to build good science process skills. Contentwise, Martha wanted her students to have the sufficient information on environmental issues, particularly pollution, and the specific terminologies accompanied with them in order for them to be able to understand newspaper articles on the subject that had the potential for direct effects on their

everyday lives as citizens. In terms of science processes, her goals to achieve with her students included teaching them critical thinking and problem solving abilities. The Fruitvale activity promoted those abilities because “inferring from evidence, analyzing data, and brainstorming solutions reinforce the teaching of the scientific process and develop higher level thought processes” (Martha, NBC portfolio, Entry 3). In Fruitvale activity, the general procedures for collecting the necessary data from numbered wells were given to students clearly whereas students were expected to make their own scientific decisions on wells that they needed to test for determining the level and the extent of contamination accurately in the neighboring areas.

Martha spent more than a week with her students in order to complete this series of problem-based student investigations of SEPUP activities. In the beginning stages of her teaching of environmental problem of water pollution, she demonstrated to her students the movement of contaminated water from higher areas to the lower places with a simple activity, which involved using a single sheet of wrinkled paper to represent the topographic properties of the land. After students highlighted several regions on their wrinkled papers with different colors, they observed the accumulation of the contaminated water in areas with lower altitudes when rain, in this case sprayed water onto the wrinkled paper, washed away the colors on the paper. In this demonstration, Martha wanted her students to understand the concept of watershed. Before starting the demonstration activity with her students, she made many connections with the water resources in the area that her students were living through asking them the different bodies of water resources in their areas and the ways that people would use those water bodies in their lives. This section of the lesson took place in question-and-answer format. Martha was the one who posed all of the questions to her students and allowed one of her students who raised her/his hand to answer the specific question. She tried to provide the opportunities to all of her students to answer through calling different students each time. Martha’s students sat on their desks passively, listened to the lesson quietly, and raised their hands in a well-behaved manner when Martha posed a question. Martha directed the flow of the lesson through addressing her students with the phrase “What I want you to do is...” several times. In this setting, there were few interactions between the students. In fact, I observed more student interactions in my

visits to Martha's classrooms. Such effects might have arisen due to the presence of the camera in this teaching episode. In her teaching videotape, she might have desired her class to be portrayed as a better organized classroom with well-behaved students under the direction of a teacher with good classroom management skills. However, such tendency for creating a neat classroom environment with full of students in compliance with predetermined norms made Martha's teaching look more teacher-centered than it normally was because her students were following the directions given by their teacher carefully in a quiet classroom environment. It is logical to think that teachers would like to present their best teaching capabilities in their videotapes to be submitted to NBC assessment center to be evaluated for the quality of their teaching practices. However, this was not always advantageous because in Martha's case, her teaching videotape portrayed her as a more traditional teacher than she actually was.

In the SEPUP module, Martha videotaped her enactment with her students as she sat around a laboratory table with her seven students to discuss the well testing data they collected a day before. The video started with Martha's brief explanation of the general purpose of the activity, which was finding out the origin of the water contamination source based on the data collected from various wells chosen strategically by the students. Immediately after this brief introduction, Martha explained to her students what she wanted them to do with the following phrase: "the first thing I want you guys to do...". She asked her students to put the respective contamination code on the map of Fruitvale wells that they selected to test for the level of contamination a day before. Martha's approach in giving their tasks to her students continuously created an environment where her students were following the directions coming from their teacher carefully with fewer opportunities for them to use their initiatives in the process of conducting activities. After students finished placing the respective contamination codes on the Fruitvale map, Martha asked them to draw a circular boundary line around the specific well from which they predicted the source of the contamination originated. In order to verify whether their answers were correct, students compared their boundary lines with the master map provided by Martha. This left little room for any dispute on student results because the master map represented the ultimate truth that the students were expected to conform.

In the videotape, Martha played the role of a moderator to direct the student discussions on their well testing data collected in the previous modules of SEPUP activity. The interaction focus of the discussion seemed to be centered mainly on Martha with very limited student-to-student interactions. After students placed the corresponding well testing results on the respective number of wells on the Fruitvale map, they compared their results with the master map that displayed the contamination levels of all wells without discussing them with their peers first. That was the main reason that some issues with the sampling error did not emerge naturally from the various data that students collected but Martha had to specify later that no scientific data could produce a hundred percent accurate results at all times. In other words, instead of students reaching this conclusion naturally from the comparison of their results with their peers, Martha reached such conclusion with her students through getting their affirmative responses to the question that she posed to them. Although a plum comparison of students with the master map informed Martha that “the students in this group did choose their wells thoughtfully” (Martha, NBC portfolio, Entry 3), she knew that some of the groups did not follow a strategic plan but made their choices of well testings arbitrarily without basing their decisions on the ongoing emergence of test results as they continued selecting and testing more wells. As Martha’s self-reflection in her NBC portfolio revealed, she was not completely cognizant of the strategic decision making processes of her students in choosing the wells to be tested for contamination levels in their investigations. She expressed the insufficiency of her discussions with her students to uncover their thought processes in their data collection stage as “I would have liked to include more discussion on the process the students used to choose their wells and will add this next year” (Martha, NBC portfolio, Entry 3). Whereas the Fruitvale activity described the ways that students needed to follow in collecting their data, it potentially left the decisions to the students for choosing the subsequent wells to be tested to reach different results based on their strategic analyses of accumulating well testing data. However, the way that Martha implemented the Fruitvale activity did not bring the differences of the student results to the forefront sufficiently to lead more fruitful discussions. In the investigation process of her students, it appeared that her continuous involvement into the activity with her questions and explanations made the

activity more structured than it could be otherwise. In her self-reflection as she commented on her enactment of inquiry with her students in her NBC portfolio, Martha in her future plans for implementing the activity exhibited her desire to give more free space to her students in conducting their investigations and going through the process from beginning to the end. In her portfolio, she noted, “For future instruction of these students, I want to take these students, acting as scientist[s], through the whole process of deciding [that] there is contamination, determining where the contamination is and how to clean it up” (Martha, NBC portfolio, Entry 3).

Mary

Mary submitted inquiry section of her NBC portfolio twice because her score fell a couple of points short at her first attempt in order to achieve her advanced teaching certificate with NBC. In order to increase her score, she needed to use another activity to exemplify her inquiry teaching abilities with her students. In her first year submission of NBC portfolio, she used a model rocket activity from Boreal Laboratories whereas in her second year, she implemented an activity with her students related to biological topic of adaptation through introducing her home pet guinea pig to her students. Although Mary knew her respective numerical scores on each of her portfolio entries, she had no clue for the reasons of her low score on the inquiry section of her NBC portfolio. That was because NBC assessment center did not provide any verbal feedback to the teachers on their NBC assessment performances other than their numerical scores. In spite of unsure about the possible reasons for her lower score on the inquiry section of her NBC portfolio, some possible factors coming to her mind that contributed to her relatively lower score on this portfolio entry included failing to address some of the questions that NBC portfolio preparation guidelines specified, using a poor writing style in the inquiry section of her portfolio, and implementing an activity unrepresentative of inquiry with her students. In this section of the dissertation study, I described the rocket activity that Mary used with her students. Due to the fact that Mary was not able to locate her NBC videotapes of her teaching, I did not have a chance to watch her enactment of rocket activity with her students but my descriptions and comments about her teaching of rocket activity were primarily built on the information that Mary provided in her reflective analyses of her teaching in her NBC portfolio.

Mary used a rocket activity in her 8th grade Integrated Science class in order to demonstrate her teaching skills of inquiry. The class consisted of 23 homogenously grouped students based on their mathematics skills because those students were taking an algebra class for their high school credit. Although all of her students participated in the activity, Mary preferred to focus on a small group of five students in her teaching videotape. The videotape portrayed their discussions on the data that they collected earlier from launching their rockets. The rocket activity was one of the activities that Mary used with her students in her teaching of physical science concept of energy. Through engaging her students into the rocket activity, Mary wanted her students “to logically go through a step by step procedure for interpreting the information and drawing educated conclusions based on data” (Mary, NBC portfolio, Entry 3). In this project-based fun activity, Mary “portrayed [her students] as scientists that had to make a design that would be used in an industry” (Mary, NBC portfolio, Entry 3). At the beginning of the activity, students worked in pairs and constructed their rockets by using the material from Boreal Laboratories kit. After the completion of the model rockets, Mary explained to her students in an imaginary scenario that they were hired to test the best working parachute in helping the rockets land safely. The investigation process took a start with a task given to students originated from Mary. In fact, the original laboratory set of Boreal did not involve testing parachutes but it was Mary's idea to direct her students to collect data in order to find the best working parachute. Although Mary asked her students to test their parachutes, they were not completely free in creating their parachutes in different design and shapes because Mary had already three templates of parachutes with different sizes for her students to choose for their testing. Therefore, each group of students chose one size of parachute template and prepared their parachutes with the help of template that they chose. After finishing their parachutes, they attached them to their rockets with strings and waited for launching their rockets with parachutes.

The actual data collection process took place on the next day. Groups of students took turns launching their rockets and recorded the size of the parachutes and the time it took them to hit the ground after their launch. Although all students were responsible from collecting their individual data, Mary assigned two students as master

time keeper and recorder. When they returned back to the classroom, they compiled the total data although there were some discrepancies among the students who were able to collect their own data. The rocket activity that Mary enacted with her students did not allow students to make the decisions to devise their own methods to test their parachutes other than choosing one of the three sizes of the parachutes to test in their investigations. Students were already given what to measure in their investigations.

Based on Mary's explanations in her portfolio, she discussed the interpretation of the data with a small group of five students on the next day. At the beginning of the discussion, she wanted to make sure that she and her students were on the same page because she thought it critical that students needed to know the purposes of conducting their activities. She started the discussion through questioning her students about the relevance of the activity with the energy concept before focusing on the actual data that students collected in their investigations. From student responses, it appeared they had difficulty in making the necessary connections with the physical concept of energy although they finished conducting their investigations. Mary modeled the movement of the rockets with a pen in her hand while explaining her students the conversion of energy from potential to kinetic and vice versa in various positions of the rockets in their journey on the air. However, Mary was not clear about expressing the relevance of the parachute data, which constituted the core of the student investigation, with the energy concept. When the actual data analysis started, Mary asked her students to organize their parachute data into logical categories and to look for any patterns emerging from their data. Based on the data, students came to the conclusion that rockets with parachute #2 took the longest time to hit the ground while parachute #3 failed to deploy properly due to its big size. Although the parachute data that students collected in their investigations led them to such conclusion, it was difficult to suggest that the activity itself was successful in supporting the student understanding of the energy concept. In the small group discussion of the data, Mary orchestrated her students' interpretation of the data through directing questions and giving directions to her students more than students taking the initiative to shape the nature of the discussion.

Comparative Overview

Despite being somewhat different from one another, all teachers in the study built their enactment of inquiry with their students on science activities. The activities that the teachers used required their students to collect data in order to support their conclusions. With the help of hard data from activities, participant teachers implicitly wanted their students to experience the way that scientists built their scientific arguments on the actual evidence that they gathered through conducting their experimental research studies. In that sense, their enactment of classroom inquiry primarily targeted replicating the similar activities that scientists used in their scientific research projects. The activities that Patricia and Mary used with their students included a project component. Whereas Patricia wanted her students to prepare a home-made kaleidoscope based on their learning experiences from mirror activity, Mary's students needed to build rockets and parachutes in order to be able to test them. Therefore, the hands-on component of the activities in which Patricia and Mary's students engaged was more noticeable than the activities of Jennifer and Martha's students. As it was the case for many of their colleagues, the experienced science teachers in the study did not base their teaching of scientific concepts primarily on inquiry-based teaching techniques. In other words, it was hard to suggest that inquiry-oriented teaching techniques constituted the main scaffolding of those teachers' exemplified teaching practices in their NBC portfolios. The teachers employed inquiry teaching techniques as the supporting agent to their rather conventional teaching practices. Therefore, their practices of inquiry with their students constituted a fragment of their overall teaching of broad science concepts to their students. Although inquiry-oriented activities were conducted within the specific context of science topics, it appeared that most of the student learning of science content knowledge took place through conventional means of teaching techniques. The activities were considered as the supporting agent to the preceding didactic teaching techniques by teachers. However, in Martha's case, her completion of the modules in SEPUP activity set took almost two weeks. Since environmental science content was embedded in the series of science activities in the SEPUP activity set, it could be said that inquiry teaching approach constituted the scaffolding of Martha's teaching of science during this two weeks period. This is not to

say that Martha never employed any didactic teaching methods. She used didactic teaching techniques in her teaching of science but her use of didactic teaching techniques usually served to the intentions of inquiry teaching supported with series of activities. Other teachers' enactment of classroom inquiry gave the impression that inquiry experiences played a supplementary role to their further teaching of the science topics within the traditional format of lecturing. For instance, Jennifer considered her implementation of bean activity as a good analogy to use in her further teaching of the chemical mole concept to her students. On the other hand, while Martha's implementation of kit-based SEPUP activities with her students determined the general frame of her teaching, her dispersion of science knowledge to her students with more lecture-based approach worked as the supporter of this inquiry-based frame.

In previous paragraph, I displayed the activity-based nature of those experienced science teachers' enactment of inquiry with their students. However, this would be an unfair representation of their inquiry teaching practices without adding that teachers involved "the scientific and constructivist rationales" (Furtak, 2006, p.454) into their implementation of inquiry-oriented activities with their students. The scientific rationale refers to engaging students in the thinking processes of practicing scientists with the involvement of science process skills. And the constructivist rationale stands for allowing students to develop their own understandings of scientific ideas from their direct experiences with the activities. In the activities of NBC portfolios that teachers exemplified their teaching of science through inquiry, basing one's conclusions on the actual evidence that s/he collected from the activity represented the scientific rationale of inquiry-based learning of science. It appeared that teachers considered that aspect of science as the most salient characteristic of scientific way of thinking. That was why they wanted their students to support their conclusions with the actual data that they gained from conducting their activities. With their consideration of the constructivist rationale, teachers intentionally retracted themselves from providing direct answers to their students so that their students could build their own understandings on the experiences that they gained from the inquiry-oriented activity. Briefly, those two aspects of scientific and constructivist rationales, namely directing students to support their conclusions with the actual evidence and refraining from providing direct answers

to the students, emerged as the most noticeable characteristics of NBCSTs' enactment of inquiry-based science with their students.

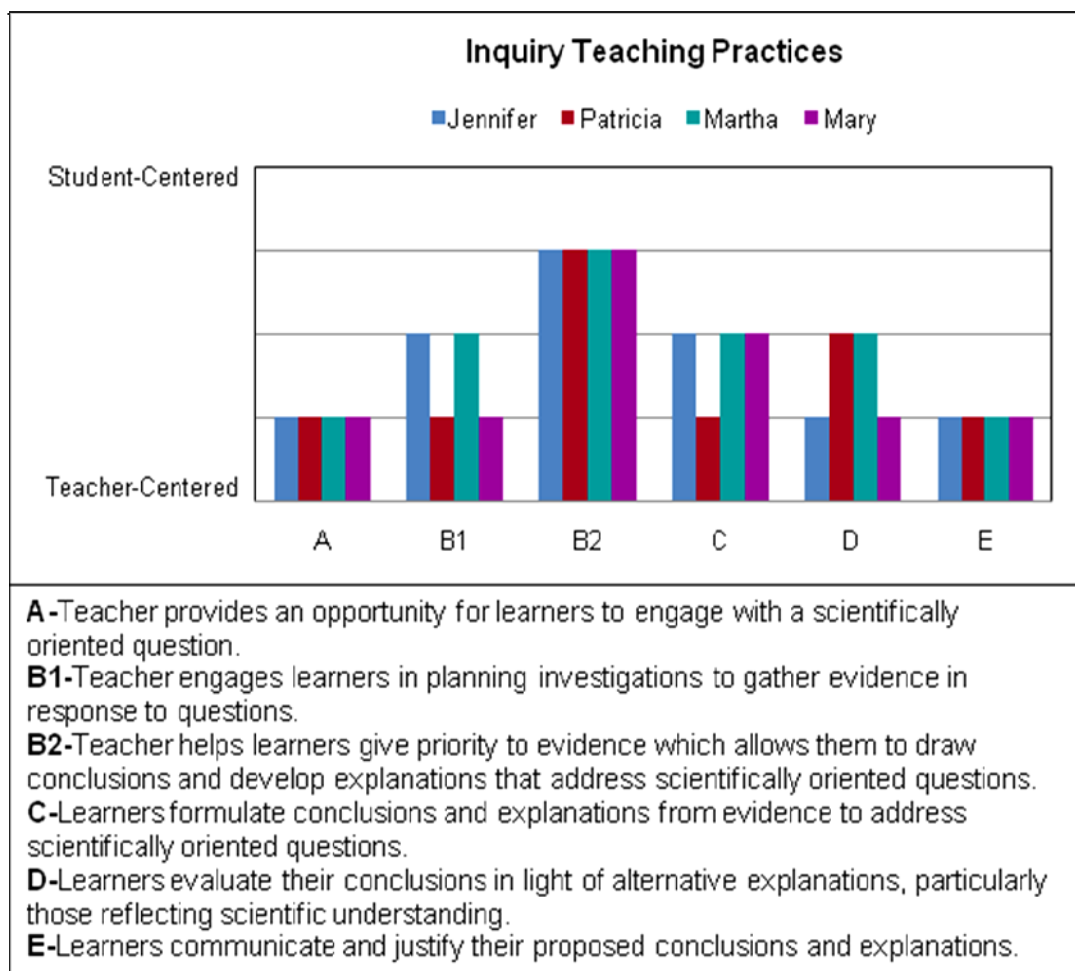


Figure 7 Inquiry Teaching Performances of NBCSTs

In order to analyze participant teachers' inquiry-oriented teaching performances in their NBC portfolios, I used an adapted version of Science Teacher Inquiry Rubric (STIR) prepared by Beerer and Bodzin in 2003 (see at the end of the chapter). Beerer and Bodzin (2003) built their inquiry rubric instrument on five essential features (A-E) of classroom inquiry characterized by NRC (2000). Those five essential features of classroom inquiry were defined with the consideration of the scientific rationales, which involved investigating scientifically oriented questions through gathering hard evidence. In the rubric, the structure of inquiry being performed by teachers decreases from left to

right. In other words, the autonomy given to students in their classroom inquiry experiences increases as moved in the rubric from left to right. The cells on the far left hand side of the rubric refer to structured inquiry with very limited student initiatives involved into the learning process. The middle cells reflect guided inquiry with more decisions being made by the students. And the far right hand side cells in the rubric can be categorized as open inquiry, which brings students to the forefront in their learning experiences. Those levels were integrated into the rubric with the motivation of the constructivist rationales, which supported the idea of allowing students to build their own understandings from their learning experiences.

From the bar chart above that displayed participant teachers' inquiry teaching performances based on STIR, it was possible to observe the five essential features of classroom inquiry in those teachers' enactment of inquiry with their students. However, the classroom inquiry practices of the teachers had a tendency to accumulate around the cells on the far left hand side of STIR rubric. In other words, the inquiry teaching practices of these experienced science teachers stationed primarily on teacher-centered phases of classroom inquiry. Teachers were able to a certain extent exhibit five essential features of classroom inquiry, driven by scientific rationales, in their inquiry teaching performances. But the level of student autonomy, motivated by constructivist rationales, in their inquiry-oriented science activities was rather limited. In other words, teachers failed to give enough opportunities to their students for taking the initiatives in their learning of science. Participant teachers intended their students to build their own understanding of scientific ideas from their experiences with the inquiry-based activities and avoided providing direct answers to their students in order for them to reach their own conclusions. However, it would be difficult to suggest that the general format of teacher-centered nature of their teaching practices supported such intention to the maximum potential. For instance, none of the teachers encouraged their students to take more active roles in deciding what questions to investigate in their inquiry-oriented science learning experiences. On the contrary, their presentation of the questions to be investigated by the students in their activities exhibited mostly an authoritarian approach. Such introductions like "What I want you to do is..." or "Your task today is..." at the beginning of their inquiry teaching practices gave the impression that students

had a task to complete rather than a question to inquire in their activities. Of course, the analyses of participant teachers' inquiry practices displayed some variations in terms of their students' autonomy in deciding the procedures that they employed in conducting their activities. Jennifer and Martha's students had a little more flexibility in their choices than Patricia and Mary's students. For instance, Martha's students had to decide strategically by themselves which water wells to test for their contamination levels. On the other hand, Patricia's students needed to follow the exact procedures included in the mirror activity in order to find the number of images occurring on the adjacent mirrors. The mirror activity already specified the values of the angles between adjacent mirrors to be used by the students in their observations. Students had no way of deciding their own strategies in observing the images on the adjacent mirrors other than using the angles provided in the mirror activity. All teachers in the study held a discussion session at the end of the activities. In these discussion sessions, teachers maintained a better communication with their students through asking them questions and allowing them to explain their conclusions. However, in each case, the interactions in those discussion sessions were usually teacher-centered. Teacher-to-student interactions monopolized almost all discussions with very limited student-to-student communications. In addition, the students had very limited opportunities in determining the general format of the discussion sessions. The format and the content of the discussion sessions were decided solely by the teachers. Due to the preceding reasons that I mentioned, the performance of the teachers in their communication with their students at the end of their activities fitted to teacher-centered phases of inquiry in STIR rubric.

Like many of their colleagues working in K-12 schools, those accomplished science teachers were not confident enough in inquiry to hand the control of the lesson to their students. In inquiry-based teaching approach, it is expected that the power shifts from teacher to the learners and the major role of the teacher becomes facilitator of the learning process. This is one of the most critical elements of practicing the true nature of classroom inquiry. In fact, I observed that teachers in their NBC teaching videotapes tended to use more control on their students' learning than their usual teaching practices of science although they had the opportunity in their videotapes to

demonstrate their teaching almost in ideal conditions without the limitations of the education system to obligate them to behave otherwise. It is my belief that the teachers refrained from portraying a chaotic classroom environment in their NBC teaching videotapes because they wanted to exhibit the strength of their classroom management skills in a well organized classroom with well-behaved students. Such concern prevented teachers from involving their students more into the decision-making mechanism in their learning of science. One another possible reason for their tendency of minimizing the active roles of students in the learning process of inquiry could be explained with the unexpected nature of the inquiry teaching approach. What I meant by the unexpected nature of the inquiry teaching approach is that teachers had no way of knowing what the next step would bring into the equation in a student controlled classroom atmosphere. In a teaching videotape to be submitted to NBPTS for an evaluation, teachers were not willing to take the chances to be exposed to the situations where their knowledge might fall short in responding to their students' needs. That seemed to play an important role in explaining the relatively higher control that teachers placed on their students' learning of science in their NBC portfolios.

In summary, we might conclude that the teachers in the study exemplified their inquiry-oriented teaching practices in NBC portfolios through exposing their students to science activities. The most noticeable theme that emerged as the essence of those experienced science teachers' teaching performances of classroom inquiry can be phrased as allowing students to reach their own conclusions supported with the actual evidence that they gathered from conducting their science activities. It would not be wrong to say that those experienced science teachers were able to have the students experience the five essential features of the classroom inquiry identified by NRC (2000) in their teaching practices of inquiry. All of the activities that teachers used with their students involved collecting data to draw conclusions. And teachers were deliberate about helping their students conduct their activities but avoiding from supplying the correct answers. However, their practices of inquiry with their students left little room for student autonomy in their learning experiences. Although they intended students to build their own understandings from inquiry experiences, which was driven by constructivist rationales, they failed to create a classroom environment in which

students had more opportunities in governing their own learning experiences. The relatively higher structure of the activities counteracted their efforts of involving students more into developing their own conclusions based on the available evidence from the activities.

STIR Analysis of Inquiry Teaching Practices of NBCSTs

Table 16 STIR Analyses of Classroom Inquiry

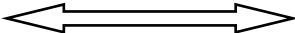
A-Teacher provides an opportunity for learners to engage with a scientifically oriented question.				
	Teacher provides learners with specific questions to be investigated.	Teacher offers learners a list of questions from which to select.	Teacher suggests topic areas to help learners formulate own questions.	Learner is prompted to formulate own questions to be investigated.
Jennifer	Jennifer started the bean activity with the general question of scientists' ways of determining the atomic mass of the chemical elements. In the analogical approach of bean activity, her students' task was to devise a procedure to find the number of beans in a cup without counting but weighing.			
Patricia	Patricia initiated the mirror activity with her students in the context of kaleidoscopes' working mechanism. The question to be investigated by students involved finding the number of images on the adjacent mirrors positioned with variety of angles.			
Martha	Martha introduced her students to a real life problem of water contamination in an imaginary town called Fruitvale, and wanted them to find out the source and the extent of the contamination.			
Mary	Mary asked her students to find the best parachute design in landing the rockets safely through testing the three sizes of parachutes prepared by students.			
More Teacher-Centered  More Student-Centered				

Table 16 Continued

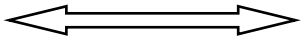
B1-Teacher engages learners in planning investigations to gather evidence in response to questions.				
	Teacher provides the procedures for the students to conduct the investigation.	Teacher provides guidelines for learners to plan and conduct part of an investigation. Some choices are made by the learners.	Teacher encourages learners to plan and conduct a full investigation, providing support with making decisions.	Learners develop procedures to independently plan and conduct a full investigation.
Jennifer		Students were asked to predict the number of beans in their cups without counting but with the method of weighing. The procedures for weighing the beans in the cups were decided by students. For instance, some weighed only one bean whereas others took the average weight of more than one bean.		
Patricia	Students were given clear instructions on what procedures to follow in finding the number of images occurring on the two adjacent mirrors, which also included the angles to be used between the mirrors.			
Martha		Students knew that they needed to test water wells for determining the levels of water contamination in them. However, they were expected to choose 12 out of 40 water wells strategically to test for finding the actual source of the water contamination. Therefore, each group of students had the chance to test different wells based on the emergent test results.		
Mary	Students were provided the clear procedures for determining the best functioning parachute from three pre-designed parachute models. Students were not given a chance to decide what to control in order to find the best parachute because they had already three parachutes with different sizes to test.			
More Teacher-Centered  More Student-Centered				

Table 16 Continued

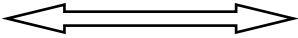
B2-Teacher helps learners give priority to evidence which allows them to draw conclusions and develop explanations that address scientifically oriented questions.				
	Teacher provides data and gives specific direction on how data is to be analyzed.	Teacher provides data and asks learners to analyze.	Teacher directs learners to collect certain data. Often provides procedures for data collection.	Learners determine what constitutes evidence and develop procedures for gathering and analyzing relevant data.
Jennifer			The nature of the bean activity required students to take the weight measurements of the beans in the cups.	
Patricia			The mirror activity specified the necessary data to collect for students, value of angles versus number of images.	
Martha			The Fruitvale activity involved testing the water wells for their contamination levels.	
Mary			The rocket activity identified the required data to collect for testing the functioning quality of the parachutes. Students measured the length of the landing time of rockets.	
More Teacher-Centered  More Student-Centered				

Table 16 Continued

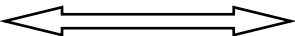
C-Learners formulate conclusions and explanations from evidence to address scientifically oriented questions.				
	Teacher directs learners' attention to specific pieces of analyzed evidence to lead learners to predetermined correct conclusion.	Teacher directs learners' attention to specific pieces of analyzed evidence to draw conclusions.	Teacher prompts learners to think about how analyzed evidence leads to conclusions, but does not cite specific evidence.	Learner is prompted to analyze evidence and formulate own conclusions.
Jennifer		Jennifer intended to show her students that basing one's answer on weighted averages would produce more accurate results or less percent error in predicting the number of beans in the cups. However, student results were not consistent enough to lead such conclusion because some students were able to find very small percent error despite building their answer on the weight of one bean.		
Patricia	Patricia directed her students' attention to the relation between the angles of the mirrors and the number of images observed on the mirrors. Some students were able to devise a formula to represent the relation between the value of the angles and the number of images. The results that failed to lead students to such relation were attributed to the faulty data.			
Martha		Martha explained to her students that the test results of Level 4 and Level 5 represented the high contamination. She then asked her students to draw a plum border on their maps to capture the highly contaminated areas that their well testing results suggested. Each student predicted the source of the contamination with the help of their well testing results.		
Mary		Mary focused her students' attention to two criteria for determining the functioning quality of parachutes: having the ability to deploy and keeping the rockets longer on the air. Students gave their decisions in the light of those two criteria with the help of parachute data.		
More Teacher-Centered  More Student-Centered				

Table 16 Continued

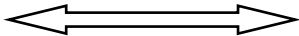
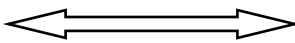
D-Learners evaluate their conclusions in light of alternative explanations, particularly those reflecting scientific understanding.				
	Teacher explicitly states specific connections to alternative conclusions, but does not provide resources.	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions. Instead, the teacher identifies related scientific knowledge that could lead to such alternatives.	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions. Teacher may or may not direct learners to examine these resources.	Learner is prompted to examine other resources and make connections independently.
Jennifer	Jennifer made the explicit connections to scientists' method of using the weighted average of all naturally occurring isotope atoms of chemical elements in determining their corresponding atomic masses. She explained the importance of proper sampling methods and repetition of trials in enhancing the reliability of experimental results.			
Patricia		Patricia directed her students' attention to the reflection phenomenon of visible light and wanted her students to build a kaleidoscope based on the information, which they learned from the mirror activity, about the relation between the value of angles and the number of images on the mirrors.		
Martha		Martha described the relevant terms like ppb (parts-per-billion), watershed, aquifer, aquitard etc. and expected from her students to give their informed decisions with the help of those scientific terms. She explained the student results that did not match with the master contamination map with sampling error.		
Mary	Mary demonstrated the phenomenon of potential and kinetic energy conversions clearly to her students with the help of her pen in her hand although the relation between the parachute data and the energy concept was not as clear.			
More Teacher-Centered  More Student-Centered				

Table 16 Continued

E-Learners communicate and justify their proposed conclusions and explanations.				
	Teacher specifies content and layout to be used.	Teacher provides possible content to include and layout that might be used.	Teacher talks about how to improve communication, but does not suggest content and layout.	Learners specify content and layout to be used to communicate and justify their conclusions.
Jennifer	Jennifer directed the discussion through posing relevant questions to her students. The students who raised their hands provided their answers to the question.			
Patricia	Patricia asked student groups whether they were able to devise a formula for the relation between angles of the mirrors and the number of images. Students shared their results with their teacher.			
Martha	Martha asked questions to her students in a small focus group format. The communication of the students was solely based on student-teacher interactions.			
Mary	Mary actively managed the discussion through her questions and explanations in a small group environment. In this environment, students played passive roles mostly in justifying their results.			
More Teacher-Centered  More Student-Centered				

CHAPTER 9

DISCUSSION, CONCLUSIONS AND IMPLICATIONS

Introduction

In the previous chapters of the dissertation study, I presented the perspectives of four experienced science teachers with recognized teaching abilities by NBPTS on the role of NBC in the professional growth of teachers and the meaning of practicing inquiry in the classroom. In this final chapter of the dissertation, I provide the specific conclusions, which emerged from the analyses of various teacher-related data sources, accompanied by the discussions of those conclusions in connection to the education literature. I then describe the possible implications of the conclusions for science education community.

The general structure of the discussions in this final chapter of the dissertation study centers on my research questions. Following are the research questions that I investigated in this study.

A) What does undergoing NBC assessment process mean for NBCSTs?

1. How do NBCSTs see the role of NBC in their professional development?
2. What learning experiences do NBCSTs identify with NBC assessment process?
3. Does NBC experience create a higher affiliation with science education reform ideas?

B) What is the meaning of practicing inquiry in classroom for NBCSTs?

1. What are NBCSTs' conceptions of classroom inquiry?
2. How did NBCSTs enact inquiry in NBC portfolios?
3. What do NBCSTs intend to accomplish with their students in their practices of inquiry?
4. What hurdles do NBCSTs identify with practicing inquiry?

The Role of NBC in Professional Development of Science Teachers

The important role of teachers is undisputable in the success of any education reform movement (NRC, 1996). That is primarily because teachers are the sole stakeholders of the enactment of reform ideas at the micro level of classroom. That is why having quality science teachers with the capabilities of implementing science education reform in their classrooms is essential for turning the reform ideals into the reality. NBC as a new generation of teacher assessment procedure not only determines the quality science teachers but also helps them become better teachers (Darling-Hammond, 2001; Lustick, 2002; Vandevoort, Amrein-Beardsley, & Berliner, 2004). Undergoing the rigorous assessment process of NBC is described by many teachers as a rewarding professional development experience (Lustick & Sykes, 2006). However, NBCSTs in this dissertation study considered their involvement into the assessment process of NBC not as a deeply influential professional development experience. For participant teachers, their experiences with NBC portfolio assessment procedure played an affirmational rather than a transformational role in their professional growth as science teachers. This meant that passing the rigorous assessment procedure of NBC strengthened their existing notions of teaching science. In other words, they came out of NBC portfolio assessment process with an elevated confidence in their existing teaching practices of science. Thus, NBC experience failed to encourage those teachers to develop alternative notions of teaching science. Although this finding stood somewhat in opposition to the majority of research studies that suggested the important place of NBC in teachers' professional development, some scholars in the education literature reached the similar conclusions as this dissertation study. For instance, Lustick (2002) discussed the affirmational role of NBC in teachers' professional development as follows:

Initially, I had hypothesized that the process of National Board certification might help change a teacher's particular beliefs and values about teaching..., I now believe this to be inaccurate. Rather, National Board certification acted as a mirror for candidates to gaze into their practice and gain a much desired affirmation of their way of teaching. (p.18)

Likewise, several teachers in Chittenden and Jones' (1997) research study brought the affirmational role of NBC assessment in their professional teaching careers: "Several described the assessment as 'affirming' or 'validating' what they believed, noting that it helped them become clearer about their philosophy, and more articulate regarding the assumptions that shaped their instruction" (p.27). Interpreting the affirmational role of NBC under the light of teachers' existing notions of teaching science might help us develop a broader understanding of the potential meaning of NBC for science education community. The teachers in the study were not equally open to science education reform ideas. Especially, two of NBCSTs in the study kept a noticeable distance from reform-oriented teaching ideas. The successful completion of NBC assessment process sharpened their confidence into their existing notions and ways of teaching science. In other words, rather than creating a higher affiliation with science education reform ideas, their participation in the assessment process of NBC strengthened their rather conventional perspectives of teaching science. In that respect, it was hard to suggest that undergoing NBC assessment process led teachers, who held more traditional views of teaching science, to adopt the central tenets of science education reform documents.

However, those conclusions need to be interpreted carefully because the affirmational experiences of those participant teachers with NBC assessment procedure do not necessarily mean that not a single teacher undergoes a transformational experience in their teaching practices of science as a result of pursuing NBC. In some cases, teachers who fail in their attempt to get their advanced teaching certificate report the high value of NBC assessment process in their professional development (Lustick & Sykes, 2006; Vandevoort & Berliner, 2004). All of the teachers in the study started their NBC journey with many years of science teaching experiences. Although they were not equally open to the ideas promoted in science education reform documents, none of them supported teaching science directly from textbooks in a most traditional manner. Rather, they used variety of different resources and activities in their science classes. With many years of teaching experience, they managed to perform their science teaching tasks successfully. They had the capabilities of aligning their teaching practices of science to advanced teaching standards of NBC with only slight modifications (Lustick, 2002). Except one, they achieved their advanced teaching

certificates with NBC in their first attempts. Those slight modifications made by participant teachers to satisfy the teaching standards of NBC were far from creating a transformational effect on their notions and ways of teaching science. The teachers who spend more effort by making significant differences in their teaching practices might have a more transformational experience in their teaching philosophies of science.

The intentions of candidate teachers in pursuing the advanced teaching certificate with NBC might be regarded as another important factor for affecting the potential benefits of NBC professional development experience for teachers. Participant teachers agreed that the NBC assessment process would be more rewarding for teachers who started NBC assessment process with sincere intentions to grow professionally in their teaching careers. Candidate teachers identify various reasons for their pursuance of advanced teaching certificate with NBC in the education literature. Chief among those include monetary incentives, affirmation of teaching excellence, and professional development (Kelley & Kimball, 2001). It was difficult to suggest that the teachers in the study started their NBC assessment journey with the primary motive of growing professionally in their science teaching careers. They saw NBC assessment process as a good opportunity for obtaining an outside validation of their accomplished science teaching abilities. Other than that, financial incentives played a significant role in their decision for pursuing their advanced teaching certificates with NBC. Therefore, the limited influence of NBC on the professional development of the participant teachers might be attributed to their original intentions for undergoing the assessment process of NBC. Their intentions with NBC process did not necessarily involve developing professionally in their teaching practices of science.

NBPTS introduced reflective practice as one of the most important outcomes of NBC as a professional development experience for teachers. Teachers in the study valued the reflective process that they underwent in their preparation of NBC portfolios. Although reflecting on their teaching did not necessarily lead them to generate new accommodations in their teaching practices of science, systematic and persistent analysis of their teaching practices helped them to better understand the underpinning psychological reasons of their teaching actions. Never before in their professional science teaching careers had they verbalized the dynamics of their science teaching

practices. They had always their educational reasons in their minds, yet verbalizing their thoughts helped them clarify their ideas better. Teachers' involvement in the portfolio assessment process of NBC reminded them of the important place of reflection in improving the quality of their science teaching practices. However, this did not necessarily mean that they developed a habitual behavior of reflection on their teaching practices of science in a consistent manner.

The ultimate goal of professional development experiences of teachers is to create a change in their views and ways of teaching science. However, change is a complex process that involves taking into account the individual factors (NRC, 2000). Every individual teacher goes through the process of professional development with their unique experiences. And they "are not equally open to, capable of, or prepared for change" (Beck & Cowan, 1996, p.76). Beck and Cowan identified people with respect to their potentials for change on a continuum from "open" to "arrested" to "closed." Some teachers start their professional development journeys with more resistance to change. This implies that undergoing a professional development experience does not necessarily produce same levels of change in teachers. Depending on their potentials for change, they might come out of their professional development experiences with different professional gains. Although the reflective process of NBC allowed the participant teachers in this study to examine their teaching practices of science, it was not capable of leading the teachers to embrace new views of teaching science. Undergoing a radical change by these experienced teachers was not an easy endeavor because they had developed firm beliefs in their ways of teaching through many years of classroom teaching experiences.

Wilber (1995) described two modes of change in human development: translational and transformational. In Wilber's human development model, translation corresponds to a horizontal change in surface structures whereas transformation involves a vertical change in deep structures. Wilber explained these two modes of change with the following three-story building analogy: "Each of the three main floors is a deep structure; the furniture, chairs, and tables on each floor are the surface structures. Rearranging the furniture on any given floor is translation; changing floors is transformation" (p.61). According to Wilber (1997c), translational change "provide[s]

legitimacy to the self—legitimacy to its beliefs, its paradigms, its worldviews, and its way in the world” (Translation versus Transformation, ¶ 12). Transformational change, on the other hand, “does not seek to bolster or legitimate any present worldview at all, but rather to provide true authenticity by shattering what the world takes as legitimate” (Wilber, 1997c, Translation versus Transformation, ¶ 15). The successful completion of NBC performance assessment process by the participant teachers in this dissertation study legitimized the superiority of their existing views of teaching science. In order to achieve their advanced teaching certificates with NBC, they made some arrangements with the furniture in their floors to make it look like the decoration of NBC standards. However, they did not necessarily move from one floor to another. The translational change that they experienced as a result of their involvement in NBC process did not create authentic changes in their views and practices of teaching science. NBC assessment process allowed the teachers to reflect on their teaching. Although the reflective process of NBC was successful in providing the support to strengthen their own identity as strong teachers, it failed to introduce them to the challenge of questioning their views of teaching science deeply under the light of science education reform ideas. It is possible to suggest that while for many the NBC assessment process assists in a translational strengthening of identity, it lacks a transformational push to move teachers to a more complex and sophisticated view of teaching science.

Teachers in the study enjoyed the professional recognition that their advanced science teaching certificates brought to them. The professional respect was primarily due to the challenging nature of completing the portfolio assessment process of NBC. Satisfying the advanced teaching standards of NBC presents a big challenge to many science teachers. Their successful completion of NBC assessment process was an important indication of their accomplished science teaching practices. However, teachers were careful to give an accurate account of NBC assessment process. They felt that the main assessment target of NBC focused on science teaching capabilities of teachers rather than their everyday teaching practices of science. That was simply because teachers presented their best teaching capabilities in their portfolios. Teachers agreed that the assessment process of NBC was fair enough in determining quality science teachers with accomplished teaching capabilities. However, they acknowledged

the importance of having good writing skills in order to pass the rigorous assessment process of NBC. In other words, having strong writing capabilities in addition to quality teaching practices increased teachers' chances of achieving their advanced teaching certificates with NBC.

Although teachers' successful completion of NBC assessment process was not necessarily an indicator of their close affiliation with science education reform ideas, they were capable of exemplifying their practices of classroom inquiry successfully in their portfolios. Yet, the specific meanings that they attributed to classroom inquiry are still an important question waiting to be answered. In the following sections, I discuss inquiry conceptions of those experienced science teachers whose accomplished teaching abilities were recognized by NBPTS.

Inquiry Conceptions of the Teachers

Inquiry is one of the most prominent terms of latest science education reform movements (Buck, Latta, & Leslie-Pelecky, 2007; Colburn, 2006). Yet, the various meanings attributed to the term inquiry by science teachers present a potential threat to the success of reform ideas. Wheeler (2000) recognized this reality in his following statement: "Inquiry itself a core tenet of the standards and the ambiguity surrounding it is a threat to reform efforts" (p.14). Biological Sciences Curriculum Study (2005) shared the similar concerns about the vague meaning of inquiry: "Mistaken notions about inquiry serve to deter efforts to reform science education" (p.27). Investigating the various meanings given to inquiry by science teachers is important for the future success of the reform movements (Jones & Eick, 2007). And if those science teachers are the ones whose accomplished teaching capabilities have been recognized by NBPTS like in this study, it is more crucial to understand their conceptions of classroom inquiry because they have the potential for influencing other science teachers in their schools. NBPTS (2006) described the various roles of NBCSTs in the school system as follows:

Recognized for their experience and expertise, National Board Certified Teachers may work with administrators and colleagues on curricular and instructional issues and may serve as mentors to new teachers and as

exemplars for their peers, thus spreading their knowledge and skills across a much broader landscape than is typically the case. (p.5)

Articulating classroom inquiry conceptions of those accomplished science teachers informs science education community about the possible roles of those teachers in the future success of science education reform.

My analysis of the perspectives of NBCSTs in the study indicated that their conceptions of classroom inquiry were driven either by scientific rationales or constructivist rationales (Furtak, 2006). For this reason, I present their notions of classroom inquiry under these two groups. Scientific rationales in general refer to introducing students in their classrooms into the cognitive experiences and the actions of practicing scientists. Constructivist rationales pertain to allowing students to generate their own understandings actively from their classroom experiences rather than acquiring information from their teachers passively.

Inquiry Conceptions Driven by Scientific Rationales

Recent trend in science education promotes introducing students in their classrooms into the thinking processes and the activities of practicing scientists. In parallel to this objective, science teachers are asked to engage their students in meaningful classroom inquiry experiences, which is consistent with the practice of science. Following are some quotes that reflect this trend in science education community: "Teaching should be consistent with the nature of scientific inquiry" (AAAS, 1993). "School science education must reflect science as it is practiced" (National Committee on Science Education Standards and Assessment, 1992, p.12). "Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing real science" (Ash & Klein, 2000, p. 227). "The analogy of the pupil as a scientist" (Izquierdo-Aymerich & Aduriz-Bravo, 2003, p.27) can be given as a good example to denote the new expectations of science education community from students by taking the same roles of practicing scientists in their science classes. However, promoting this approach puts classroom inquiry into a challenging and a problematic position for teachers in three respects: 1) Teachers are expected to develop sophisticated knowledge on the actual practices of scientists 2) Teachers are given the impression that school science builds on the same epistemological foundations of real science 3)

Teachers are restricted from creating broader images of classroom inquiry. In the following paragraphs, I will articulate those problematic positions in connection to the inquiry conceptions of NBCSTs in the study.

Imitating the similar experiences of practicing scientists in science classrooms requires teachers to develop more sophisticated understandings of the scientific inquiry process. However, this is not an easy task for teachers to do because no single approach representing the work of all scientists in their scientific endeavors exists for teachers to model in their classrooms. Indeed, giving an accurate account of the nature of the cognitive processes and the actions of practicing scientists presents many challenges to scholars (Lawson, 2005). Inductive or deductive or hypothetico-deductive nature of scientific inquiry is still the subject of controversy for many scholars (Lawson, 2005). Even scientists who actively practice science may not provide an accurate picture of their scientific reasoning patterns because they do not necessarily give enough thought about their actions in the process of generating scientific knowledge (Lawson, 2005). Therefore, introducing students in their classrooms to the scientific reasoning processes of practicing scientists presents a big challenge to teachers. That is because the dynamic nature of the scientific inquiry mechanism, which exhibits differences from one field of science to another and from one individual scientist to another, keeps it from being formulated in a simple manner for teachers to transfer easily into their classroom contexts. The specific cases in this study indicated that NBCSTs lacked a sophisticated understanding of the scientific inquiry process. They tended to equate the knowledge building process of science with empirical practices of scientists. Accordingly, their conceptions of classroom inquiry involved introducing students to the cognitive processes and the actions of scientists by engaging them into empirically driven laboratory science activities. In addition, they promoted the important place of the scientific method in enacting inquiry with their students. However, their perception of the scientific method consisted of well-known linear steps to be followed by students in their classroom inquiry experiences. Even if they refrained from reducing the scientific method into simple linear steps, their practices of inquiry still involved using the traditional model of the scientific method.

The history of the traditional representation of the scientific method in schools goes back to John Dewey (Biological Sciences Curriculum Study, 2005; Rudolph, 2003). Dewey (1910) introduced the idea of students' learning of the scientific method in their classrooms to science education community. Today, scientific inquiry in schools is almost equated to the traditional portrayal of the scientific method with simple steps to be followed in practicing science (Finley & Pocovi, 2000). Finley and Pocovi (2000) explained the underpinning reasons for the high profile of the scientific method in the history of science education community:

Our profession has always sought something we could teach that would make problem solving easier and critical thinking more precise. We thus have been seeking a magical intellectual prescription—a way of thinking that is learnable in a finite time with limited resources, and applicable to multiple areas of our life. We have good social, political, and economic reasons to believe that the scientific method can be that prescription and there has been extensive additional support from various philosophical and psychological theories. The method appears to be simple to understand and simple to teach. There are a few steps to learn, they can be used over and over again, and each step in its own right seems to be achievable by students at various ages and levels of knowledge and skill. (p.51)

On the other hand, many scholars today agree that scientific inquiry process does not follow a linear pathway as it is presented popularly in traditional version of the scientific method (Bauer, 1994; Biological Sciences Curriculum Study, 2005; Finley & Pocovi, 2000; Gauch, 2003; Grandy & Duschl, 2007; Hodson, 1998; Spiece & Colosi, 2000; Windschitl, 2004). Bauer (1994) considered the traditional scientific method as “an ideal—an admittedly unattainable ideal—[but] not as a description of actual practice” (p.39). Grandy and Duschl (2007) criticized the conventional representation of the scientific method due to the fact that it “oversimplif...[ies] the nature of observation and theory and almost entirely ignores the role of models in the conceptual structure of science” (p.144). However, many school textbooks continue displaying the oversimplified version of the scientific method for students to learn in their science classes (Spiece & Colosi, 2000). Reiff (2004) described the portrayal of science by

school textbooks as “sterilized versions of scientific processes” (p.19) by implying their failure to give an accurate representation of the complex efforts of scientists in their scientific endeavors. The sequential flow of the presentation of scientific findings published in scientific reports also misleads people to believe that scientists conduct their research studies by following a stepwise linear pathway (Biological Sciences Curriculum Study, 2005; Reiff, 2004). As it was the case with teachers in this study, the misrepresentation of the scientific inquiry process in popular science plays an important role in perpetuating the naïve ideas held by teachers about science and scientists (Spiece & Colosi, 2000).

Before giving their students appropriate experiences of scientific inquiry in their classes, science teachers themselves need to develop better models of practicing science in their minds (Wallace & Kang, 2004). However, that is not an easy task for teachers to achieve because “science is a...messy process of inquiry” (Ramalay, 2003, p.228). Polanyi (1958) argued that practicing science is “an art which cannot be specified in detail” (as cited in Rudolph, 2003, p.74). Hurd (2002) shared the similar thoughts with Polanyi in his following argument:

Traditionally, the focus of science teaching has been on presumed inquiry procedures used by scientists. Students are expected to learn and practice these processes and to “think like a scientist.” However, there is no standard method for the practice of science. Today research in the sciences is viewed more as a craft or an art, more like problem solving. (p. 5)

Based on the discussions of scholars about science in the literature, one might come to the conclusion that learning the art of scientific inquiry requires teachers to have direct experiences with the actual practice of scientific research. As Polanyi (1958) argued, the process of scientific inquiry “cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice” (as cited in Rudolph, 2003, p.74). Hodson (1998) supported the similar ideas about the important role of experiencing actual scientific research process in learning to practice science:

One cannot learn to do science by learning a prescription or a set of processes to be applied in all situations. The only effective way to learn to do science is by

doing science, alongside a skilled and experienced practitioner who can provide on-the-job support, criticism and advice. (p.200)

Therefore, teachers' exposure to real scientific research experiences is crucial in developing appropriate models of scientific inquiry, on which they can build their practices of classroom inquiry with their students (Windschitl, 2004). NBCSTs in the study thought that having science research experience was helpful for practicing classroom inquiry with their students but not necessary. However, none of the teachers had a prior scientific research experience in a field of science. Their somewhat naïve notions of scientific inquiry, on which they based their classroom inquiry teaching practices, were primarily shaped by the popular representation of science portrayed as an experimental process conducted through the involvement of the traditional scientific method. Even if they denied the existence of a single scientific method to represent the practices of scientists as in the case of Patricia, they were not able to create an alternative model of scientific method to be used with their students in their classroom inquiry experiences. This might be interpreted in a way that teachers need real experiences of the scientific research process in order to develop more accurate representations of scientific inquiry process in their minds.

In my previous arguments based on science education literature, I tried to denote the challenge in drawing an accurate picture of actions and thinking processes of scientists in their efforts for generating scientific knowledge. Ironically, science teachers are expected to build sophisticated understandings of the scientific inquiry process to be able to give appropriate classroom inquiry experiences to their students consistent with the practice of science. In an environment surrounded by many controversies about the true nature of the scientific inquiry, finding a readily available solution for educating teachers equipped with the knowledge and the abilities necessary for the practice of inquiry is a challenging task for science education community. Another dimension of the discussion needed to be addressed is the epistemological foundations of school science and real science. The general approach promoted by science education reform to introduce students in their science classes to the similar type of experiences of scientists bears the connotations that school science experiences of students reflects the same epistemological grounds of the real practice of science (Flick, 1997). Although

that is one of the ideals of current science education reform movements, fulfilling this ideal in classroom conditions is a topic open to debate (Waight & Abd-El-Khalick, 2007). Therefore, it is important that teachers develop a better understanding of the limitations of school science experiences of students in comparison to real science. This helps them to be more realistic about the inquiry experiences of their students in their science classes. NBCSTs in the study did not see much difference between inquiry practiced by scientists and performed by students. They were confident that they could introduce students to the similar experiences of scientists through engaging them into “experimental” science activities. However, acknowledging real science and school science on the same epistemological grounds restricts teachers’ ability to construct alternative models of classroom inquiry.

Teachers in the study gave a special emphasis to the role of “experimentation” in their students’ learning of scientific inquiry process. This experimental approach to exposing students to the similar actions and thinking processes of scientists is one of the most common ways for teachers in their classroom inquiry practices (Grandy & Duschl, 2007; Windschitl et al., 2007). School science experiments are assumed by science teachers to be a good representation of the actual practices of scientists. However, Hodson (1998) criticized this assumption in his following argument: “Scientific experimentation is not a simple matter, and science education that portrays it as such is misleading” (p.194). Likewise, Izquierdo-Aymerich and Aduriz-Bravo (2003) shared the similar thoughts about the place of experiments in school science: “Experimentation cannot have the same place in school science as in the science of scientists, nor the same epistemological value” (p.37). Chinn and Malhotra (2002) found “the epistemology of many school inquiry tasks is antithetical to the epistemology of authentic science” (p.175). Representing the activities of scientists with experimental approaches fails to capture a broader understanding of the actions of scientists (Windschitl et al., 2007). Grandy and Duschl (2007) pointed out the narrower representation of science in current science education community:

Science education continues to be dominated by hypothetico-deductive views of science while philosophers of science have shown that scientific inquiry has other equally essential elements: theory development, conceptual change, and

model-construction. This is not to imply that scientists no longer engage in experiments. Rather, the role of experiments is situated in theory and model building, testing and revising, and the character of experiments is situated in how we choose to conduct observations and measurements...The danger is privileging one aspect of doing science to the exclusion of others. (p.143)

All those arguments made by different scholars indicate the limitations of school science in introducing students to the similar epistemological considerations of scientists. However, science teachers including the experienced ones in this study tend to assume that engaging their students in experimentally driven science activities in their classrooms gives them appropriate understanding and experiences of the scientific inquiry process (Hart et al, 2000). In that sense, developing a better understanding of the limitations of school science is necessary for teachers because this makes them more cognizant of the relative values of various classroom inquiry tasks in introducing their students to the actions and the thinking processes of scientists. Science teachers who fail to develop a more realistic understanding of the place of school science experiences of students in their learning of scientific reasoning skills are subject to conceptualize simple inquiry tasks as sufficient experience for students to delve into the complex works of scientists. Teachers in their inquiry teaching practices need to recognize the differentiating goals of scientists and students to achieve in their respective contexts. Scientists perform their jobs for explaining the unknowns for all humanity whereas students struggle to settle their personal unknowns (Izquierdo-Aymerich & Aduriz-Bravo, 2003). In comparison to novice students, scientists, who are experts in their specific fields (Biological Sciences Curriculum Study, 2005), “choose the problems that interest them, create their own theoretical models and their own language” (Izquierdo-Aymerich & Aduriz-Bravo, 2003, p.33). Teachers need to understand that creating the appropriate opportunities for students to help them experience the similar reasoning patterns of practicing scientists is not a simple matter to be accomplished with unauthentic experimental activities.

In my previous arguments, I presented the different epistemological assumptions of school science and real science. However, the idea of placing students into the roles of practicing scientists gives an impression to the teachers that school science functions

on the same epistemological grounds with real science. This approach trivializes the distinct roles taken by scientists and students in their respective endeavors and misleads teachers to believe that experiencing the similar reasoning patterns of scientists can be attainable easily by engaging students into simple inquiry tasks in their classrooms. The effort of replicating the similar activities and thinking processes of practicing scientists for students to experience the scientific inquiry process in their science classes might play an important role in perpetuating science teachers' inability for developing broader perspectives of classroom inquiry experiences with their students. Accordingly, teachers, including the ones in this study, tend to conceptualize classroom inquiry as a platform for students to experience the scientific inquiry process with no reference given to learning scientific concepts. That is partly because the current model of classroom inquiry has been built on the ideas of two distinctive figures of science education, John Dewey and Joseph Schwab, who "placed a distinct emphasis on process over content" (Rudolph, 2003, p.68).

NRC (1996) avoided advocating a single scientific method for teachers to use with students in their classroom investigations. Likewise, NBPTS (2003b) refrained from equating student investigations with following a simple set of steps: "In the classrooms of accomplished science teachers, the scientific process is not a linear series of steps but a cyclical process based on data collection and the continual refinement of questions" (p.39). However, NBCSTs in the study tended to reduce the meaning of student investigations into experimentally driven laboratory experiences of students. This showed that teachers had difficulty in developing more sophisticated operational models of classroom inquiry than the experimental approach (Crawford, 1997; Songer, Lee, & McDonald, 2003; Windschitl, 2004). This narrower image of classroom investigations of students kept participant teachers from using inquiry with their students in a broader perspective.

NRC (1996) promoted inquiry as "the central strategy for teaching science" (p.31). However, in order for this perspective to gain a wider approval by science teachers, they need to build broader models of classroom inquiry to use in their teaching practices of science (Schwarz & Gwekwerere, 2007). Otherwise, the general perception of classroom inquiry as experimental experiences of students promotes their

notions of inquiry as an ineffective strategy for teaching scientific concepts. When teachers conceptualize classroom inquiry as an incompatible mean of teaching science concepts to students, they tend to resist acknowledging inquiry as a central strategy in their science teaching. This indicates the need for more inclusive models of inquiry, which promise better acceptance by teachers in teaching both the processes and the content of science to their students. Flick (1997) noted that “the common model of inquiry as a scientific investigation or controlled experiment should be understood as having limited pedagogical use” (p.5). Teachers need to recognize that placing students into experimental experiences is just one dimension of classroom inquiry process (Windschitl et al., 2007).

“Experimental” experiences of students found itself a place in the advanced science teaching standards of NBPTS (2003c). As can be noticed from the following statements, NBPTS (2003c) recognized “the experimental approach” as one of the important classroom inquiry experiences of students:

Teachers also understand the experimental approach, which is typically identified as “scientific inquiry,” and in which the teacher and/or students select a problem to investigate, design a method for investigating it, conduct the experiment or investigation, and then analyze and report the results. (p.40)

However, NBPTS (2003c) avoided equating classroom inquiry with the experimental science activities of students. Other than “the experimental approach”, NBPTS (2003c) considered a rational approach as a valuable inquiry experience for students as well:

Science teachers may use a rational approach, which directs students to generalizations by the use of reason and entails the use of open-ended questions. They may employ deductive inquiry activities, in which students work with concepts and general ideas in efforts to narrow down solutions to specific answers. (p.40)

Although NBPTS (2003c) included different forms of classroom inquiry in its advanced science teaching standards, participant teachers considered the experimental approach as the most intrinsic aspect of classroom inquiry process. However, NRC (1996) suggests a change in the dominant perception of “science as exploration and experiment” (p.113) among science teachers by placing more emphasis on “science as

argument and explanation” (p.113). Abell, Anderson and Chezem (2000) argued the failure of current representations of classroom inquiry, which was primarily built on the ideas of Schwab, in recognizing science as argument and explanation:

Schwab described a process of classroom inquiry that includes finding problems, collecting and interpreting data, and forging conclusions. This sounds very much like “science as exploration and experiment.” Schwab’s description fails to provide an adequate portrayal of inquiry in classrooms devoted to “science as argument and explanation.” (p.66)

NRC (1996)’s definition of full inquiry consisted of the following four essential elements: “Asking a simple question, completing an investigation, answering the question, and presenting the results to others” (p.123). In investigation stage of classroom inquiry experiences of students, NRC (1996) abstained from limiting the activities of students with “observation, data collection, reflection, and analysis of firsthand events and phenomena” (p.33) but also embraced “the critical analysis of secondary sources—including media, books, and journals in a library” (p.33). This could be used as a basis for a broader interpretation of classroom inquiry experiences of students to help them learn science concepts (Keys, 1997). Similarly, Sutton and Krueger (2001) noted that “reading, discussion, and research are fruitful techniques for practicing scientific inquiry when scientific questions and evidence-based arguments are used” (p.30). Hodson (1999) identified classroom inquiry in a general sense as “literature/media-based” (p.246) and in a more specific sense as “field experience/laboratory-based” (p.246). Based on NRC’s (1996) definition of full inquiry and Hodson’s (1999) classification of classroom inquiry as a general and a specific sense, I display an expanded view of classroom inquiry in Figure-8 below.

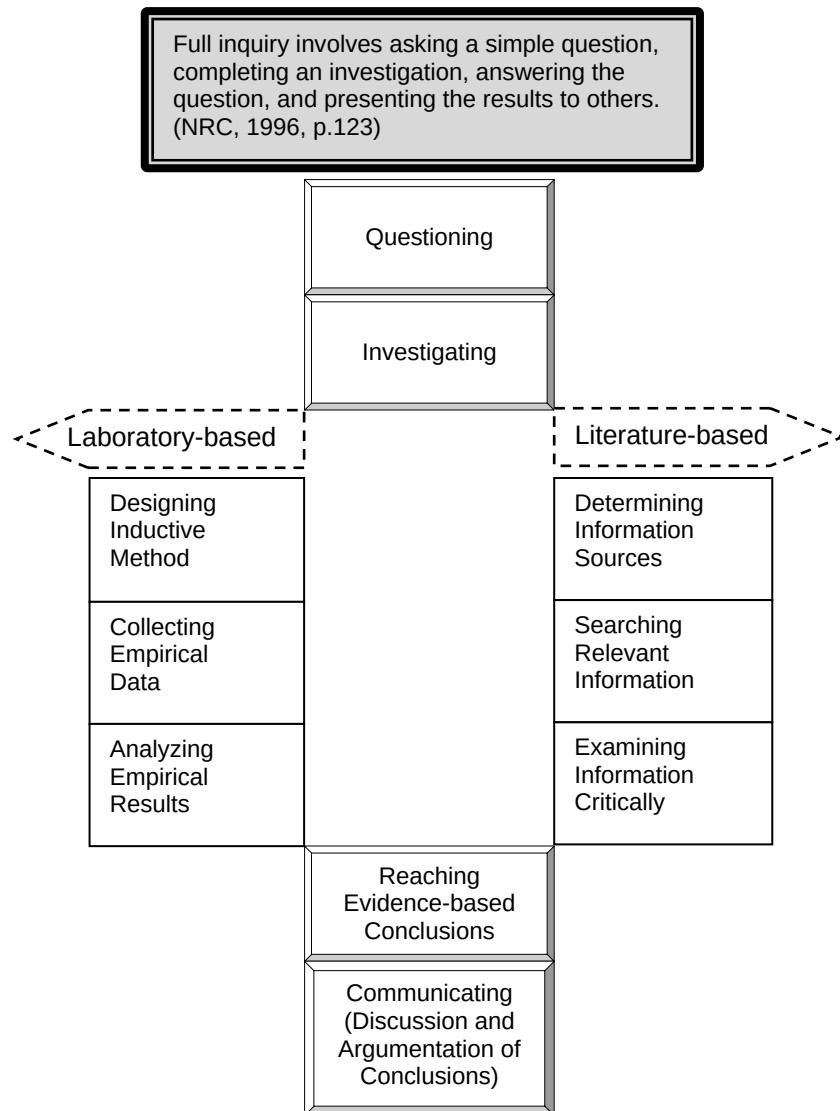


Figure 8 Expanded View of Classroom Inquiry

This model of classroom inquiry might be helpful for science teachers to conceptualize in a broader sense. NBCSTs in the study equated inquiry with students' experimental laboratory experiences and none recognized an alternative model of classroom inquiry. The expanded model presented here might enhance the functionality of classroom inquiry as a strategy of teaching both the processes and the content of science to students. Depending on the educational goals of teachers, the nature of questions to be investigated and the availability of resources, student investigations might take a form of either "laboratory-based" or "literature-based." Conceptualizing classroom inquiry in a broader sense allows science teachers to use inquiry teaching

strategies in their classrooms more effectively both with abstract and concrete science topics.

Inquiry Conceptions Driven by Constructivist Rationales

Science education reform documents envision students as active inquirers of knowledge rather than passive recipients of information. Achieving this vision involves giving higher levels of autonomy to students in their efforts of learning science (Bodzin & Beerer, 2003). However, this presents a dilemma to science teachers in their science teaching practices. Driver (1983) described this dilemma experienced by teachers in their inquiry teaching practices as “On the one hand pupils are expected to explore a phenomenon for themselves, collect data and make inferences based on it; on the other hand this process is intended to lead to the currently accepted scientific law or principle” (as cited in Furtak, 2006, p.455). Keys (1997) acknowledged the same dilemma faced by science teachers in their inquiry teaching practices: “Students need freedom to develop authentic knowledge, by building on their own ideas, yet science is an enterprise that has been constructed through the privileging of some ideas over others” (p.8). The arguments made by those scholars could explain the reluctance of NBCSTs to employ inquiry strategies to teach scientific principles to their students. Teachers in the study identified the autonomy given to students in their classroom investigations as an inseparable aspect of inquiry. They expected students to devise their own methods and to reach their own conclusions in their classroom investigations if they considered themselves practicing inquiry with their students. However, characterizing classroom inquiry with autonomy given to students created a conflict with their intentions of teaching science concepts to their students. Due to the fact that participant teachers perceived the level of student autonomy inversely proportional to students’ learning of scientific principles, they regarded classroom inquiry as an incompatible strategy for teaching scientific concepts. They classified any classroom activity with predetermined methods to follow in solving questions as “cookbook experiences” for students. And teachers found cookbook activities more effective in students’ learning of scientific principles. This discouraged teachers from using more inquiry teaching strategies in their classrooms at the expense of learning accepted scientific ideas. Developing a better understanding of inquiry continuum might be helpful for teachers to use the

different levels of inquiry effectively in their teaching of science to achieve different goals with their students. However, the dualistic notion of cookbook science and inquiry science held by teachers promoted their general attitudes toward inquiry as an unsuitable strategy for teaching science concepts. In the following paragraphs, I will give more details about the dualistic image of teachers about cookbook and inquiry science.

NBCSTs in the study found classroom inquiry experiences vital for the mental engagement of students. Even if students failed to solve their questions in their classroom inquiry activities, teachers considered the thinking efforts generated by students as valuable experiences for their learning. In order to promote students' mental engagements in their investigations, teachers brought the importance of student autonomy in choosing their own methods to solve their questions to the forefront. They argued that teachers needed to let students generate their own answers by following their own methods rather than giving them direct answers. Teachers also identified questioning as another important component of classroom inquiry in order to stimulate the mental capabilities of students. Without a doubt, student autonomy is one of the most important characteristic elements of classroom inquiry. However, the autonomy given to students exhibits differences from one level of inquiry to another depending on the educational goals intended to be achieved with students. Based on "the different levels of openness and permissiveness" (p.55) of laboratory science activities described by Schwab (1962), the three levels of classroom inquiry recognized commonly by science education community are structured, guided and open inquiry (Colburn, 2000). Schwab (1962) explained those three levels of inquiry briefly as follows:

At the simplest level, the manual can pose problems and describe ways and means by which the student can discover relations he does not already know from his books. At a second level, problems are posed by the manual but methods as well as answers are left open. At a third level, problem, as well as answer and method, are left open. (p.55)

Those various levels of inquiry are represented by many science educators on a continuum "by the degree of independence students have in asking and answering questions" (Windschitl, 2003, p.114) from confirmatory science experiences to open

inquiry (e.g. Bell et al., 2003; Bonnsetter, 1998; Colburn, 1997; Cuevas, Lee, Hart, & Deaktor, 2005; Tamir, 1991; Windschitl, 2003). The primary purpose of representing inquiry on a continuum is to ease the transitions of science teachers from one form of inquiry to the other level in their teaching practices of science. In this model, structured inquiry between confirmatory science experiences and guided inquiry plays a critical role in helping teachers make the required shift to transform cookbook experiences of students into more compatible forms of inquiry. On the contrary to the general recognition of inquiry continuum by science education community, NBCSTs in the study developed a dualistic understanding of cookbook and inquiry science. The duality centered on methods to be given to students or to be decided by students. In other words, teachers classified activities with predetermined methods by teachers as cookbook experience for students whereas they expected students to generate their own methods in their classroom inquiry experiences. This indicated that teachers failed to recognize structured inquiry in their description of cookbook and inquiry science. Teachers' failure to recognize structured inquiry might be regarded as one of the contributing factors to their consideration of inquiry as an unfitting strategy for teaching scientific concepts to students. Holding an image of structured inquiry in their minds would have caused teachers to evaluate the role of inquiry in students' learning of scientific concepts with a better judgment.

The existence of misconceptions about classroom inquiry among science teachers is not a secret. On the one hand, there are teachers who consider themselves practicing inquiry through leading their students to known answers (Biological Sciences Curriculum Study, 2005). On the other hand, there are teachers who believe that they fail to perform inquiry unless they engage their students into extensive open inquiry experiences, which closely imitate the reasoning patterns of practicing scientists (Biological Sciences Curriculum Study, 2005). One of those misconceptions expressed by some of NBCSTs in the study was to equate the true nature of inquiry with investigating questions whose answers were known neither by teachers nor by students. This notion primarily resulted from teachers' close association of classroom inquiry experiences of students with the actual practice of science. Another misconception was to accept student investigations conducted through given methods

by teachers as cookbook experiences for students. That was primarily because teachers had difficulty in distinguishing cookbook science from structured inquiry experiences. Although the two exhibit similar characteristics in many respects, cookbook science leads students to verify the known outcomes, which is communicated by the teacher in class beforehand, by following the given procedures in a step-by-step format (Bell et al., 2003). Structured inquiry, on the other hand, gives the opportunities to students to generate unknown conclusions in their investigation experiences although they are still guided with given procedures to follow in solving their questions (Windschitl, 2003). Therefore, structured inquiry experiences of students “lead rather than lag behind the classroom phase of science teaching” (Bybee, 2000, p.27) in making sure that students are introduced to untaught scientific concepts in order to allow them to construct their own understandings from classroom inquiry experiences. Making clear distinctions between different levels of inquiry continuum might help teachers, who find classroom inquiry unsuitable for teaching science concepts, use inquiry teaching strategies with their students more effectively. NBPTS (2003) expected that “accomplished science teachers use the entire spectrum of inquiry, from teacher-guided inquiry through student-driven investigations” (pp.39-40).

The analysis of NBCSTs’ teaching practices of inquiry with their students presented in their NBC portfolios indicated that they based their enactment of inquiry on science activities. Their teaching practices of inquiry were driven both by scientific and constructivist rationales. In order to help students experience the similar scientific reasoning patterns of scientists, they expected students to base their conclusions on actual evidences from their activities. Each activity involved collecting some type of data for students to draw their conclusions. In their enactments of inquiry, teachers refrained from giving direct answers to students in order to encourage them to generate their own understandings. However, it was difficult to say that teachers were able to give high levels of autonomy to their students in their classroom inquiry experiences. Although the structure of activities enacted by teachers in their NBC portfolios exhibited some differences from one to another, it would not be wrong to say that they directed students to the proper data to collect in order to reach their conclusions. This restricted students in deciding their own methods in an autonomous way. Teachers enacted inquiry with

their students in the context of a specific science topic. However, this did not necessarily mean that inquiry constituted the major teaching strategy to help students learn the scientific concepts. The inquiry activities were preferred by teachers as supplementary experiences for students to enhance their learning of science concepts, which was communicated by their teachers through direct instruction at earlier stages of their introduction to the science topics. In other words, teachers tended to regard inquiry experiences of students as supportive agents to their rather didactic presentation of science topics. Considering inquiry as a supporting agent indicated that teachers were not comfortable with teaching a whole science topic through inquiry teaching strategies. This was not in conflict with their general conceptions of inquiry as a major teaching agent for introducing students to the cognitive processes and actions of practicing scientists rather than the subject matter of science.

Teacher's tendency of using inquiry as a supplementary agent to more conventional teaching strategies of science concepts might be attributed to their failure to conceptualize classroom inquiry experiences of students in a broader sense. Developing alternative conceptions of inquiry might help teachers consider using inquiry to introduce their students both to the principles and processes of science. For that purpose, I propose the following model in Figure-9 below for teachers to use inquiry more effectively with their students. Depending on the needs of their students, science teachers might fulfill their educational goals driven both by scientific and constructivist rationales through adopting the general template of the model proposed in Figure-9. By considering that teachers had a general tendency for equating classroom inquiry with engaging students in laboratory-based science activities, this model might help teachers conceptualize teaching of science with a broader perspective.

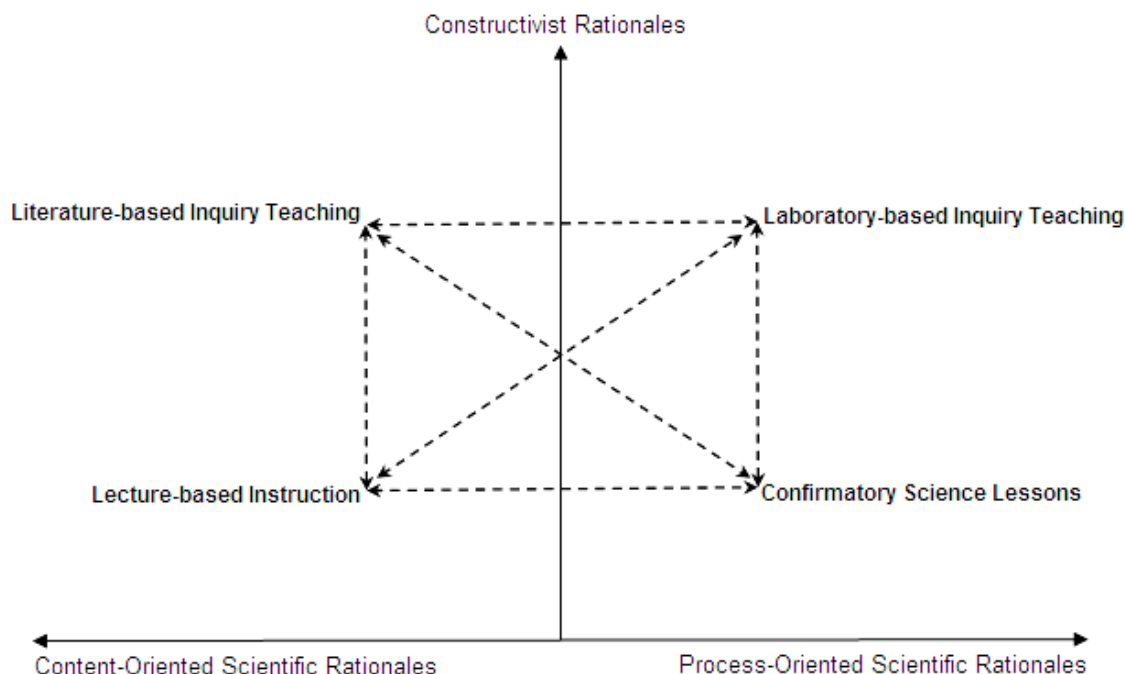


Figure 9 Alternative Modes of Teaching Science

In the model, I separated the educational goals of teachers motivated by scientific rationales into the following two components: content-oriented scientific rationales and process-oriented scientific rationales. NBCSTs in the study considered inquiry primarily for introducing their students to the similar thinking processes and activities of practicing scientists. Their teaching of science concepts usually took place through more conventional teaching strategies. By conceptualizing inquiry both as literature-based and laboratory-based, teachers might practice inquiry effectively by maintaining higher levels of constructivist approach with their students. Proposing different classroom inquiry approaches enriches the repertoires of science teachers with new operational models of inquiry-based science teaching.

Educational Goals with Classroom Inquiry

There is no doubt that the latest science education reform movements are built on the central premise of educating scientifically literate students (Bianchini & Kelly, 2003; Buxton, 2001; Eisenhart, Finkel, & Marion, 1996; Hammrich, 1998; Parsons, Matson, & Quintanar, 2002). For instance, NRC (1996) stated, “The National Science

Education Standards are designed to guide our nation toward a scientifically literate society...The standards describe a vision of the scientifically literate person and present criteria for science education that will allow that vision to become reality” (p.11). In parallel to the high profile of this premise in science education reform documents, NBPTS (2003b, 2003c) expects accomplished science teachers to demonstrate their teaching practices of science to serve enhancing scientific literacy with their students.

However, despite being promoted as the ultimate goal of science education, the science education community suffers from a lack of consensus on the meaning of the concept of scientific literacy (DeBoer, 2000; Laugksch, 2000; Parsons, Matson, & Quintanar, 2002). Although the debate for the specific qualities of scientifically literate people continues among scholars, it seems that developing the appropriate knowledge of both the products and the processes of science is acknowledged to be essential for students to become scientifically literate individuals (Oliver et al., 2001). NRC (1996) included both aspects of science into its definition of scientific literacy: “Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (p.22). Eisenhart, Finkel, and Marion (1996) remarked on the broad nature of scientific literacy presented in science education reform documents: “Although the specifics of...[the science education reform documents] vary somewhat, there is remarkable agreement that scientific literacy is a broad and inclusive vision, requiring considerably more than familiarity with a set of scientific facts” (p.262). NBCSTs in the study recognized scientific literacy as an important outcome of science education. In their description of scientifically literate people, they placed somewhat more emphasis on the content knowledge of science. In other words, their understanding of scientific literacy was primarily driven by the subject matter of science. They expected scientifically literate people to possess a sound foundation of scientific facts. However, this did not necessarily mean that they completely omitted the importance of gaining scientific thinking skills in their science classes. They mentioned the importance of developing scientific reasoning capabilities in giving rational decisions in their everyday lives. However, they brought the crucial role of having strong foundation of scientific principles to the forefront in the general description of scientifically literate people. This

was especially noticeable in their perspectives on the specific ways of educating scientifically literate students. They supported exposing students to a broad scope of scientific topics in order to help them establish a strong foundation of scientific facts in their journey for becoming scientifically literate individuals. However, DeBoer (2000) criticized the narrower representation of scientific literacy that centered on the mastery of a specific body of science knowledge:

Although all of...[the] goals [of science education] depend to some extent on being familiar with the facts and principles of science, exactly what content is needed is impossible to specify. For this reason, efforts at scientific literacy will be much more successful if we remove the burden of requiring all students to achieve mastery of a specific body of content. (p.598)

In my preceding discussions, I presented the important place of scientific literacy in current science education reform movement. Science education community acknowledges the significant promise of classroom inquiry experiences of students in achieving the vision of creating scientifically literate populace (Bodzin & Beerer, 2003; Llewellyn, 2004). NBCSTs in the study found the experiences of students in their engagement into inquiry-oriented lessons valuable for enhancing their thinking skills. They considered the efforts of students to solve questions by devising their own methods as crucial experiences for improving their mental capabilities. They also acknowledged classroom inquiry as a fertile platform for students to experience the similar reasoning patterns and actions of practicing scientists. However, like many other science teachers, those experienced science teachers in the study were hesitant to visualize classroom inquiry as a good strategy for teaching scientific concepts (Matson & Parsons, 2006). They excluded teaching scientific concepts in their educational goals to be achieved with practicing inquiry with their students. This stood in opposition to the general intentions of science education reform documents to accomplish with classroom inquiry performances of students. NRC (1996) promoted inquiry as the central strategy for teaching science. And it did not limit the educational function of classroom inquiry with engaging students in their classrooms into the similar experiences of practicing scientists. NRC (1996) targeted the following educational goals to be accomplished with classroom inquiry experiences of students:

Engaging students in inquiry helps students develop

- ❖ Understanding of scientific concepts.
- ❖ An appreciation of “how we know” what we know in science.
- ❖ Understanding of the nature of science.
- ❖ Skills necessary to become independent inquirers about the natural world.
- ❖ The dispositions to use the skills, abilities, and attitudes associated with science. (p.105)

As can easily be noticed, the list of educational goals provided by NRC (1996) included learning scientific concepts as one of the most important outcomes of classroom inquiry. DeBoer (2002) explained the educational expectations of science education community from classroom inquiry experiences of students as follows:

Inquiry teaching was based on the premise that students could be scientific inquirers in the classroom and generate meaning more or less independently of the teacher. Student inquiries would teach them both the methods of science and the concepts of science. (p.408)

As I discussed earlier in this section, NBCSTs in the study developed a content-oriented understanding of the concept of scientific literacy. They supported giving a sound science education to students in order to make them more knowledgeable about important scientific facts. However, this content-focused approach to scientific literacy by teachers might inhibit their efforts of searching more avenues with teaching of science through inquiry. That was primarily because those experienced science teachers in the study were not in favor of employing inquiry in their teaching of scientific concepts to their students. This put classroom inquiry into an incompatible teaching strategy for educating scientifically literate students because teachers felt that inquiry experiences of students failed to offer a sound science education with a strong knowledge base on scientific facts to students. In order for science education reform ideals to become a reality, the central premises of the reform documents perceived by science teachers are needed to be coherent with each other. However, many science teachers develop misconceptions about the ideas promoted in reform documents (Lynch, 1997; Matson & Parsons, 2006). And those misconceptions held by teachers present a threat to the success of science education reform efforts. The peculiar

understandings developed by participant teachers about scientific literacy and classroom inquiry created a conflict between educating scientifically literate students and embracing more inquiry teaching strategies. This indicated that the vague terms, which are open to misinterpretations, in science education reform documents need to be understood more carefully by science teachers.

Challenges Presented by Classroom Inquiry

Science education throughout the nation is in the midst of reform. In parallel to the central premises of latest reform movements in science education, science teachers are asked to play more challenging roles in their teaching practices of science. For instance, teachers are encouraged to engage their students in inquiry-oriented investigations in their classrooms to help them experience the reasoning patterns and actions of practicing scientists. And the new roles given to teachers require them to build their teaching practices of science with a more student-centered fashion (Bodzin & Beerer, 2003; Schneider, Krajcik, & Blumenfeld, 2005). However, it is difficult to suggest that the overall progress made by science teachers is satisfactory enough in embracing the new roles proposed in the reform documents (Crawford, 2007; Davis, 2003; Trautmann, MaKinster, & Avery, 2004). Many science teachers exhibit a reluctant approach to the idea of teaching science through inquiry (Crawford, 2007; Johnson, 2006). And the ones who show more interest in reform ideas see the role of inquiry teaching strategies as complementary rather than alternative to their more traditional teaching practices of science (Horizon Research, 2003). It seems that the ongoing struggles of science teachers with practicing inquiry in their classrooms keep them from embracing inquiry as the central strategy of teaching science.

It would be inaccurate to suggest that NBCSTs in the study used inquiry teaching strategies consistently with their students. In many cases, they considered the inquiry teaching practices as supplementary to their direct instruction of science topics. And they identified several obstacles in the education system that made the consistent practice of inquiry more challenging for science teachers. In science education literature, the obstacles encountered by science teachers in enacting inquiry “ranged from external factors, such as state testing, to internal ones, such as a lack of in-depth

understanding of what the standards mean” (Horizon Research, 2003, p.93). The obstacles described by those experienced science teachers in this study corresponded mostly to external factors, which was primarily a result of the general characteristics of the current education system. NBCSTs in the study reported many stereotypical obstacles expressed by many science teachers such as time constraints, content standards, standardized testing, student characteristics, insufficient materials (Anderson & Helms, 2001; Furtak, 2006; Hofstein & Lunetta, 2004; Johnson, 2005). Participant teachers’ attribution of their hurdles with practicing inquiry to external factors might be interpreted in a way that they found current education system unsupportive to their consideration of engaging students more into inquiry experiences in their science classes. DeBoer (2002) portrayed the existing conflict between the science education reform and the school system as “in the present environment of curricular and pedagogical reform, a tension exists between the ideals of student-centered learning and the realities of the classroom” (p.411). DeBoer articulated his thoughts as follows:

A natural tension existed between the demands of the curriculum...and the potential interests of the students. The teacher was then left in the awkward position of trying to negotiate those two positions, allowing the students enough freedom to investigate questions that might be of interest to them while still meeting content standards. (p.409)

In the similar vein, Trautmann, MaKinster and Avery (2004) questioned the opposite stand of standardized tests to science teachers’ willingness to teach science through inquiry in his following argument: “As high stakes exams become ever more prominent at the state and national levels, the pressure to prepare students for test-taking presents a formidable challenge to inquiry-based teaching” (p.2). Those external factors caused primarily by the current education system present many challenges to science teachers in practicing inquiry with their students. Expecting science teachers to adopt new roles given to them in science education reform documents seems to be a utopia without changing the whole education system. The following statement from NSES indicated that NRC (1996) already acknowledged this reality: “To attain the vision of science education described in the Standards, change is needed in the entire system. Teachers are central to education, but they must not be placed in the position of being solely

responsible for reform” (p.27). However, necessary changes for bringing the reform ideals into reality do not seem to be taking place in the education system (Davis, 2003). Yet, science teachers are expected to adopt the central premises of science education reform ideals to start the transformation of the education system from inside. The inability of science education community in changing the whole system brings extra burdens to science teachers. The persistence of various incompatibilities in the education system with science education reform ideas fertilizes the excuses produced by teachers for failing to enact science education reform in their classrooms. Two of NBCSTs in the study maintained a distance to science education reform ideas. It might be hard to convince those experienced science teachers of the goodness of reform ideas. As members of the current education system, they did not have much difficulty in justifying their reluctance to employ inquiry strategies more consistently in their teaching of science.

Teachers in the study felt that teaching of science through inquiry fit better with science subject areas with lighter content and science topics with a more concrete nature. This notion resulted primarily from their failure to conceptualize classroom inquiry from a broader perspective. Because they equated the classroom inquiry experiences of students with experimentally driven science activities, they felt uncomfortable in finding inquiry-oriented activities for students to help them learn abstract science topics. This indicated teachers' need for developing alternative views of classroom inquiry. The inquiry workshops that teachers attended failed to help them generate alternative views of classroom inquiry but rather promoted their general notions of inquiry as an unsuitable teaching strategy for science subject areas with heavy content. Teachers found inquiry models exemplified in those workshops unrealistic for the actual conditions of their classrooms. They were critical about completely open nature of inquiry activities chosen from science subject areas with less intense content such as environmental science. They felt that the idealistic representation of classroom inquiry in those workshops offered no valuable experience to them to transfer into their own classroom contexts. This indicated that one-shot inquiry workshops were of little help to teachers in overcoming their challenges in practicing inquiry with their students (Kennedy, 1998; Matson & Parsons, 2006; Wee,

Shepardson, Fast, & Harbor, 2007). Teachers needed extended experiences of inquiry in their teaching field of science.

Implications of the Study

Although advanced science teaching standards of NBC support the parallel ideas of science education reform documents, the findings of this dissertation study suggest that science teachers who achieve their advanced teaching certificates with NBC do not necessarily support the central tenets of science education reform ideas. The specific cases in this study indicate that teachers who have the capabilities of meeting the teaching standards of NBC with slight adjustments to their teaching practices of science may complete the requirements of NBC portfolio assessment procedure successfully even if they keep a distance from the reform ideas. Undergoing the assessment process of NBC does not necessarily create a higher affiliation with science education reform ideas. On the contrary, teachers who support more traditional views of teaching science may come out of NBC assessment process with a sharpened confidence in their existing conventional notions of teaching science. This shows that acknowledging all NBCSTs as reform-minded teachers would be misleading. This result also implies that successful completion of the performance assessment process of NBC does not necessarily result in embracing more inquiry strategies in teachers' everyday teaching practices. NBCSTs' sharpened confidence in their existing traditional views of teaching science as a result of their successful completion of NBC assessment process might even be considered as an inhibiting factor in their further development as inquiry science teachers.

Like many other science teachers in the school system, NBCSTs conceptualized classroom inquiry as the experiences of students with experimentally driven laboratory science activities. And the scientific method represented traditionally in many resources as a stepwise linear process was seen as the major way of introducing students to the cognitive world of scientists. However, engaging students into simplistic "fair test" approaches or following a stepwise method of science does not reflect an accurate picture of the work of scientists. Science teachers need to develop more sophisticated understandings of the scientific inquiry process before introducing their students to the

reasoning patterns and actions of practicing scientists. This brings the crucial role of having real science research experience to the surface. Participating in authentic scientific research is supported in the literature as a valuable experience for teachers to develop a more realistic understanding of the work of scientists (Brown & Melear, 2006; Windschitl, 2004). Participant teachers' unsophisticated understandings of scientific inquiry might be attributed partly to their lack of real science research experiences. Therefore, having scientific research experiences with practicing scientists could be helpful for teachers to create more accurate pictures of the actual work of scientists (Brown & Melear, 2007). Science teachers who develop better informed images of scientific inquiry might create more sophisticated classroom inquiry experiences for their students.

Another important implication of the study is that NBCSTs failed to create broader perspectives on classroom inquiry experiences with students. They confined classroom inquiry to activity-driven, laboratory-based, experimentally-oriented experiences of students. However, this limited understanding of classroom inquiry restricts teachers' ability to use inquiry to teach science concepts to their students. It is largely because teachers tend to conceptualize inquiry as a platform for introducing students to the thinking processes and activities of practicing scientists. In order for inquiry to be a central strategy of teaching science as proposed by NRC (1996), science teachers need to develop alternative models of classroom inquiry through which they can teach both the content and the process of science to their students. However, the short-term inquiry workshops that NBCSTs attended were not helpful for giving them a broader meaning of classroom inquiry. They criticized those "one-shot" workshops for modeling inquiry unrealistically for the actual classroom conditions. Science teachers need to recognize that enactment of inquiry can be achieved through basing student investigations on the critical analysis of secondary sources of information (Hodson, 1999; NRC, 1996). Teachers need to keep in mind that NRC (1996) placed more emphasis on science as argumentation and explanation as opposed to science as exploration and experimentation. This suggests that classroom inquiry is not limited to empirical laboratory experiences of students. Teachers need to develop a literature-based perspective of classroom inquiry in addition to their existing notions of laboratory-

based inquiry. This helps them use inquiry with their students more effectively. Therefore, creating professional development opportunities for science teachers to show them the alternative models of inquiry might be helpful for a wider usage of inquiry by science teachers in their everyday teaching practices of science.

Although student autonomy is one of the most essential features of classroom inquiry, the level of autonomy given to students in their classroom inquiry experiences changes depending on the specific goals intended to be achieved with students and the existing capabilities of students. Based on different levels of student autonomy, classroom experiences of students are represented on a continuum from confirmatory science to open inquiry. However, inquiry conceptions of teachers do not necessarily match with those various levels of classroom inquiry. For instance, NBCSTs in the study developed a dualistic understanding of confirmatory science and classroom inquiry. The duality centered on the methods used by students in solving their questions. Teachers tended to classify science activities with given methods to students as “cookbook” experience. This might be attributed to teachers’ difficulty of differentiating structured inquiry from confirmatory science. However, developing an appropriate image of inquiry continuum is important for science teachers to be able to use different levels of inquiry with their students effectively. NBCSTs in the study were not in favor of employing inquiry teaching strategies for teaching science concepts to their students. Teachers’ reluctance to use inquiry for teaching science concepts might have developed in parallel to their tendency of equating inquiry with high levels of student autonomy. Engaging students in structured inquiry activities might be a helpful tool for teachers to introduce their students to the science concepts. All levels of inquiry represented on the continuum are needed to be understood clearly by science teachers in order to be able to make an accurate evaluation of inquiry nature of science activities.

Developing appropriate understandings of the central ideas of science education reform by science teachers is crucial for reform ideals to become reality. However, ambiguous terms in science education reform documents inhibit teachers’ adoption of reform ideas (Biological Sciences Curriculum Study, 2005; Wheeler, 2000). Any incoherence perceived by teachers among the central tenets of reform ideas creates a potential threat to the future success of science education reform efforts. For instance,

NBCSTs in the study developed an understanding of scientific literacy based primarily on the content knowledge of science. However, the content-oriented understanding of scientific literacy might influence teachers' willingness to use more inquiry teaching strategies in their classrooms because NBCSTs in the study were reluctant to embrace inquiry strategies in teaching the content knowledge of science. This example indicated that uncovering any incompatibilities perceived by teachers in science education reform documents is necessary for developing better strategies to address potential problems of teachers. Earlier efforts which exhibited a top-down approach to reform education were not successful enough to create necessary changes in science education (Jones & Eick, 2007). That was primarily because the beliefs and understandings of science teachers were not taken into consideration in the success of reform efforts. By realizing this reality, latest science education reform movements placed more emphasis on science teachers in order to create a bottom-up change in the science education (Jones & Eick, 2007). However, successful reform of science education requires changes in the whole education system (Collins, as cited in Anderson, 1999; NRC, 1996). NBCSTs in the study showed the capabilities of enacting inquiry with their students but the external factors described by participant teachers in the education system inhibited teachers' abilities to practice inquiry with their students in a wider sense. One thing that we need to keep in mind is that those accomplished science teachers have the capabilities of adapting their teaching practices of science to new education systems. Existing problems in the education system keep those accomplished science teachers from using their capabilities to the maximum potential. Moreover, the unsupportive nature of education system to the practice of inquiry produces the underpinning reasons for teachers to justify their reluctance to embrace inquiry in their everyday teaching practices of science.

Limitations of the Study

Due to naturalistic inquiry research methodology adopted in this dissertation study, the findings of the study do not claim any generalizability beyond four NBCSTs who participated in the study. This places a limitation on the applicability of the findings to a larger science teacher population. However, this should not be interpreted in a way

that the specific conclusions that emerged from the study cannot find themselves a place in the lives of readers. It is up to the readers to decide whether the results of this dissertation study can be transferable into their own contexts. For that purpose, the study provides rich details on the perspectives of NBCSTs, which owes primarily to the specific research methodology used in the study. Those rich details help readers contextualize the conclusions of the study better. In-depth investigation of select cases is the strength of this study.

As a researcher, I had limitations in selecting science teachers to participate in the study. Due to the limited numbers of NBCSTs in the county where my university was located, my options for choosing the teachers to include in the dissertation study were slim. I located the names of fifteen NBCSTs who were working in the school district. Four science teachers in the study were the ones who agreed to participate in the research study from those fifteen NBCSTs. Therefore, I did not have many options for selecting the teachers to participate in the study based on their potential contributions to the study. Those NBCSTs who participated into the study did not necessarily hold different opinions on the general issues discussed in the study. Working with teachers who represented a broader scope of ideas might enhance our understanding of the central ideas discussed in the study further.

The perceptions of teachers in the study about their experiences with NBC assessment process represented their perspectives after several years of their completion of NBC portfolio artifacts. This might be considered as a limitation of the study because participant teachers had some difficulties in remembering the details of their specific experiences with NBC portfolio assessment process. Working with teachers who received their advanced teaching certificates more recently might have helped gain more detailed information on their NBC experiences. On the other hand, teachers' participation in a research study after settling their insights into their NBC experiences presented some advantages to the study in terms of allowing teachers to make an overall evaluation of the role of NBC in their professional development as a science teacher.

APPENDIX A
Science Teacher Inquiry Rubric (STIR)
Developed by
(Bodzin & Beerer, 2003)

Science Teacher Inquiry Rubric (STIR)

Directions: Reflect on the science lesson that you taught today. In your reflection, consider each of the following categories and the six statements on the left, written in bold. After looking at each bold statement, assess today's science instruction based on the categories delineated for statement. Place one "X" in the corresponding cell for each bold-faced statement. If there is no evidence of one of the statements in today's lesson, place a slash through the bold-faced statement. When you are finished, you should have 6 total responses.

Learner Centered ↔ Teacher Centered			
Learners are engaged by scientifically oriented questions.			
Teacher provides an opportunity for learners to engage with a scientifically oriented question.	Learner is prompted to formulate own questions or hypothesis to be tested. ☐	Teacher suggests topic areas or provides samples to help learners formulate own questions or hypothesis. ☐	Teacher offers learners lists of questions or hypotheses from which to select. ☐
Teacher provides specific stated (or implied) questions or hypotheses to be investigated. ☐	Teacher provides learners with specific stated (or implied) questions or hypotheses to be investigated. ☐		
Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.			
Teacher engages learners in planning investigations to gather evidence in response to questions.	Learners develop procedures and protocols to independently plan and conduct a full investigation. ☐	Teacher encourages learners to plan and conduct a full investigation, providing support and scaffolding with making decisions. ☐	Teacher provides guidelines for learners to plan and conduct part of an investigation. Some choices are made by the learners. ☐
Teacher helps learners give priority to evidence which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions. ☐	Teacher provides the procedures and protocols for the students to conduct the investigation. ☐		
Teacher provides data and gives specific direction on how data is to be analyzed. ☐	Teacher provides data and asks learners to analyze. ☐		
No evidence observed.			

Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.				
Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.	Learner is prompted to analyze evidence (often in the form of data) and formulate own conclusions/explanations.	☐	Teacher prompts learners to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence.	☐
		☐	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusion/explanation (verification).	☐
		☐	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusion/explanation (verification).	☐
Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.				
Learners evaluate their conclusions and/or explanations in light of alternative conclusions/explanations, particularly those reflecting scientific understanding.	Learner is prompted to examine other resources and make connections and/or explanations independently.	☐	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. Teacher may or may not direct learners to examine these resources, however.	☐
		☐	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions and/or explanations. Instead, the teacher identifies related scientific knowledge that could lead to such alternatives, or suggests possible connections to such alternatives.	☐
		☐	Teacher explicitly states specific connections to alternative conclusions and/or explanations, but does not provide resources.	☐
		☐	Teacher explicitly states specific connections to alternative conclusions and/or explanations, but does not provide resources.	☐
Learners communicate and justify their proposed explanations.				
Learners communicate and justify their proposed conclusions and/or explanations.	Learners specify content and layout to be used to communicate and justify their conclusions and explanations.	☐	Teacher provides possible content to include and/or layout that might be used.	☐
		☐	Teacher specifies content and/or layout to be used.	☐
		☐	Teacher specifies content and/or layout to be used.	☐

APPENDIX B
Formal Interview Questions

Interview Questions-1

1. What is your educational background? How long have you been teaching? How long have you been working at this school? What are you currently teaching? How do you describe your school, students, neighborhood etc?
2. Why should our students learn science? What should be our goals in teaching science?
3. How do you define your philosophy of teaching and learning? What are the roles of the teacher and the students in the learning process?
4. What are the qualities of a good science teacher and science teaching?
5. Do you have any familiarity with National Science Education Standards [NSES]? If yes, what do you think about the vision of that document in terms of science teaching and learning? Do you find your teaching compatible with the standard's vision?
6. When did you hear about National Board Certification [NBC] first? How did you decide to apply for NBC? How much time did you spend on your portfolio entries?
7. What did you like most and least in NBC process? What were your biggest challenges? How did you overcome them?
8. What do you think that you learned through NBC process? How do you see the role of NBC in your professional development?
9. In what ways do you use the knowledge you gained from NBC process?
10. When you think about science, scientific research, inquiry-based science, scientist, what is the first thing that comes into your mind? Where do you think these images originate from?
11. What is your conception of inquiry-based science in the classroom? What characteristics of a lesson make it inquiry-based? How do you enact inquiry in the classroom?
12. Why do you think that inquiry-based science is important for Science Education Community and National Board for Professional Teaching Standards?
13. How frequently do you teach in a manner that you presented in your NBC portfolio?

Interview Questions-2

1. How do you describe scientific inquiry? How similar and different is “scientific inquiry” from “inquiry-based science in classroom”? Do you think whether we can teach our students the process of scientific method in classroom conditions? How?
2. How do you think scientific research process works, deductively or inductively? Is teaching science through inquiry in classroom a deductive or an inductive activity? How?
3. What does it mean to teach science through inquiry for you? What would be the three most important characteristics of a successfully implemented inquiry-based science activity? What would be your ideal image of inquiry-based science teaching like?
4. How similar and different is “inquiry-based science” from “cookbook science”? Which teaching strategy is better for your students’ learning of science? What might be the strengths of each teaching strategy?
5. What goals do you aim to achieve as you teach your students science through inquiry?
6. Would you tell me three hurdles that make the enactment of inquiry in your classroom harder?
7. Which one of the following describes better the way you teach science? Why do you think your preference is more effective?
 - a. Teaching theoretical bases of science concepts comes first. Afterwards, students make better sense of the science topic as they experience the concrete activities designed to exemplify the topic.
 - b. New science topic begins with an activity to show students some of the aspects of the new science concept in a concrete manner. After students have first-hand experience with the topic, teaching them the theoretical aspects of the topic follows.
8. How did NBC experience influence your conception of inquiry-based science teaching? What type of activity does NBPTS expect from teachers to include in their portfolios to evidence their enactment of inquiry in their classrooms? How did you come up with the inquiry activity that you presented in your portfolio?
9. Some teachers define inquiry as a “way of thinking” while some others think that it is a “process of investigation.” Which one would you agree more?
10. Some of the teachers think that inquiry-based science teaching works better for lower level students, would you agree that? Why do you think so?

11. Some of the teachers think that inquiry-based science may trigger misconceptions in students' learning of science because students may misidentify what they see in inquiry activities before they learn some basic science vocabulary, would you agree that? Why do you think so?
12. Would you agree that having prior science research experience is an important prerequisite for being able to teach science through inquiry successfully? Why do you think so?
13. What professional development activities did you attend in regard to inquiry-based science teaching? How did these activities influence the way you conceptualize inquiry-based science?
14. How do students learn science better; (a) from abstract concepts to concrete examples or (b) from concrete examples to abstract concepts? Why do you think so?
15. When you think about a scientifically literate person, what qualities does this person possess? How can we equip our students with such qualities?

APPENDIX C
Teacher Invitation Letter

Dear Teacher,

I am a Science Education doctoral student in the Department of Middle and Secondary Education, Florida State University. Under the guidance of Dr. Nancy T. Davis, I am conducting my dissertation research study on National Board Certified Science Teachers [NBCSTs]. In this qualitative research study, I specifically aim to gain an understanding of how NBCSTs perceive their National Board Certification experiences and how NBCSTs conceptualize and enact inquiry-based science.

This letter is a request for you to participate in my research study. Your participation will involve permitting me to observe your teaching and to conduct interviews with you. Additionally, I would like to review your National Board portfolio. The observations will help me to identify your enactment of inquiry in your classrooms whereas the interviews will inform me about your perceptions of National Board Certification process and your conceptions of classroom inquiry. I will audio record interviews with a purpose of generating a more accurate data by converting them into written transcripts.

If you agree to participate in my dissertation research study, I am planning to visit and observe 2 or 3 of your classes regularly throughout the semester. In addition, I intend to conduct interviews with you throughout the school semester. I anticipate that each interview would take about an hour. If you select to participate in the study, you will have the opportunity to learn other NBCSTs' perspectives on their experiences with National Board and their teaching of inquiry in their classrooms, and to reflect on these diverse perspectives. Hence, you may find this study beneficial as a continuation of the professional development activity that you experienced in National Board Certification process.

If you have any questions or concerns about this research study, please call me at (850) 575-7995 or send me an e-mail (akk8661@fsu.edu). You may also contact Dr. Nancy T. Davis at (850) 644-7804 or by e-mail (ndavis@fsu.edu).

Sincerely,
Ayhan Karaman

APPENDIX D
Human Subject Committee Approval Forms



Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 1/14/2005

To:
Ayhan Karaman
925 E. Magnolia Dr. #M6
Tallahassee, FL 32301

Dept.: MIDDLE AND SECONDARY EDUCATION

From: John Tomkowiak, Chair

Re: Use of Human Subjects in Research
National Board Certified Science Teachers and Inquiry Science: Their Perceptions of the National Board Experiences, and Their Conceptions & Enactment of Inquiry

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Exempt per 45 CFR § 46.101(b) 1 and has been approved by an accelerated review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If the project has not been completed by 1/13/2006 you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

Cc: Nancy T Davis
HSC No. 2004.879

INFORMED CONSENT LETTER FOR TEACHERS

Dear Teacher,

I am a Science Education doctoral student in the Department of Middle and Secondary Education, Florida State University. Under the guidance of Dr. Nancy T. Davis, I am conducting my dissertation research study on National Board Certified Science Teachers [NBCSTs]. As a researcher, I specifically aim to gain an understanding of how NBCSTs perceive their National Board Certification experiences and how NBCSTs conceptualize and enact inquiry science.

I request you to participate in my research study. Your participation will involve permitting me to observe your teaching and to conduct interviews with you. The observations will help me to identify your enactment of inquiry science in your classrooms whereas the interviews will inform me about your perceptions of National Board Certification process and your conceptions of inquiry science. I will audio record interviews with a purpose of generating a more accurate data by converting them into written transcripts.

As the principle researcher, I assure you that I will strictly maintain your confidentiality in the study to the extent allowed by law by assigning you a pseudonym of your choice. I may publish some of the results of this research study but I will never use your name in any of these published documents. Throughout the research process, I will give you the opportunities to review your interview transcripts and my specific interpretations whether they reflect your perspectives accurately so that I will allow you to make the required changes on your perspectives represented in the study. I will keep all data artifacts such as audiotapes, interview transcripts, portfolio documents etc. in a locked file cabinet. I will keep these artifacts up to two years from the completion of the study, and destroy them by February 1, 2008.

Your participation in this study is completely voluntary. If you agree to participate in this study, you are completely free to withdraw from the study at any time if you wish to do so. Please keep in mind that there will be absolutely no penalty for your withdrawal from the study. There are no foreseeable risks or discomforts for you upon your participation in this research study. On the contrary, you may find this study beneficial as a continuation of the professional development activity that you experienced in National Board Certification process.

If you have any questions or concerns about this research study, please call me at (850) 575-7995 or send me an e-mail (akk8661@fsu.edu). You may also contact Dr. Nancy T. Davis at (850) 644-7804. If you have any questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you can contact the chair of the human subjects committee at (850) 644-8633.

Sincerely,
Ayhan Karaman (Principle Researcher)

I agree to participate in the research study described above. I understand that the researcher will record the interviews he conducts with me by using an audiotape recorder. The researcher will keep these audiotapes in a locked file cabinet. I understand that only the researcher will have an access to these tapes, and they will be destroyed by February 1, 2008.

(NAME & SURNAME)-----

(SIGNATURE)-----

(DATE)-----





Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8633 FAX (850) 644-4392

REAPPROVAL MEMORANDUM

Date: 2/3/2006

To:
Ayhan Karaman
925 E. Magnolia Dr. #M6
Tallahassee, FL 32301

Dept.: **MIDDLE AND SECONDARY EDUCATION**

From: **Thomas L. Jacobson, Chair**

Re: **Reapproval of Use of Human subjects in Research:**
National Board Certified Science Teachers and Inquiry Science: Their Perceptions of the
National Board Experiences, and Their Conceptions & Enactment of Inquiry

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 2/2/2007 please request renewed approval.

You are reminded that a change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must report to the Chair promptly, and in writing, any unanticipated problems involving risks to subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols of such investigations as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Nancy T Davis
HSC No. 2006.0067-R

INFORMED CONSENT LETTER FOR TEACHERS

Dear Teacher,

I am a Science Education doctoral student in the Department of Middle and Secondary Education, Florida State University. Under the guidance of Dr. Nancy T. Davis, I am conducting my dissertation research study on National Board Certified Science Teachers [NBCSTs]. As a researcher, I specifically aim to gain an understanding of how NBCSTs perceive their National Board Certification experiences and how NBCSTs conceptualize and enact inquiry science.

I request you to participate in my research study. Your participation will involve permitting me to observe your teaching and to conduct interviews with you. The observations will help me to identify your enactment of inquiry science in your classrooms whereas the interviews will inform me about your perceptions of National Board Certification process and your conceptions of inquiry science. I will audio record interviews with a purpose of generating a more accurate data by converting them into written transcripts.

As the principle researcher, I assure you that I will strictly maintain your confidentiality in the study to the extent allowed by law by assigning you a pseudonym of your choice. I may publish some of the results of this research study but I will never use your name in any of these published documents. Throughout the research process, I will give you the opportunities to review your interview transcripts and my specific interpretations whether they reflect your perspectives accurately so that I will allow you to make the required changes on your perspectives represented in the study. I will keep all data artifacts such as audiotapes, interview transcripts, portfolio documents etc. in a locked file cabinet. I will keep these artifacts up to two years from the completion of the study, and destroy them by February 1, 2008.

Your participation in this study is completely voluntary. If you agree to participate in this study, you are completely free to withdraw from the study at any time if you wish to do so. Please keep in mind that there will be absolutely no penalty for your withdrawal from the study. There are no foreseeable risks or discomforts for you upon your participation in this research study. On the contrary, you may find this study beneficial as a continuation of the professional development activity that you experienced in National Board Certification process.

If you have any questions or concerns about this research study, please call me at (850) 575-7995 or send me an e-mail (akk8661@fsu.edu). You may also contact Dr. Nancy T. Davis at (850) 644-7804. If you have any questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you can contact the chair of the human subjects committee at (850) 644-8633.

Sincerely,
Ayhan Karaman (Principle Researcher)

I agree to participate in the research study described above. I understand that the researcher will record the interviews he conducts with me by using an audiotape recorder. The researcher will keep these audiotapes in a locked file cabinet. I understand that only the researcher will have an access to these tapes, and they will be destroyed by February 1, 2008.

(NAME & SURNAME)-----

(SIGNATURE)-----

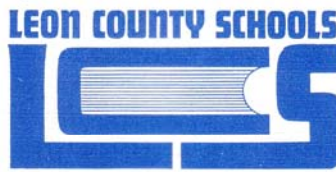


APPENDIX E
Leon County School District Approval Letter

BOARD CHAIR
Georgia "Joy" Bowen

BOARD VICE-CHAIR
Sheila Costigan

**DIRECTOR, PROGRAM MONITORING
AND EVALUATION SERVICES**
Margarida Souhard, Ph.D.



BOARD MEMBERS
Dee Crumpler
Maggie B. Lewis
H. Fred Varn

SUPERINTENDENT
William J. Montford, III

March 21, 2005

Ayhan Karaman
925 East Magnolia Dr.
Tallahassee, Florida 32301

Topic: "*National Board Certified Science Teachers (NBCSTs)
Conceptions and Enactment of Inquiry-Based Teaching*"

Dear Mr. Karaman:

The Leon County Research Review Board has approved your request for research. Based on your proposal, the research will be approved for the period of March 2005 through March 2006. Should you desire to continue the research efforts after this period of time, you must submit a progress report on the status of your research and request renewed approval for continuation of the project. Any significant changes or amendments to the procedures or design of this study must be approved by resubmitting the request for research to the Research Review Board.

You will need to contact the principals of the schools in which you wish to conduct your study as soon as possible. The principal is responsible for making the decision relative to his or her school. It is your responsibility to return the enclosed "Principal's Consent for Research Participation," signed by the principal(s) of the school(s) to be involved, prior to the start of any research. Receipt of this consent form by this office will complete the approval process.

If the research study involves direct contact with students, the background check policy requires the research applicant(s) to be fingerprinted for clearance. It is the responsibility of the applicant(s) to complete all required documentation prior to beginning the study.

In the interest of continued research benefits and the coordination of research interests, please send this office one copy of your results and discussion. This information, and any other relevant information you may have, will be filed in our research library and added to the annotated listing of research projects. We look forward to your results and any suggestions they may offer toward improving the educational process in Leon County Schools.

Please feel free to call me if I be can of further assistance. I may be reached at 488-7007.

Sincerely,

A handwritten signature in cursive script, appearing to read "Margarida F. Southard".

Margarida F. Southard, Ph.D.
Program Monitoring and Evaluation
Chair, Research Review Board

MFS/db

cc: Jackie Pons/Deerlake, Roger Pinholster/Fairview, Carl Misener/Raa, Randy Free/Belle Vue,
Randy Pridgeon/Godby, Margo Hall/Leon

3955 West Pensacola Street * Tallahassee, Florida 32304-2998 * Phone (850) 488-7007 * Fax (850) 922-5979 * Suncom (850) 278-7007

Building the Future Together
Affirmative Action/Equal Opportunity Employer (850) 487-7105

REFERENCES

- Abd-El-Khalick, F. (2004). Introduction. In F. Abd-El-Khalick, S. Boujaoude, R. Duschl, N.G. Lederman, R. Mamlok-Naaman, & A. Hofstein et al., *Inquiry in science education: International perspectives* (pp. 398-400). *Science Education*, 88(3), 397-419.
- Abell, S.K., Anderson, G., & Chezem, J. (2000). Science as argument and explanation: Exploring concepts of sound in third grade. In J. Minstrell, & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp.65-79). Washington, DC: American Association for the Advancement of Science.
- Akerson, V.L., & Hanuscin, D.L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching*, 44(5), 653-680.
- American Association for the Advancement of Science. (1990). *Science for all Americans*. Washington, DC: American Association for the Advancement of Science. Retrieved August 27, 2004, from <http://www.project2061.org/tools/sfaol/sfaatoc.htm>
- American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. Washington, DC: American Association for the Advancement of Science. Retrieved August 27, 2004, from <http://www.project2061.org/tools/benchol/bolintro.htm>
- Anderson, R.D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, 13(1), 1-12.
- Anderson, R.D., & Helms, J.V. (2001). The ideal of standards and the reality of schools: Needed research. *Journal of Research in Science Teaching*, 38(1), 3-16.
- Anderson, S.S. (1999). Standards are not enough: Interview with Angelo Collins, director of the National Science Education Standards Project (1991-1995), and associate director for NCISLA. *Principled Practice in Mathematics and Science Education*, 3(1), 2-3.
- Areglado, N. (1999, Winter). I became convinced: How a certification program revitalized an educator. *National Staff Development Council*, 35-37.
- Ash, D., & Klein, C. (2000). Inquiry in the informal learning environment. In J. Minstrell, & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp.216-241). Washington, DC: American Association for the Advancement of Science.
- Baker, W.P., Lang, M., & Lawson, A.E. (2002). Classroom management for successful student inquiry. *The Clearing House*, 75(5), 248-252.

- Ballou, D. (2003). Certifying accomplished teachers: A critical look at the National Board for Professional Teaching Standards. *Peabody Journal of Education*, 78(4), 201-219.
- Barrow, L.H. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, 17, 265-278.
- Bartholomew, H., Osborne, J., & Ratcliffe, M. (2004). Teaching students "ideas-about-science": Five dimensions of effective practice. *Science Education*, 88(5), 655-682.
- Bauer, H.H. (1994). *Scientific literacy and the myth of the scientific method*. Urbana, IL: University of Illinois.
- Beck, D.E., & Cowan, C.C. (1996). *Spiral dynamics: Mastering values, leadership, and change*. Malden, MA: Blackwell Publishing.
- Bell, C., Shepardson, D., Harbor, J., Klagges, H., Burgess, W., Meyer, J., et al. (2003). Enhancing teachers' knowledge and use of inquiry through environmental science education. *Journal of Science Teacher Education*, 14(1), 49-71.
- Benz, J. (1997). Measuring up: a personal journey through National Board Certification in art. *Art Education*, 50(5), 20-24, 49-50.
- Bianchini, J.A., & Kelly, G.J. (2003). Challenges of standards-based reform: The example of California's science content standards and textbook adoption process. *Science Education*, 87(3), 378-389.
- Biological Sciences Curriculum Study. (2005). *Doing science: The process of scientific inquiry*. Colorado Springs, CO: BSCS.
- Bodzin, A.M., & Beerer, K.M. (2003). Promoting inquiry-based science instruction: The validation of the Science Teacher Inquiry Rubric (STIR). *Journal of Elementary Science Education*, 15(2), 39-49.
- Boeije, H. (2002). A purposeful approach to the constant comparative method in the analysis of qualitative interviews. *Quality & Quantity*, 36, 391-409.
- Bogdan, R.C., & Biklen, S.K. (1998). *Qualitative research in education: An introduction to theory and methods* (3rd ed.). Needham Heights, MA: Allyn & Bacon.
- Bond, L. (1997). *Adverse Impact and Teacher Certification*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

- Bonnstetter, R.J. (1998). Inquiry: Learning from the past with an eye to the future. *Electronic Journal of Science Education*, 3(1).
- Britner, S.L., & Finson, K.D. (2005). Preservice teachers' reflections on their growth in an inquiry-oriented science pedagogy course. *Journal of Elementary Science Education*, 17(1), 39-54.
- Brown, P.L., Abell, S.K., Demir, A., & Schmidt, F.J. (2006). College science teachers' views of classroom inquiry. *Science Education*, 90, 784-802.
- Brown, S.L. (2002). *Theory to practice: A study of science teachers' pedagogical practices as measured by the Science Teacher Analysis Matrix (STAM) and Teacher Pedagogical Philosophy Interview (TPPI)*. Unpublished doctoral dissertation, College of Education, University of Tennessee, Knoxville.
- Brown, S.L., & Melear, C.T. (2006). Investigation of secondary science teachers' beliefs and practices after authentic inquiry-based experiences. *Journal of Research in Science Teaching*, 43(9), 938-962.
- Brown, S.L., & Melear, C.T. (2007). Preservice teachers' research experiences in scientists' laboratories. *Journal of Science Teacher Education*, 18, 573-597.
- Buck, G.A., Latta, M.A.M., & Leslie-Pelecky, D.L. (2007). Learning how to make inquiry into Electricity and Magnetism discernible to middle level teachers. *Journal of Science Teacher Education*, 18, 377-397.
- Buday, M.C., & Kelly, J.A. (1996). National Board Certification and the teaching profession's commitment to quality assurance. *Phi Delta Kappan*, 78(3), 215-219.
- Burr, V. (1998). Overview: Realism, relativism, social constructionism and discourse. In I. Parker (Ed.), *Social constructionism, discourse and realism* (pp.13-26). Thousand Oaks, CA: Sage Publications, Inc.
- Burroughs, R. (2001). Composing standards and composing teachers: The problem of National Board Certification. *Journal of Teacher Education*, 52(3), 223-232.
- Burroughs, R., Schwartz, T.A., & Hendricks-Lee, M. (2000). Communities of practice and discourse communities: Negotiating boundaries in NBPTS certification. *Teachers College Record*, 102(2), 344-374.
- Buxton, C.A. (2001). Exploring science-literacy-in-practice: Implications for scientific literacy from an anthropological perspective. *Electronic Journal of Literacy through Science*, 1(1), 1-36.

- Bybee, R.W. (2000). Teaching science as inquiry. In J. Minstrell, & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp.20-46). Washington, DC: American Association for the Advancement of Science.
- Bzdewka, S. (1996). In M.C. Buday, & J.A. Kelly (1996), National Board Certification and the teaching profession's commitment to quality assurance. *Phi Delta Kappan*, 78(3), 215-219.
- Carnegie Task Force on Teaching as a Profession (1986). *A nation prepared: Teachers for the 21st century*. New York, NY: Carnegie Forum on Education and the Economy.
- Cartier, J.L., & Stewart, J. (2000). Teaching the nature of inquiry: Further developments in a high school genetics curriculum. *Science and Education*, 9, 247-267.
- Cavalluzzo, L.C. (2004). *Is National Board Certification an effective signal of teacher quality?*. Alexandria, VA: The CAN Corporation.
- Center for the Future of Teaching and Learning. (2002). *California teachers' perceptions of National Board Certification*. Santa Cruz, CA: Center for the Future of Teaching and Learning.
- Chapman, O. L. (2000). Learning science involves language, experience, and modeling. *Journal of Applied Developmental Psychology*, 21(1), 97-108.
- Chiari, G., & Nuzzo, M.L. (1996). Psychological constructivisms: A metatheoretical differentiation. *Journal of Constructivist Psychology*, 9, 163-184.
- Chin, C., Brown, D.E., & Bruce, B.C. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education*, 24(5), 521-549.
- Chinn, C.A., & Malhotra, B.A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, 86(2), 175-218.
- Chittenden, E., & Jones, J. (1997). An observational study of National Board candidates as they progress through the certification process. In K. Kowalski, E. Chittenden, W. Spicer, J. Jones, & C. Tocci, *Professional development in the context of National Board for Professional Teaching Standards certification: Implications beyond certification* (pp. 14-31). Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.
- Colburn, A. (1997, Fall). How to make lab activities more open ended. *CSTA Journal*, 4-6.

- Colburn, A. (2000, March). An inquiry primer. *Science Scope*, 42-44.
- Colburn, A. (2006). *What teacher educators need to know about inquiry-based instruction*. Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Akron, OH.
- Committee on Science and Mathematics Teacher Preparation. (2001). *Educating teachers of science, mathematics, and technology: New practices for the new millennium*. Washington, DC: National Academy Press.
- Crawford, B.A. (1997). A Community of Inquiry: Changing Roles for Teachers and Students. In L.B. Flick, C.W. Keys, S.L. Westbrook, B.A. Crawford, & N.G. Cames, *Perspectives on inquiry-oriented teaching practice: Conflict and clarification* (pp.17-22). Symposium conducted at the meeting of the National Association for Research in Science Teaching, Oak Brook, IL. (ERIC Document Reproduction Service No. ED407255).
- Crawford, B.A. (1999). Is it realistic to expect a preservice teacher to create an inquiry-based classroom?. *Journal of Science Teacher Education*, 10(3), 175-194.
- Crawford, B.A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching*, 37(9), 916-937.
- Crawford, B.A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44(4), 613-642.
- Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Thousand Oaks, CA: Sage Publications, Inc.
- Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. *Journal of Research in Science Teaching*, 42(3), 337-357.
- Darling-Hammond, L. (1990). Teachers and teaching: Signs of a changing profession. In W.R. Houston, M. Haberman, & J. Sikula (Eds.), *Handbook of research on teacher education* (pp.267-290). New York, NY: Macmillan.
- Darling-Hammond, L. (1999a). *Reshaping teaching policy, preparation, and practice: Influences of the National Board for Professional Teaching Standards*. Washington, DC: American Association of Colleges for Teacher Education.
- Darling-Hammond, L. (1999b). *Professional development for teachers: Setting the stage for learning from teaching*. Santa Cruz, CA: The Center for the Future of Teaching & Learning.

- Darling-Hammond, L. (1999c). *Teacher quality and student achievement: A review of state policy evidence*. Seattle, WA: Center for the Study of Teaching and Policy, University of Washington.
- Darling-Hammond, L. (2001). Teacher testing and the improvement of practice. *Teaching Education*, 12(1), 11-34.
- Darling-Hammond, L., & Youngs, P. (2002). Defining “highly qualified teachers”: What does “scientifically-based research” actually tell us?. *Educational Researcher*, 31(9), 13-25.
- Davis, K.S. (2003). “Change is hard”: What science teachers are telling us about reform and teacher learning of innovative practices. *Science Education*, 87(1), 3-30.
- DeBoer, G.E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science teaching*, 37(6), 582-601.
- DeBoer, G.E. (2002). Student-centered teaching in a standards-based world: Finding a sensible balance. *Science & Education*, 11, 405-417.
- deCourcy Hinds, M. (2002). *Teaching as a clinical profession: A new challenge for education*. New York, NY: Carnegie Corporation of New York.
- Delandshere, G., & Arens, S.A. (2001). Representations of teaching and standards-based reform: Are we closing the debate about teacher education?. *Teaching and Teacher Education*, 17, 547-566.
- Delandshere, G., & Petrosky, A. (2004). Political rationales and ideological stances of the standards-based reform of teacher education in the US. *Teaching and Teacher Education*, 20, 1-15.
- Deng, Z. (2001). The distinction between key ideas in teaching school physics and key ideas in the discipline of physics. *Science Education*, 85(3), 263-278.
- Denzin, N.K. (1978). *The research act: A theoretical introduction to sociological methods* (2nd ed.). New York, NY: McGraw-Hill.
- Denzin, N.K., & Lincoln, Y.S. (2000). Introduction: The discipline and practice of qualitative research. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp.1-28). Thousand Oaks, CA: Sage Publications, Inc.
- Dewey, J. (1910). *How we think*. Lexington, MA: D.C. Heath.

- Dewey, J. (1910). Science as subject-matter and as method. *Science*, 31(787), 121-127.
- Doll, W.E. (1993). *A post-modern perspective on curriculum*. New York, NY: Teachers College Press.
- Duran, L.B., McArthur, J., & Van Hook, S. (2004). Undergraduate students' perceptions of an inquiry-based physics course. *Journal of Science Teacher Education*, 15(2), 155-171.
- Edelson, D.C., Gordin, D.N., & Pea, R.D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *The Journal of the Learning Sciences*, 8, 391-450.
- Edley, N. (2001). Unravelling social constructionism. *Theory & Psychology*, 11(3), 433-441.
- Eick, C., Meadows, L., & Balkcom, R. (2005). Breaking into inquiry. *The Science Teacher*, 72(7), 49-53.
- Eick, C.J., & Reed, C.J. (2002). What makes an inquiry-oriented science teacher? The influence of learning histories on student teacher role identity and practice. *Science Education*, 86(3), 401-416.
- Eisenhart, M., Finkel, E., & Marion, S.F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal*, 33(2), 261-295.
- Feldman, A. (2002). Multiple perspectives for the study of teaching: Knowledge, reason, understanding, and being. *Journal of Research in Science Teaching*, 39(10), 1032-1055.
- Finley, F.N., & Pocovi, M.C. (2000). Considering the scientific method of inquiry. In J. Minstrell, & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp.47-62). Washington, DC: American Association for the Advancement of Science.
- Flick, L.B. (1997). Focusing research on teaching practices in support of inquiry. In L.B. Flick, C.W. Keys, S.L. Westbrook, B.A. Crawford, & N.G. Cames, Perspectives on inquiry-oriented teaching practice: Conflict and clarification (pp.5-7). Symposium conducted at the meeting of the National Association for Research in Science Teaching, Oak Brook, IL. (ERIC Document Reproduction Service No. ED407255).
- Flick, L.B. (2000). Cognitive scaffolding that fosters scientific inquiry in middle level science. *Journal of Science Teacher Education*, 11(2), 109-129.

- Fradd, S.H., & Lee, O. (1999). Teachers' roles in promoting science inquiry with students from diverse language backgrounds. *Educational Researcher*, 28, 14-20.
- Furtak, E.M. (2006). The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education*, 90, 453-467.
- Gadamer, H.G. (1989). *Truth and method* (2nd rev. ed., J. Weinsheimer & D.G. Marshall, Trans.). New York, NY: Crossroad Publishing Corp.
- Gadamer, H.G. (1997). Reflections on my philosophical journey. In L.E. Hahn (Ed.), *The philosophy of Hans-Georg Gadamer* (pp.3-63). Chicago, IL: Open Court.
- Gauch, H.G. (2003). *Scientific method in practice*. Cambridge, UK: Cambridge University Press.
- Gergen, K.J. (1985). The social constructionist movement in modern psychology. *American Psychologist*, 40(3), 266-275.
- Gergen, K.J., & Gergen, M.M. (1991). Toward reflexive methodologies. In F. Steier (Ed.), *Research and reflexivity* (pp.76-95). London: Sage Publications, Inc.
- Glaser, B.G., & Strauss, A.L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Hawthorne, NY: Aldine Publishing Company.
- Goldhaber, D., & Anthony, E. (2003). *Teacher quality and student achievement*. (ERIC Document Reproduction Service No. ED477271).
- Goldhaber, D., & Anthony, E. (2004). Can Teacher Quality be Effectively Assessed?. Seattle, WA: Center on Reinventing Public Education, University of Washington.
- Goldhaber, D., Perry, D., & Anthony, E. (2003). *NBPTS certification: Who applies and what factors are associated with success?*. (ERIC Document Reproduction Service No. ED475841).
- Grandy, R., & Duschl, R.A. (2007). *Reconsidering the character and role of inquiry in school science: Analysis of a conference*. *Science & Education*, 16, 141-166.
- Grondin, J. (2002). Gadamer's basic understanding of understanding. In R.J. Dostal (Ed.), *The Cambridge companion to Gadamer*. New York, NY: Cambridge University Press.
- Guba, E.G. (1990). The alternative paradigm dialog. In E.G. Guba (Ed.), *The paradigm dialog* (pp.17-27). Newbury Park, CA: Sage Publications, Inc.

- Guba, E.G., & Lincoln, Y.S. (1981). *Effective Evaluation*. San Francisco, CA: Jossey-Bass.
- Guba, E.G., & Lincoln, Y.S. (1989). *Fourth generation evaluation*. Newbury Park, CA: Sage Publications, Inc.
- Haefner, L.A., & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education*, 26(13), 1653-1674.
- Hallinan, M.T., & Khmelkov, V.T. (2001). Recent developments in teacher education in the United States of America. *Journal of Education for Teaching*, 27(2), 175-185.
- Hammrich, P.L. (1998). What the science standards say: Implications for teacher education. *Journal of Science Teacher Education*, 9(3), 165-186.
- Hart, C., Mulhall, P., Berry, A., Loughran, J., & Gunstone, R. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments? *Journal of Research in Science Teaching*, 37(7), 655-675.
- Harwood, W.S., Reiff, R., & Phillipson, T. (2002). *Scientists' conceptions of scientific inquiry: Voices from the front*. Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science, Charlotte, NC. (ERIC Document Reproduction Service No. ED465632).
- Haycock, K. (1998). Good teaching matters: How well-qualified teachers can close the gap. *Thinking K-16*, 3(2), 1-14. (ERIC Document Reproduction Service No. ED457260).
- Hayes, M.T. (2002). Elementary preservice teachers' struggles to define inquiry-based science teaching. *Journal of Science Teacher Education*, 13(2), 147-165.
- Haynes, D.D. (1995). One teacher's experience with National Board assessment. *Educational Leadership*, 52 (6), 58-60.
- Hein, G. (2002). Director, Program Evaluation and Research Group, Lesley College, Cambridge, MA. In D. Llewellyn, *Inquire within: Implementing inquiry-based science standards*. Thousand Oaks, CA: Corwin Press.
- Helms, J.V., & Carlone, H.B. (1999). Science education and the commonplaces of science. *Science Education*, 83, 233-245.
- Henson, K.T. (1986). Inquiry learning: A new look. *Contemporary Education*, 57, 181-183.
- Herron, M.D. (1971). The nature of scientific enquiry. *School Review*, 79(2), 171-212.

- Hodson, D. (1998). Science fiction: The continuing misrepresentation of science in the school curriculum. *Curriculum Studies*, 6(2), 191-216.
- Hodson, D. (1999). Building a case for a sociocultural and inquiry-oriented view of science education. *Journal of Science Education and Technology*, 8(3), 241-249.
- Hofstein, A., & Lunetta, V.N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, 88, 28-54.
- Hogan, K., & Berkowitz, A.R. (2000). Teachers as inquiry learners. *Journal of Science Teacher Education*, 11(1), 1-25.
- Holmes Group. (1986). *Tomorrow's teachers*. East Lansing, MI: Holmes Group.
- Horizon Research. (2003). The influence of the National Science Education Standards on teachers and teaching practice. In K.S. Hollweg, & D. Hill (Eds.), *What is the influence of the National Science Education Standards?: Reviewing the evidence, a workshop summary* (pp.91-107). Washington, DC: The National Academies Press.
- Hurd, P.D. (1998). Scientific literacy: New minds for a changing world. *Science Education*, 82(3), 407-416.
- Hurd, P.D. (2002). Modernizing science education. *Journal of Research in Science Teaching*, 39(1), 3-9.
- Indiana Professional Standards Board. (2002). *Status of National Board certified teachers in Indiana*. Indianapolis, IN: Indiana Professional Standards Board.
- Ingersoll, R.M. (2002). In D. Viadero, Researcher skewers explanations behind teacher shortage. *Education Week*, 21(30), 7.
- Interstate New Teacher Assessment and Support Consortium. (1992). *Model standards for beginning teacher licensing, assessment and development: A resource for state dialogue*. Washington, DC: Interstate New Teacher Assessment and Support Consortium.
- Iovacchini, L.C. (1998). *National Board for Professional Teaching Standards: What teachers are learning*. Unpublished doctoral dissertation, College of Education, University of South Carolina, Columbia.
- Irvine, J.J., & Fraser, J.W. (1998). Warm demanders: Culturally responsive pedagogy of African-American teachers. *Education Week*, 17(35), 42.

- Izquierdo-Aymerich, M., & Aduriz-Bravo, A. (2003). Epistemological foundations of school science. *Science & Education*, 12, 27-43.
- Jeanpierre, B. (2006). What teachers report about their inquiry practices. *Journal of Elementary Science Education*, 18(1), 57-68.
- Jenkins, E. (2007). School science: A questionable construct? *Journal of Curriculum Studies*, 39(3), 265-282.
- Johnson, C.C. (2006). Effective professional development and change in practice: Barriers science teachers encounter and implications for reform. *School Science and Mathematics*, 106(3), 150-161.
- Johnson, C.C. (2007). Technical, political, and cultural barriers to science education reform. *International Journal of Leadership in Education*, 10(2), 171-190.
- Johnson, D. (2005). *Challenges to implementing inquiry: In the senior science classroom*. Saskatoon, SK: Dr. Stirling McDowell Foundation for Research into Teaching Inc.
- Johnson, W.R. (1987). Empowering practitioners: Holmes, Carnegie, and the lessons of history. *History of Education Quarterly*, 27(2), 221-240.
- Johnston, A. (2000). Deliberating over science curricula: A 'mundane' solution. *The National Honors Report*, 23-27.
- Jones, M.T., & Eick, C.J. (2007). Implementing inquiry kit curriculum: Obstacles, adaptations, and practical knowledge development in two middle school science teachers. *Science Education*, 91, 492-513.
- Keiffer-Barone, S., Mulvaney, C., Hillman, C., & Parker, M. (1999). *Toward a professional development community: A descriptive study of the experiences of National Board candidates*. Paper presented at the annual meeting of the Spring Meeting of the National Council of Teachers of English, Cincinnati, OH.
- Kelley, C., & Kimball, S.M. (2001). Financial incentives for National Board Certification. *Educational Policy*, 15(4), 547-574.
- Kennedy, M. (1998). *Form and substance in inservice teacher education*. Madison, WI: National Institute for Science Education Publications.
- Kennedy, M.M. (1998). Education reform and subject matter knowledge. *Journal of Research in Science Teaching*, 35(3), 249-263.
- Keys, C.W. (1997). Understanding the concepts of freedom and privileging in inquiry teaching and learning. In L.B. Flick, C.W. Keys, S.L. Westbrook, B.A. Crawford,

- & N.G. Cames, *Perspectives on inquiry-oriented teaching practice: Conflict and clarification* (pp.8-12). Symposium conducted at the meeting of the National Association for Research in Science Teaching, Oak Brook, IL. (ERIC Document Reproduction Service No. ED407255).
- Keys, C.W., & Kennedy, V. (1999). Understanding inquiry science teaching in context: A case study of an elementary teacher. *Journal of Science Teacher Education*, 10(4), 315-333.
- Keys, C.W., & Bryan, L.A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, 38(6), 631-645.
- Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching*, 39(7), 551-578.
- King Rice, J. (2003). *Teacher quality: Understanding the effectiveness of teacher attributes*. Washington, DC: Economic Policy Institute.
- Klein, H.K., & Myers, M.D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, 23(1), 67-94.
- Klein, S.P. (1998). Standards for teacher tests. *Journal of Personnel Evaluation in Education*, 12(2), 123-138.
- Kluger-Bell, B. (1999). Recognizing inquiry: Comparing three hands-on teaching techniques. In National Science Foundation (Ed.), *Inquiry thoughts, views, and strategies for the K-5 classroom* (pp.39-50). Arlington, VA: National Science Foundation.
- Koppich, J.E., & Knapp, M.S. (1998). *Federal research investment and the improvement of teaching 1980-1997*. Seattle, WA: Center for the Study of Teaching and Policy, University of Washington.
- Korthagen, F.A.J. (2004). In search of the essence of a good teacher: Towards a more holistic approach in teacher education. *Teaching and Teacher Education*, 20, 77-97.
- Kowalski, K. (1997). Professional development and the NBPTS certification process: A candidate's perspectives. In K. Kowalski, E. Chittenden, W. Spicer, J. Jones, & C. Tocci, *Professional development in the context of National Board for Professional Teaching Standards certification: Implications beyond certification* (pp. 4-8). Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

- Kraft, N.P. (2001). *Standards in teacher education: A critical analysis of NCATE, INTASC, and NBPTS (A conceptual paper/review of the research)*. Paper presented at the annual meeting of the American Educational Research Association, Seattle, WA.
- Laugksch, R.C. (2000). Scientific literacy: A conceptual overview. *Science Education*, 84(1), 71-94.
- Lawson, A.E. (2005). What is the role of induction and deduction in reasoning and scientific inquiry? *Journal of Research in Science Teaching*, 42(6), 716-740.
- Lederman, N. G. (1998). The state of science education: Subject matter without context. *Electronic Journal of Science Education*, 3(2). Retrieved February 13, 2005, from <http://unr.edu/homepage/jcannon/ejse/lederman.html>
- Lederman, N.G. (2004). Scientific inquiry and science education reform in the United States. In F. Abd-El-Khalick, S. Boujaoude, R. Duschl, N.G. Lederman, R. Mamlok-Naaman, & A. Hofstein et al., *Inquiry in science education: International perspectives* (pp. 402-404). *Science Education*, 88(3), 397-419.
- Levitt, K.E. (2001). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education*, 86(1), 1-22.
- Lewthwaite, B. (2007). Critiquing science lessons for their authenticity as a means of evaluating teacher-candidate understanding of the nature of science. *Journal of Science Teacher Education*, 18, 109-124.
- Lincoln, Y.S., & Guba, E.G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage Publications, Inc.
- Lincoln, Y.S., & Guba, E.G. (1986). But is it rigorous? Trustworthiness and authenticity in Naturalistic evaluation. In D.D. Williams (Ed.), *Naturalistic evaluation* (No.30, pp.73-84). San Francisco: Jossey-Bass.
- Llewellyn, D. (2002). *Inquire within: Implementing inquiry-based science standards*. Thousand Oaks, CA: Corwin Press.
- Llewellyn, D. (2004). *Teaching high school science through inquiry: A case study approach*. Thousand Oaks, CA: Corwin Press.
- Lotter, C., Harwood, W.S., & Bonner, J.J. (2007). The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching*, 44(8), 1-30.
- Luera, G.R., Moyer, R.H., & Everett, S.A. (2005). What type and level of science content knowledge of elementary education students affect their ability to

- construct an inquiry-based science lesson? *Journal of Elementary Science Education*, 17(1), 12-25.
- Lustick, D. (2002). *National Board Certification as professional development: A study that identifies a framework and findings of teachers learning to manage complexity, uncertainty, and community*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Lustick, D., & Sykes, G. (2006). National board certification as professional development: What are teachers learning? *Education Policy Analysis Archives*, 14(5), 1-46.
- Lynch, M.J., & Zenchak, J.J. (2002). *Use of scientific inquiry to explain counterintuitive observations*. Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science, Charlotte, NC. (ERIC Document Reproduction Service No. ED465617).
- Lynch, S. (1997). Novice teachers' encounter with national science education reform: Entanglements or intelligent interconnections? *Journal of Research in Science Teaching*, 34(1), 3-17.
- Matson, J.O., & Parsons, S. (2006). Misconceptions about the nature of science, inquiry-based instruction, and constructivism: Creating confusion in the science classroom. *Electronic Journal of Literacy through Science*, 5(6), 1-10.
- McComas, W.F. (1998). The principle elements of the nature of science: Dispelling the myths. In W.F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp.53-70). Dordrecht, the Netherlands: Kluwer Academic Publishers.
- McComas, W.F. (2005a). Laboratory instruction in the service of science teaching and learning. *The Science Teacher*, 72(7), 24-29.
- McComas, W.F. (2005b). *Teaching the nature of science: What illustrations and examples exist in popular books on the subject?* Paper presented at the annual meeting of the International History, Philosophy and Science Teaching Group (IHPST), Leeds, UK.
- McDermott, L.C., Shaffer, P.S., & Constantinou, C.P. (2000). Preparing to teachers to teach physics and physical science by inquiry. *Physics Education*, 35(6), 411-416.
- Milanowski, A., Odden, A., & Youngs, P. (1998). Teacher knowledge and skill assessments and teacher compensation: An overview of measurement and linkage issues. *Journal of Personnel Evaluation in Education*, 12(2), 83-101.

- Miles, M.B., & Huberman, A.M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage Publications, Inc.
- Minstrell, J., & van Zee, E. (2000). Introduction. In J. Minstrell, & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp.xi-xx). Washington, DC: American Association for the Advancement of Science.
- Mitchell, K.J., Robinson, D.Z., Plake, B.S., & Knowles, K.T. (2001). *Testing teacher candidates: The role of licensure tests in improving teacher quality*. Washington, DC: National Academy Press.
- Moseley, C., & Rains, A. (2002, Summer). National Board for Professional Teaching Standards: A reflective essay. *The Delta Kappa Gamma Bulletin*, 68(4), 44-48.
- National Board for Professional Teaching Standards. (1989). *Toward high and rigorous standards for the teaching profession*. Detroit, MI: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2000). *A distinction that matters: Why national teacher certification makes a difference*. Arlington, VA: National Board for Professional Teaching Standards
- National Board for Professional Teaching Standards. (2001a). *I am a better teacher: What candidates for National Board Certification say about the assessment process*. Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2001b). *The impact of National Board Certification on teachers: A survey of National Board certified teachers and assessors*. Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2002). *What teachers should know and be able to do*. Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2003a). *A candidate's guide to National Board Certification 2003-04*. Washington, DC: American Federation of Teachers and National Education Association.
- National Board for Professional Teaching Standards. (2003b). *Adolescence and young adulthood science standards* (2nd ed.). Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2003c). *Early adolescence science standards* (2nd ed.). Arlington, VA: National Board for Professional Teaching Standards.

- National Board for Professional Teaching Standards. (2004a). *Why America needs National Board certified teachers*. Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2004b). *Early adolescence science portfolio instructions*. Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2004c). *Adolescence and young adulthood science: Scoring guide*. Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2004d). *Adolescence and young adulthood science portfolio instructions*. Arlington, VA: National Board for Professional Teaching Standards.
- National Board for Professional Teaching Standards. (2006). *Early adolescence science scoring guide*. Arlington, VA: National Board for Professional Teaching Standards.
- National Center for Education Statistics. (1997). *The status of teaching as a profession: 1990-91*. Washington, DC: U.S. Department of Education
- National Center for Education Statistics. (1999). *Teacher quality: A report on the preparation and qualifications of public school teachers*. Washington, DC: U.S. Department of Education.
- National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Retrieved April 08, 2004, from <http://www.ed.gov/pubs/NatAtRisk/risk.html>
- National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before it's too late*. Washington, DC: U.S. Department of Education.
- National Commission on Teaching and America's Future. (1996). *What matters most: Teaching for America's future*. New York, NY: National Commission on Teaching and America's Future.
- National Commission on Teaching and America's Future. (1997). *Doing what matters most: Investing in quality teaching*. New York, NY: National Commission on Teaching and America's Future.
- National Committee on Science Education Standards and Assessment. (1992). *National science education standards: A sampler*. Washington, DC: National Research Council.

- National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.
- National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.
- Nelson, G.D. (1999). Science literacy for all in the 21st century. *Educational Leadership*, 57(2), 14-17.
- Newman, W.J., Abell, S.K., Hubbard, P.D., McDonald, J., Otaala, J., & Martini, M. (2004). Dilemmas of teaching inquiry in elementary science methods. *Journal of Science Teacher Education*, 15(4), 257-279.
- Nightingale, D.J., & Cromby, J. (2002). Social constructionism as ontology: Exposition and example. *Theory & Psychology*, 12(5), 701-713.
- Northwest Regional Educational Laboratory. (1997). *Inquiry strategies for science and mathematics learning: It's just good teaching*. Portland, OR: Northwest Regional Educational Laboratory.
- Northwest Regional Educational Laboratory. (1999). *Science inquiry for the classroom: A literature review*. Portland, OR: Northwest Regional Educational Laboratory.
- Oliver, J.S., Jackson, D.F., Chun, S., Kemp, A., Tippins, D.J., Leonard, R., et al. (2001). The concept of scientific literacy: A view of the current debate as an outgrowth of the past two centuries. *Electronic Journal of Literacy through Science*, 1(1), 1-33.
- O'Sullivan, C.Y., & Weiss, A.R. (1999). *Student work and teacher practices in science: A report on what students know and can do*. Washington, DC: National Center for Education Statistics, U.S. Department of Education.
- Palmer, R.E. (1969). *Hermeneutics: Interpretation theory in Schleiermacher, Dilthey, Heidegger, and Gadamer*. Evanston, IL: Northwestern University Press.
- Parsons, S., Matson, J.O., & Quintanar, R. (2002). Making sense of literacy through science (its): A model for professional development. *Electronic Journal of Literacy through Science*, 1(2), 1-19.
- Patton, M.Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage Publications, Inc.
- Piaget, J. (1964). Development and learning. In R.E. Ripple, & V.N. Rockcastle (Eds.), *Piaget rediscovered*. Ithaca, NY: Cornell University Press.

- Pinar W.F., Reynolds, W.M, Slattery, P., & Taubman, P.M. (2000). *Understanding curriculum: An introduction to the study of historical and contemporary curriculum discourses*. New York, NY: Peter Lang Publishing.
- Polman, J.L., & Pea, R.D. (2001). Transformative communication as a cultural tool for guiding inquiry science. *Science Education*, 85(3), 223-238.
- Pool, J.E., Ellett, C.D., Schiavone, S., & Carey-Lewis, C. (2001). How valid are the National Board of Professional Teaching Standards assessments for predicting the quality of actual classroom teaching and learning? Results of six mini case studies. *Journal of Personnel Evaluation in Education*, 15(1), 31-48.
- Prasad, A. (2002). The contest over meaning: Hermeneutics as an interpretive methodology for understanding texts. *Organizational Research Methods*, 5(1), 12-33.
- Radford, D.L. (1998). Transferring theory into practice: A model for professional development for science education reform. *Journal of Research in Science Teaching*, 35(1), 73-88.
- Ramalay, J. (2003). Building public understanding of science: A matter of trust. In S.P. Marshall, J.A. Scheppler, & M.J. Palmisano (Eds.), *Science literacy for the twenty-first century* (pp.221-232). Amherst, NY: Prometheus Books.
- Rankin, L. (1999). Lessons learned: Addressing common misconceptions about inquiry. In National Science Foundation (Ed.), *Inquiry thoughts, views, and strategies for the K-5 classroom* (pp.33-37). Arlington, VA: National Science Foundation.
- Raskin, J.D. (2002). Constructivism in psychology: Personal construct psychology, radical constructivism, and social constructionism. In J.D. Raskin & S.K. Bridges (Eds.), *Studies in meaning: Exploring constructivist psychology* (pp.1-25). New York: Pace University Press.
- Rasmussen, J. (2002). *Textual interpretation and complexity-Radical hermeneutics*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Reiff, R.R. (2004). *Scientists' conceptions of scientific inquiry: Revealing a private side of science*. Unpublished doctoral dissertation, School of Education, Indiana University, Bloomington.
- Roth, W.M., McGinn, M.K., & Bowen, G.M. (1998). How prepared are preservice teachers to teach scientific inquiry? Levels of performance in scientific representation practices. *Journal of Science Teacher Education*, 9(1), 25-48.

- Rowbottom, D.P., & Aiston, S.J. (2006). The myth of "scientific method" in contemporary educational research. *Journal of philosophy of Education*, 40(2), 137-156.
- Rudolph, J.L. (2003). Portraying epistemology: School science in historical context. *Science Education*, 87(1), 64-79.
- Sanders, W.L., & Rivers, J.C. (1996). *Cumulative and residual effects of teachers on future student academic achievement*. Knoxville, TN: University of Tennessee.
- Sandoval, W.A. (2003). The inquiry paradox: Why doing science doesn't necessarily change ideas about science. In C.P. Constantinou & Z.C. Zacharia (Eds.), *Proceedings of the sixth International Computer-Based Learning in Science Conference* (pp.825-834). Nicosia, Cyprus. Retrieved February 13, 2005, from <http://www.gseis.ucla.edu/faculty/sandoval/pdf/sandoval-cblis03.pdf>
- Sandoval, W.A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, 89, 634-656.
- Sandoval, W.A., & Daniszewski, K. (2004). Mapping trade-offs in teachers' integration of technology-supported inquiry in high school science classes. *Journal of Science Education and Technology*, 13(2), 161-178.
- Sato, M. (2000). *The National Board for Professional Teaching Standards: Teacher learning through the assessment process*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Schacter, J. (2001). *Teacher performance-based accountability: Why, what and how*. Santa Monica, CA: Milken Family Foundation.
- Schneider, R.M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching*, 42(3), 283-312.
- Schwab, J.J. (1962). The teaching of science as enquiry. In J.J. Schwab & P.F. Brandwein (Eds.), *The teaching of science*, (pp.3-103). Cambridge, MA: Harvard University Press.
- Schwandt, T.A. (1999). On understanding understanding. *Qualitative Inquiry*, 5(4), 451-464.
- Schwarz, C.V., & Gwekwerere, Y.N. (2007). Using a guided inquiry and modeling instructional framework (EIMA) to support preservice K-8 science teaching. *Science Education*, 91, 158-186.
- Schwartz, R.S., Lederman, N.G., & Crawford, B.A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap

- between nature of science and scientific inquiry. *Science Education*, 88(4), 610-645.
- Serafini, F. (2002). Possibilities and challenges: The National Board for professional Teaching Standards. *Journal of Teacher Education*, 53(4), 316-327.
- Settlage, J. (2007). Demythologizing science teacher education: Conquering the false ideal of open inquiry. *Journal of Science Teacher Education*, 18, 461-467.
- Sexton, T.L. (1997). Constructivist thinking within the history of ideas: The challenge of a new paradigm. In T.L. Sexton & B.L. Griffin (Eds.), *Constructivist thinking in counseling practice, research, and training* (pp.1-19). New York: Teachers College Press.
- Shaker, P. (2001). Teacher testing: A symptom. *Teaching Education*, 12(1), 65-80.
- Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.
- Smith, T.M., Desimone, L.M., Zeidner, T.L., Dunn, A.C., Bhatt, M., & Rumyantseva, N.L. (2007). Inquiry-oriented instruction in science: Who teaches that way? *Educational Evaluation and Policy Analysis*, 29(3), 169-199.
- Smolleck, L.D., Zembal-Saul, C., & Yoder, E.P. (2006). The development and validation of an instrument to measure preservice teachers' self-efficacy in regard to the teaching of science as inquiry. *Journal of Science Teacher Education*, 17, 137-163.
- Snodgrass, A., & Coyne, R. (1997). Is designing hermeneutical? Architectural theory review. *Journal of the Department of Architecture*, the University of Sydney, 1(1), 65-97.
- Sockett, H. (1985). Towards a professional code in teaching. In P. Gordon (Ed.), *Is teaching a profession?* (pp.26-43). London: Institute of Education, University of London.
- Songer, N.B., Lee, H., & McDonald, S. (2003). Research towards an expanded understanding of inquiry science beyond one idealized standard. *Science Education*, 87(4), 490-516.
- Southerland, S.A., Gess-Newsome, J., & Johnston, A. (2003). Portraying science in the classroom: The manifestation of scientists' beliefs in classroom practice. *Journal of Research in Science Teaching*, 40(7), 669-691.
- Spiece, K.R., & Colosi, J. (2000). Redefining the "scientific method." *The American Biology Teacher*, 62(1), 32-40.

- Sund, R.B., & Trowbridge, L.W. (1967). *Teaching science by inquiry in the secondary school*. Columbus, OH: Charles E. Merrill Books, Inc.
- Sutton, J., & Krueger, A. (Eds.). (2001). *EDThoughts: What we know about science teaching and learning*. Aurora, CO: Mid-continent Research for Education and Learning. (ERIC Document Reproduction Service No. ED465535).
- Tafoya, E., Sunal, D., & Knecht, P. (1980). Assessing inquiry potential: A tool for curriculum decision makers. *School Science and Mathematics*, 80(1), 43-48.
- Tamir, P. (1991). Practical work in school science: An analysis of current practice. In B. Woolnough (Ed.), *Practical Science* (pp.13-20). Milton Keynes: Open University Press.
- Taylor, G.A. (2000). *Teacher change and National Board for Professional Teaching Standards: A case study of eleven Colorado teachers*. Unpublished doctoral dissertation, College of Education, University of Colorado, Boulder.
- Taylor, J.A., & Dana, T.M. (2003). Secondary school physics teachers' conceptions of scientific evidence: An exploratory case study. *Journal of Research in Science Teaching*, 40(8), 721-736.
- Tobin, K., Tippins, D., & Gallard, A.J. (1994). Research in instructional strategies for teaching science. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp.43-93). New York: Macmillan.
- Trautmann, N., MaKinster, J., & Avery, L. (2004). *What makes inquiry so hard? (And why is it worth it?)*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Vancouver, Canada.
- Trumbull, D.J., Scarano, G., & Bonney, R. (2006). Relations among two teachers' practices and beliefs, conceptualizations of the nature of science, and their implementation of student independent inquiry projects. *International Journal of Science Education*, 28(14), 1717-1750.
- Vandevoort, L.G., Amrein-Beardsley, A., & Berliner, D.C. (2004). National Board certified teachers and their students' achievement. *Education Policy Analysis Archives*, 12(46), 1-117.
- van Driel, J.H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, 38(2), 137-158.
- Volkman, M.J., & Anderson, M.A. (1998). Creating professional identity: Dilemmas and metaphors of a first-year chemistry teacher, *Science Education*, 82(3), 293-310.

- Volkman, M.J., & Zgagacz, M. (2004). Learning to teach physics through inquiry: The lived experience of a graduate teaching assistant. *Journal of Research in Science Teaching*, 41(6), 584-602.
- von Glaserfeld, E. (1991). Knowing without metaphysics: Aspects of the radical constructivist position. In F. Steier (Ed.), *Research and reflexivity* (pp.12-29). London: Sage Publications, Inc.
- von Glaserfeld, E. (1995). *Radical constructivism: A way of knowing and learning*. London: The Falmer Press.
- Waight, N., & Abd-El-Khalick, F. (2007). The impact of technology on the enactment of "inquiry" in a technology enthusiast's sixth grade science classroom. *Journal of Research in Science Teaching*, 44(1), 154-182.
- Wallace, C.S., & Kang, N. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, 41(9), 936-960.
- Wallen, N.E., & Fraenkel, J.R. (2001). *Educational research: A guide to the process* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Wee, B., Shepardson, D., Fast, J., & Harbor, J. (2007). Teaching and learning about inquiry: Insights and challenges in professional development. *Journal of Science Teacher Education*, 18, 63-89.
- Weiss, I.R. (1997). The status of science and mathematics teaching in the United States: Comparing teacher views and classroom practice to national standards. *Nise Brief*, National Institute for Science Education, 1(3), 1-7.
- Welch, W.W., Klopfer, L.E., Aikenhead, G.S., & Robinson, J.T. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education*, 65(1), 33-50.
- Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality*. Princeton, NJ: Educational Testing Service.
- Wenning, C.J. (2005). Levels of inquiry: Hierarchies of pedagogical practices and inquiry practices. *Journal of Physics Teacher Education Online*, 2(3), 3-11.
- Wheeler, G.F. (2000). The three faces of inquiry. In J. Minstrell, & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp.14-19). Washington, DC: American Association for the Advancement of Science.

- Wiebke, K. (2000, Nov/Dec). My journey through National Board Certification. *Scholastic Instructor*, 110, 26-27.
- Wilber, K. (1995). *Sex, ecology, spirituality: The spirit of evolution*. Boston, MA: Shambhala Publications, Inc.
- Wilber, K. (1997a). *The eye of spirit: An integral vision for a world gone slightly mad*. Boston, MA: Shambhala Publications, Inc.
- Wilber, K. (1997b). An integral theory of consciousness. *Journal of Consciousness Studies*, 4(1), 71-92. Retrieved July 26, 2003, from <http://www.imprint.co.uk/Wilber.htm>
- Wilber, K. (1997c, Fall). A spirituality that transforms. *What is Enlightenment?*, 12. Retrieved July 31, 2007, from <http://wilber.shambhala.com/html/misc/spthtr.cfm/>
- Wilber, K. (2000). *Integral psychology: Consciousness, spirit, psychology, therapy*. Boston, MA: Shambhala Publications, Inc.
- Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice?. *Science Education*, 87(1), 112-143.
- Windschitl, M. (2004). Folk theories of "inquiry": How preservice teachers reproduce the discourse and practices of an atheoretical scientific method. *Journal of Research in Science Teaching*, 41(5), 481-512.
- Windschitl, M., Dvornich, K., Ryken, A.E., Tudor, M., & Koehler, G. (2007). A comparative model of field investigations: Aligning school science inquiry with the practices of contemporary science. *School Science and Mathematics*, 107(1), 382-390.
- Windschitl, M., & Thompson, J. (2006). Transcending simple forms of school science investigation: The impact of preservice instruction on teachers' understandings of model-based inquiry. *American Educational Research Journal*, 43(4), 783-835.
- Wise, A.E., & Leibbrand, J. (2000). Standards and teacher quality: Entering the new millennium. *Phi Delta Kappan*, 81(8), 612-621.
- Zion, M., Slezak, M., Shapira, D., Link, E., Bashan, N., Brumer, M., et al. (2004). Dynamic, open inquiry in biology learning. *Science Education*, 88, 728-753.

BIOGRAPHICAL SKETCH

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