DESIGNING FOR CULTURALLY RESPONSIVE SCIENCE EDUCATION THROUGH PROFESSIONAL DEVELOPMENT

By

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To my mother, Janice Ferguson: You are the best friend and greatest mother I could have prayed for. Thank you for always believing in me.

To my father, David Ferguson: You are my first and everlasting hero. I love you with all my heart.

To my husband, Barry Brown: You will forever be the love of my life.

To our daughter, Jolene: Being your mommy has been my greatest accomplishment yet.

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LIST OF ABBREVIATIONS

AAAS	American Association for the Advancement of Science
BARSTL	*Beliefs About Reformed Science Teaching and Learning*
CRIOP	Culturally Responsive Instruction Observation Protocol
CRP	Culturally Responsive Pedagogy
CRP Science	Culturally Responsive Pedagogies in Science education
CTS	Curriculum Topic Study
DBR	Design-Based Research
DDR	Design Decisions Document
ELL	English Language Learners
ESOL	English for Speakers of Other Languages
GAIn	Growing Awareness Inventory
NAEP	National Assessment of Educational Progress
NAS	National Academy of Sciences
NCES	National Center for Education Statistics
NRC	National Research Center
NSF	National Science Foundation
oTPD	Online Teacher Professional Development
PD	Professional Development
PDC	Pedagogical Design Capacity
PG	Professional Growth tasks
PLC	Professional Learning Community
PST	Preservice Teacher
RTOP	Reformed Teaching Observation Protocol

RWP	Reflective Writing Prompt
SSI	Socioscientific Issues
SSI	Summer Science Institute
STARTS	Science Teachers Are Responsive To Students
STEM	Science, Technology, Engineering, and Mathematics

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Many scholars argue that bridging students' backgrounds with canonical science is necessary when educating diverse students as it reduces incongruences between home and school (Aikenhead & Jegede, 1999) and increases the authenticity of science learning (Buxton, 2006). However, teachers are often underprepared for such an endeavor and struggle with enacting culturally responsive pedagogies in science education (CRP Science). Moreover, responsive teaching within restrictive school environments is daunting due to political backlash (Sleeter, 2012) and scarcity of curriculum resources (Lee, 2004; Mensah, 2009). Thus, not only do science teachers require explicit supports for CRP Science teaching and constructing culturally responsive instructional materials, such initiatives must also address the larger contextual influences at play. The STARTS (Science Teachers Are Responsive To Students) PD program was created as a response to these challenges.

This qualitative study employed a design-based research (DBR) framework (Barab & Squire, 2004; Wang & Hannafin, 2005) to examine the professional growth of six high school life science teachers as they participated in the 7-month STARTS PD

program as well as the relationships between STARTS design elements and teachers' CRP Science knowledge and practices. Classroom observations, focus group interviews, and numerous program artifacts were analyzed through multiple methods, including grounded theory analysis (Strauss & Corbin, 1998), typological analysis (Hatch, 2002), and matrix analysis (Miles & Huberman, 1994). Characteristic of DBR, the study produced usable knowledge through the generation of local theory, a design framework, and accompanying design principles, thereby demonstrating both local impact and general relevance.

Findings identified six themes characteristic of teachers' progression as CRP Science educators in this setting: their views of students, CRP Science conceptions, student repositioning, community building, toolbox, and instructional changes. Additionally, several design elements were associated with teachers' professional growth, including critical exploration of and reflection on practice, collective participation, examining critical perspectives on education for diverse students, brainstorming CRP Science lesson ideas, and structured opportunities to learn about students' lives alongside the scaffolded integration of students' backgrounds with reform-based science instruction. These results highlight the need for explicit and empirically grounded PD elements when supporting CRP Science teachers' development.

CHAPTER 1
INTRODUCTION

As the United States experiences population growth greater than any other industrialized nation (El Nasser, 2006; El Nasser & Overberg, 2011), unequal increases among populations have transformed the nation's demographics. In the past century, the U.S. has witnessed a rapid change in its racial profile. The 1900 U.S. Census reported that non-White citizens represented one out of every eight members of the population. A little over a century later that ratio is now one in three (Howard, 2010).

Simultaneously, the notion of education as the great equalizer has been challenged as achievement disparities stratified by race and socioeconomic status persist across all academic disciplines and grade levels (Kelly-Jackson & Jackson, 2011; National Center for Education Statistics [NCES], 2010; National Assessment of Educational Progress [NAEP], 2009). According to 2007 Department of Education data, students of color comprised 42% of the entire public school population and are projected to reach majority status over the next few decades (NCES, 2007). With the diversity of the U.S. citizenry and students rapidly increasing, the economic and social implications of the achievement gap can yield negative outcomes.

Current U.S. educational practices leave a significant portion of the nation's citizens undereducated and underprepared for competition in the global economy (Howard, 2010). Students from diverse racial backgrounds do want to pursue studies in science, technology, engineering, and mathematics- (STEM) related fields (Riegle-Crumb, Moore, & Ramos-Wada, 2010), yet by the time they enter STEM professions they comprise only 10% of the entire workforce (National Science Foundation [NSF], 2006). Populations that consistently remain underrepresented in the STEM disciplines include Black (i.e., African American, Caribbean American) and Hispanic (i.e., Latino/a) individuals as well as those from low socioeconomic backgrounds (NCES, 2010).

The well-documented inaccessibility of STEM to students from diverse backgrounds perpetuates the existing achievement gap (NAEP, 2009) and is considered to be a contributing factor to the marginal presence of diverse individuals in STEM professions (Campbell, Denes, & Morrison, 2000; Riegle-Crumb, Moore, & Ramos-Wada, 2010). For instance, the STEM professions, which boast some of the highest-paying jobs in the nation, remain largely exclusive in terms of race (National Science Foundation [NSF], 2011). A majority of STEM professions require some form of postsecondary or advanced degree, which further constrains the workforce population, as higher education attendance rates for students from low income backgrounds and underrepresented racial groups are lower when compared to White and Asian students (Aud et al., 2011).

With a growing number of 21st century occupations requiring scientific literacy, the exclusion of diverse populations from the STEM workforce constricts economic opportunities, making it considerably more difficult to pursue liberties such as access to quality housing, healthcare, and education (Aud et al., 2010; Bullard, 2001). For example, when compared with workers who enter other professional fields, STEM professionals experience lower unemployment rates. Additionally, STEM occupations are fast growing and offer salaries significantly above the national average (Thomasian, 2011).

Engaging students in current science content and practices has become the cornerstone of the most recent science education reform movement and is espoused in the National Research Council's (NRC) 2012 report, *The Framework for K-12 Science Education,* as a means to "(1) educat[e] all students in science and engineering and (2) provid[e] the foundational knowledge for those who will become the scientists, engineers, technologists, and technicians of the future" (p. 10). The form of science education advocated in the *Framework* stands in stark contrast to traditional notions of science in the classroom, which emphasize teacher-directed instruction built around textbook-driven lessons (Akkus, Gunel, & Hand, 2007; DeBoer, 1991). Aimed at achieving great coherence throughout K-12 science teaching and learning, the *Framework* has explicated core science ideas and crosscutting concepts on which instruction should build over time. Furthermore, priority is placed on enacting authentic science and engineering practices, facilitated through inquiry and engineering design. Inquiry is a prominent facet of reform-based science education according to the *National Science Education Standards* (NSES) (NRC, 1996) and *Next Generation Science Standards* (NGSS) (Achieve, 2014) and serves as "the instructional bridge that connects doing and learning science" (Jackson & Ash, 2012, p. 724). These shifts have led to the drafting of specific performance expectations for students as learners. To realize the vision of modern reform-based science education, all students must actively engage with science concepts, collect and analyze data, construct and defend arguments from evidence, and communicate scientific information (NRC, 1996; NRC, 2012).

In an attempt to address the persistent achievement gap in science by race and income level (NAEP, 2009), the *Framework* has also made prominent a desire to achieve "Science for All" through curriculum and instruction. A growing research base argues that integrating students' cultures with science instruction bridges the discontinuity between home and school, thereby making science more accessible and meaningful (Aikenhead & Jegede, 1999; Calabrese Barton, 1998; Lee, 2004). Culturally responsive pedagogy (CRP) (Gay, 2010; Ladson-Billings, 1994; 1995) is one approach to reducing current achievement disparities. CRP aims to bolster the academic performance of diverse students by "using the[ir] cultural knowledge, prior experiences, frames of reference, and performance styles" (Gay, 2010, p.31) to make learning opportunities more equitable and effective. Culturally responsive pedagogies in science education (hereafter referred to as CRP Science) (Johnson, 2009; Laughter & Adams, 2012; Mensah, 2009) utilize multiple strategies in addition to reform-based science instruction to facilitate the academic achievement of diverse students. Some of these strategies include: language supports (Johnson, 2009; Lee & Fradd, 1998), relationship building and care (Kelly-Jackson & Jackson, 2011; Mensah, 2011), and social action (Bouillion & Gomez, 2001; Fusco, 2001).

Despite the potential of CRP Science to ameliorate current academic trends, it is not widely implemented (Bianchini & Brenner, 2010; Patchen & Cox-Petersen, 2008). Teachers report feeling underprepared to educate diverse students (Lee & Buxton, 2010; Song, 2006) and struggle to teach in ways that are culturally responsive (Patchen & Cox-Petersen, 2008; Rodriguez, 1998). Because of the great influence teachers have on students' learning and enacting educational reform (Abell, 2007; Atwater, 1996), as well as the promise of CRP Science to positively impact the academic performance of diverse students, teachers' development as culturally responsive science educators must be supported before CRP Science can be realized.

Purpose of the Study

The widespread implementation of CRP Science is needed to increase educational opportunities and achievement for diverse students. In order to achieve 21st century Science for All, science education reform efforts must focus on supporting teachers as they attempt to enact the myriad responsibilities within the *Framework.* Preservice teacher preparation alone is inadequate (NRC, 2012); therefore, professional development (PD) for highly effective science teachers who can successfully educate diverse students is warranted. In this study, the STARTS (*Science Teachers Are Responsive To Students*) PD framework was examined through a design-based approach to better understand the impact of this intervention on the learning progression of six high school life science teachers and to identify any salient mediating features of the framework. To this end, the first attempt to explore CRP Science through design-based research was completed with the prominent goals of uncovering mechanisms influencing teachers' progression as well as the construction of a local theory and design framework for the STARTS PD program (Edelson, 2002; McKenney & Reeves, 2012).

The STARTS program has been designed to build capacity for sustainable change by empowering high school life science teachers with both the practical and theoretical base required to become CRP Science teachers. The program is dual-focused on pedagogy and content, thereby addressing challenges common to PD initiatives such as providing teachers with the tools to learn about their students while also connecting instructional decisions to science content and state standards. Further, STARTS addresses the current lack of culturally responsive curricular resources (Lee, 2004; NRC, 2000) by supporting science teachers as designers of their own CRP Science instructional units.

Accordingly, the purpose of this dissertation was to: (1) characterize the progression of CRP Science knowledge and practices in a group of six high school life science teachers who participated in the STARTS PD program and (2) identify STARTS design elements associated with supporting this professional growth.

Statement of the Problem

Changing Demographics and Accompanying Achievement Disparities

Longstanding achievement disparities among Black and Hispanic students and their White and Asian counterparts exist. These gaps transcend subject areas and grade levels (NAEP, 2009; NCES, 2010; NRC, 2012). Scholars believe that action must be taken to alter achievement disparities within the U.S. educational system. These scholars contend that positive changes can be made when students, teachers, and schools form meaningful connections, in addition to utilizing the culture of the students as educational resources in the classroom (Banks et al, 2005; Gay, 2010; Howard, 2010; Villegas & Lucas, 2002). Pedagogy such as this can be described as culturally responsive and is a direct challenge to traditional forms of schooling in which "academic success often depends on assimilation into mainstream norms" (Lee & Luykx, 2007, p. 173).

Despite the potential of CRP to improve current academic trends, widespread implementation has been lackluster due to a number of challenges, including a paucity of research connecting CRP with student achievement (Sleeter, 2012), lack of supporting resources (Bianchini & Brenner, 2010; Lee, 2004; NRC, 2012), and teacher resistance (Barnes & Barnes, 2005; Rodriguez, 1998). Yet, as one of the most influential factors on student learning (Abell, 2007; Atwater, 1996), teachers play an integral role in facilitating science education reform. Therefore, studies exploring how teachers become facilitators of CRP Science in the classroom, as well as which experiences support this development, are needed.

Teachers are Linchpins for Science Education Reform

For teachers to simultaneously implement reform-based science and connect instruction to students' lives, they must possess a wealth of knowledge, skills, and dispositions. For instance, in order to be culturally responsive and reform-based, science teachers must command deep content knowledge, topic-specific pedagogical content knowledge, and they must provide authentic learning experiences rich in scientific practices, disciplinary core ideas, and crosscutting concepts (NRC, 2012). Additionally, they must impart care, promote a sense of community in the classroom, use instruction to uncover oppression, and foster students' cultural competence (i.e., supporting them in academic success that does not run counter to, or at the expense of, their identities) (Gay, 2010; Ladson-Billings, 1994; 1995; Powell et al., 2011; Villegas & Lucas, 2002). Compounding the challenges inherent to embodying these practices, many science teachers are already at a disadvantage because they tend to teach in the same traditional ways they were taught as students (Hammerness et al., 2005; Lortie, 1975). As students, many science teachers never experienced true reform-based learning (Barnes & Barnes, 2005; Crippen, 2012). Hence, the professional development of practicing teachers is necessary to support changes in their knowledge and practices.

However, not all PD experiences are created equal. An expansive literature base indicates that effective professional learning opportunities are connected to teachers' daily work (Borko, 2004; Coggshall, Rasmussen, Colton, Milton, & Jacques, 2012;

Desimone, 2009) and enable collaboration (Garet et al., 2001). Teachers' knowledge should be developed through authentic, active learning experiences (Garet et al., 2001; Loucks-Horsley et al., 2010); involvement in the analysis of student work (Lewis, Perry, Hurd, & O'Connell, 2006; Mutch-Jones, Puttick, & Minner, 2012; Shimizu, 2002); and provision of ongoing supports such as equipment (Brown et al., 2014; Zozakiewicz & Rodriguez, 2007) and mentoring (Davis & Varma, 2008). Moreover, despite the implementation of research-grounded PD experiences, teachers' struggles with enacting reform are common and can seriously impede program goals (Bell & Gilbert, 1994; Crippen et al., 2010; Parke & Coble, 1997; Yerrick & Beatty-Adler, 2011).

Increasing Widespread Implementation of CRP Science

CRP Science (a) contextualizes instruction in students' lives and experiences (Basu & Calabrese Barton, 2007; Calabrese Barton, 1998; Mensah, 2011); (b) engages learners in inquiry (Bianchini & Brenner, 2010; Kelly-Jackson & Jackson, 2011); (c) occurs in respectful and inclusive learning environments where multiple perspectives are acknowledged (Lee, 2004; Elmesky & Tobin, 2005) and language supports are widely implemented (Lee, 2004; Johnson, 2009); (d) uses science as a platform to uncover negative stereotypes and biases (Brown, 2013; Tate et al., 2008; Laughter & Adams, 2012); and (e) frequently establishes genuine, community-based partnerships to support social action projects (Bouillion & Gomez, 2001; Fusco, 2001). However, with the exception of isolated studies (e.g., Emdin, 2011; Laughter & Adams, 2012), the literature is currently missing a focus on the application of CRP Science to teacher-student discourse and assessment.

The STARTS PD program is an educational innovation aimed at increasing widespread implementation of CRP Science by bolstering science teachers' content knowledge, pedagogical knowledge, and pedagogical design capacity (i.e., the ability of teachers to design learning environments and instructional materials). The STARTS program addresses current barriers to wide scale enactment of CRP Science on multiple fronts, thereby making CRP Science more accessible while directly impacting student achievement. Moreover, due to the central role of curriculum materials in teaching (Ball & Cohen, 1996; Parke & Coble, 1997), and the dearth of CRP Science instructional materials (Lee, 2004; Mensah, 2009; NRC, 2012), PD must also provide opportunities for teachers to design such materials. Therefore, to realistically actualize the vision and full potential for CRP Science, ongoing design-based research approaches to PD and curricula design, enactment, and refinement are required.

Theoretical Framework

Design-Based Research

Design-based research (DBR) serves as the theoretical framework for this dissertation. An integration of applied and basic research, DBR has foundations in formative research, developmental research, and design experiments (Brown, 1992; Shavelson & Towne, 2002; van den Akker, 1999; Wang & Hannafin, 2005). DBR is used for constructing effective learning environments via theoretically grounded educational interventions and is suited for examining learning processes in environments that are designed and systematically altered by the researcher (Barab, 2006; McKenney & Reeves, 2012). A focus of design studies is the exploration of mechanisms undergirding learning through testing the design, implementation, systematic study, and refinement of a novel *in situ* educational intervention (Confrey, 2006; Shavelson & Towne, 2002).

Similar to engineers who consider multiple variables when designing a solution or prototype, researchers design for and continually refine specific learning environments, while concurrently examining the impact of mediating factors on learning within that environment (Barab, 2006; Hjalmarson & Diefes-Dux, 2008). Thus, the exploration of a given context's influence on learning is prominent within design studies (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Squire, MaKinster, Barnett, Luehmann, & Barab, 2003), as it often places constraints on the enacted design (Joseph, 2004). However, researchers acknowledge that this context is unique in that it is not solely comprised of routine classroom practices, but rather includes those practices in the presence of a designed intervention (Kelly, 2004).

DBR intends to provide "experience-near significance and experience-distant relevance" (Barab & Squire, 2004, p.6) through the production of *usable knowledge* about learning in a given context and theory that guides future educational tool design (Barab, 2006; Confrey, 2006; Songer, 2006). Studying the progression of educational tools from design to implementation provides a sense of how these tools are appropriated in action as well as connections between tool and context (Squire et al., 2003).

While demonstrating local impact is one goal of design research, three additional outcomes are of central importance to the paradigm: local theories, design frameworks, and design methodologies (Edelson, 2002). These outcomes enable work from design studies to be adopted by others and adapted to new contexts, further lending to the pragmatic nature of DBR. Through these three outcomes DBR transcends basic empirical studies capable of documenting an intervention’s impact or merely demonstrating effective practice.

However, design research is not without critique. Critics of DBR have questioned the certainty of assertions and findings (Barab & Squire, 2004; Edelson, 2002), lack of focus on external factors necessary for intervention support (Fishman et al., 2004), limited generalizability (Kelly, 2004), and researcher bias (Confrey & Lachance, 2000; Kelly, 2004). Attempts to address these valid concerns have been made by establishing methodological rigor in all phases of design research.

Demonstrating Methodological Rigor.

Like any sound educational research endeavor, it is the responsibility of design studies to demonstrate methodological rigor. Design researchers attempt to establish rigor through various criteria (Squire et al., 2003). According to Confrey and Lachance (2000), it is essential to demonstrate the quality of internal processes guiding DBR. Additionally, because the nature of design studies is to design, test, and refine an intervention, quality must also be demonstrated by assessing the intervention’s impact on teaching and learning. Specific criteria must be met in order to ensure quality in internal processes and impact on practice. Regarding internal processes, quality is determined by establishing credibility, dependability, and confirmability through rich detail of the research process (Guba & Lincoln, 1989). These specific criteria include assessing: (a) face validity of the conjecture as well as its ability to stand up to peer review; (b) coherence of the story, which should clearly articulate a dialectical relationship between the theory-driven conjecture and classroom events; and (c) fidelity to an ideological stance throughout the study (Confrey & Lachance, 2000).

Because design studies aim to connect research to practice through educational interventions, it is fundamental to evaluate the potential impact of a designed intervention. To this end, Confrey and Lachance (2000) posit multiple criteria to evaluate impact: (a) feasibility; (b) sustainability; (c) compelling nature (i.e., convincing practitioners to act with urgency); (d) adaptability; and (e) generativity (i.e., helping practitioners reconceptualize classroom interactions and practices) (pp.262-3).

In this dissertation, the iterative cycle of analysis, design, implementation, and redesign (Wang & Hannafin, 2005, p.8) was employed to construct, test, and refine the STARTS PD program. Much like existing educational DBR studies, this study was primarily concerned with characterizing a designed intervention (the STARTS program) through a set of design principles, associated learning outcomes (teachers' progression as CRP Science teachers and designers of culturally relevant instructional materials) through the production of a local theory, and the mechanisms undergirding these learning progressions through a prescriptive design framework (Barab, 2006; Edelson, 2002; Kelly, 2004; Shavelson & Towne, 2002). Methodological rigor was demonstrated through the production and maintenance of a Design Documentation Report (DDR), which contained "records of each decision, whether motivated by literature review, field research, or the demands of practice" (Joseph, 2004, p.241). Additionally, to establish trustworthiness and reliability, this study provides a variety of evidence about the research process and the impact of the STARTS program on the culturally responsive knowledge and practices of high school life science teachers.

Research Questions

The following questions guided this dissertation study:

1. For high school life science teachers participating in an explicit PD program on CRP Science, what defines the process of becoming culturally responsive educators?

   a. As teachers participate in the STARTS program, how does their CRP Science knowledge progress over time?

   b. As teachers participate in the STARTS program, how do their CRP Science practices change over time?

2. What features of the STARTS design framework can be associated with supporting the changes in CRP Science knowledge and practices of high school life science teachers?

Significance of Study

The science education reform movement aims to reduce achievement gaps by race and income level by supporting high academic standards for all students (Gamoran, 2008; Lee & Fradd, 1998). CRP Science has been advocated as a pathway to decrease these educational disparities. Yet, teachers report feeling underprepared to educate culturally diverse students. Therefore, programs must be created that enhance teachers' ability to educate diverse students through approaches that acknowledge the influence of culture on learning (Gay, 2010; Howard, 2010) and lead to increased science achievement.

Culturally responsive science teachers possess a unique set of knowledge, skills, and dispositions that must be developed (Brown & Crippen, in review), such as viewing themselves as change agents, approaching the curriculum from a critical perspective, and affirming students' backgrounds through relevant instruction (Villegas & Lucas, 2002). This form of science teacher education is rarely supported through PD (e.g., Lee, 2004; Johnson, 2011; Zozakiewicz & Rodriguez, 2007). Of the few instances where it does occur, missing is explicit attention to the relationship between the teacher change process and accompanying structural supports.

To effectively design PD programs capable of supporting teachers' growth as CRP Science teachers, research is needed on identifying mechanisms supporting this process. Hence, a dual focus on *process* and *structure* is required. This dissertation advances research on CRP Science and PD in science education in several ways, most notably through its emphasis on process and structure, thereby producing usable knowledge about salient STARTS design elements which support the growth of teachers as culturally responsive science teachers.

Moreover, there exists a need for studies that analyze and describe "the interaction of myriad elements comprising science teaching and learning, especially in large, urban settings where teacher and student resistance to change are continual challenges" (Barnes & Barnes, 2005, p.68). Situated within multiple Title I high schools in a large and diverse Southeastern United States school district, the STARTS program aimed to directly address this lack of research. In response to this call, the present dissertation proposes a conceptual model describing teachers' progression as culturally responsive science teachers within the context of the STARTS PD program.

To overcome the paucity of CRP Science curriculum resources (Lee, 2004; Mensah, 2009), the program was also designed to support the creation of CRP Science instructional materials by high school life science teachers, which is both widely called for within the literature (Lee & Luykx, 2007; Sleeter, 2012), and not covered adequately in previous studies of CRP Science (e.g., Basu & Calabrese Barton, 2007; Calabrese Barton, 1998). Research on PD in science education has featured teachers as curriculum adaptors (Brown & Edelson, 2003; Davis & Varma, 2008; Luft, 2001) and, less frequently, creators of innovative instructional materials (Parke & Coble, 1997; Stolk, DeJong, Bulte, & Pilot, 2011). Yet, these studies lack rich descriptions detailing the progression of teachers as designers.

Because the STARTS program supported teachers through the creation of culturally responsive instructional materials aligned with state science education standards, district-mandated pacing guides, and End of Course exams, this study addresses a lack of research exploring and explicating ways to make such innovative materials compatible with the time constraints, logistical concerns, and instructional goals of schools serving underrepresented students (Calabrese Barton, 2007). In the process, the study illustrates a relationship among teachers' participation in the PD program, their professional growth, and teacher-reported student outcomes (Lee & Luykx, 2007).

Dissertation Overview

This dissertation consists of six chapters. Chapter 1 introduces the problem, theoretical framework guiding the research, and significance of the study. Chapter 2 describes the relevant literature that grounded and justified this study. Chapter 3 details the study's design and methodology. Chapter 4 presents findings about the progression of STARTS teachers as CRP Science teachers, which has been prepared in manuscript format. Chapter 5 presents a manuscript detailing findings on the influence of the STARTS program activities on high school life science teachers' CRP Science knowledge and practices, as well as a resulting design framework. Finally, Chapter 6 consists of a discussion of the findings, their implications for science education, and suggestions for future research.

CHAPTER 2
REVIEW OF THE LITERATURE

Introduction

As one of the most influential factors on student learning (Abell, 2007; Atwater, 1996), teachers are linchpins for substantial K-12 science education reform (National Research Council [NRC], 2012). For underrepresented students in particular, success in science, technology, engineering, and mathematics (STEM) involves a highly qualified teacher using the cultural and linguistic backgrounds of students to facilitate academically challenging instruction (Banks et al., 2005; National Academy of Sciences [NAS], 2007). Yet, teachers tend to teach in the same traditional ways they were taught (Hammerness et al., 2005; Lortie, 1975). As students, many science teachers never experienced true reform-based science learning experiences (i.e., practices of science [NRC, 2012]), but rather passive learning opportunities, leaving them to struggle with enacting reform-oriented instructional approaches (Barnes & Barnes, 2005; Crippen, 2012).

While it is undoubtedly important to prepare prospective science teachers to teach science in engaging, authentic, and student-centered ways, preservice teacher education alone is insufficient to build a strong workforce capable of enacting the vision of science education espoused by the *Framework for K–12 Science Education* (NRC, 2012). Thus, the science education community must also provide inservice teachers with high-quality professional development (PD) experiences aligned to 21st century visions of science education (NRC, 2012), connect to student achievement (Crippen, Biesinger, & Ebert, 2010), and be sustainable (Davis & Varma, 2008).

Furthermore, in attempting to make science accessible to all students, the NRC (2012) emphasizes making science education more inclusive of diverse student populations through instruction that “build(s) on students’ interests and backgrounds so as to engage them more meaningfully and support them in sustained learning” (p.283). In order to support implementation of the new standards and ideals for equity espoused in the *Framework*, PD in science education must be redesigned to include experiences that develop teachers’ rich understanding in all three dimensions of 21st century science education (practices, core ideas, and crosscutting concepts) (NRC, 2012) as well as to offer specific strategies for meeting the challenges involved in providing accessible science to all (Zozakiewicz & Rodriguez, 2007).

Calls for science education reform that attend simultaneously to diverse students’ needs and academic rigor are not new (Lee & Fradd, 1998), yet they often remain unanswered (Mensah, 2011; Zozakiewicz & Rodriguez, 2007). Even science teachers deemed highly effective require ongoing PD to successfully meet the needs of diverse learners, as they must address the constraints inherent in responsive teaching in restrictive environments (Tate, Clarke, Gallagher, & McLaughlin, 2008). Teachers need ample time and support to collaborate with colleagues and create culturally responsive instructional materials (Morrison, Robbins, & Rose, 2008) as well as establish partnerships with students’ families and communities (Morrison et al., 2008; Seitz, 2011).

Building on requests within science education for greater emphasis on equity and the need for culturally responsive science instruction, this chapter will argue that science teachers working with diverse students must be culturally responsive and teach reform-based science as envisioned by the *Framework for K-12 Science Education*. I will begin by presenting a synthesis of the work on culturally responsive pedagogies in science education (CRP Science), and identifying and describing current challenges to widespread implementation of CRP Science as I argue for the intellectual merit of the STARTS (Science Teachers Are Responsive To Students) PD program.

I will continue by reviewing the field of PD in science education, noting trends in goals, specific supports, outcomes and challenges, as well as acknowledge the limited studies of PD for CRP Science. I then identify issues affecting the widespread implementation of CRP Science, including teacher resistance and lack of resources. Following this section I discuss the relevant literature on preparing culturally responsive teachers before detailing additional conceptual frameworks that guided the design of the STARTS program. To further argue for a design-based research (DBR) approach to examining PD for CRP Science, I provide a synthesis of the literature on STEM-focused educational design research. I then illuminate how this dissertation expands the field of science education by showcasing three particular PD studies, each with elements similar to the STARTS program. I conclude the chapter with final remarks and a summary. To build the theoretical basis of the STARTS PD program, I will synthesize the field of CRP Science, beginning with its foundations in culturally responsive pedagogy (CRP).

CRP Foundations

Extensive research has documented that uniformity in education via curricula, teaching, and assessment has not worked for culturally and linguistically diverse students, and leads not only to achievement gaps but also to the high dropout rates seen in Black and Hispanic populations (Howard, 2010; National Center for Education

Statistics [NCES], 2010). While competing theories on the academic underperformance of diverse students abound (Bradshaw, 2007), some of which articulate deficit-based conceptions (Gay, 2010; Howard, 2010), few hold the power to overturn current trends as well as CRP. Culturally responsive pedagogy offers an approach to ameliorate chronic educational problems as it challenges deficit-based thinking, acknowledges students' diverse backgrounds, and uses these backgrounds as educational resources to support learning. Yet, it is not widely implemented in the science classroom (Bianchini & Brenner, 2010; Patchen & Cox-Petersen, 2008).

The literature on CRP is vast and at times ambiguous. Several terms in education literature have been used synonymously with CRP – *culturally relevant, culturally congruent, culturally sensitive*, and so forth. In many instances, such terms are used interchangeably; however, there are often slight distinctions among the constructs. The foundations of CRP Science are grounded in Ladson-Billings' (1994; 1995) theory of culturally relevant pedagogy and Gay's (2010) scholarship on culturally responsive pedagogy. Therefore, in preparation for the synthesis of CRP Science, this section will briefly characterize CRP as a pedagogical paradigm, which has foundations in social justice and multicultural education.

Culturally Relevant Pedagogy

Stemming from her work with successful teachers of African American students, Ladson-Billings (1994) first described culturally relevant teaching as assisting students in "the development of a 'relevant black personality' that allows African American students to choose academic excellence yet still identify with African and African American culture" (p.17), thus promoting cultural competence. According to Ladson-Billings (1995), culturally relevant teachers create learning environments that affirm students' identities and backgrounds, thereby providing a means for students to "maintain their cultural integrity while succeeding academically" (p.476). Culturally relevant teaching emerged at a time when much of the work regarding African Americans and education was approached from a deficit perspective, often describing the academic underperformance of African American students as a result of what they lacked in terms of educational resources and support. In contrast, CRP positioned education from an asset-based mindset and focused on empowering students intellectually, emotionally, and politically.

Culturally relevant teachers impart an ethic of care and personal accountability, foster academic success, and develop cultural competence within their students. Developing sociocultural consciousness in students, i.e., an awareness that their worldview is reflective of their experiences, as well as recognizing the unequal distribution of power in social institutions (Villegas & Lucas, 2002), is a core CRP tenet because it provides students with opportunities to critically examine the world and others (Ladson-Billings, 1995). Ladson-Billings (1994) found that teachers with culturally relevant practices embodied three distinct attributes: conceptions of self and others, social relations between teacher and student, and conceptions of knowledge.

Teachers with culturally relevant conceptions of self and others hold their students and their profession in high regard. These teachers view teaching as an art, believe all students can succeed, see their profession as a way to give back to the local community, and recognize "*who* students are and how they are connected to wider communities" (p.49, italics in original). Culturally relevant teachers organize fluid and equitable social relations in their classrooms, encourage collaborative learning, demonstrate connections with all students, and emphasize community. A teacher who espouses culturally relevant conceptions of knowledge “attempts to help students understand and participate in knowledge-building” from a critical perspective (Ladson-Billings, 1994, p.81). Teachers who enact CRP are passionate about the content they teach, view knowledge as dynamic and find it important that knowledge be shared by students and teachers, and they act as a facilitator. Though Ladson-Billings originally wrote of culturally relevant teaching for African American students, this critical and emancipatory pedagogy can benefit students from a multitude of backgrounds.

Culturally Responsive Pedagogy

When Gay (2010) first described culturally responsive pedagogy she suggested it was a compilation of various pedagogies that make use of students’ cultures in the process of learning, including Ladson-Billings’ (1994; 1995) work. Gay espoused culturally responsive pedagogy as a means to enhance the learning of all ethnically diverse students. In describing Gay’s notion of culturally responsive pedagogy, Howard (2010) writes “[the paradigm] recognizes the rich and varied cultural wealth, knowledge, and skills that students from diverse groups bring to schools, and seeks to develop…a philosophical view that is dedicated to nurturing student academic, social, emotional, cultural, and physiological well-being” (pp.67-8). Gay (2010) identified several characteristics of CRP, describing it as validating, comprehensive, multidimensional, empowering, transformative, and emancipatory.

Culturally responsive teachers validate students by acknowledging their cultural heritages, using these backgrounds as a bridge between school and home, and incorporating multicultural resources into the curriculum, regardless of content area. Teachers who enact CRP provide a comprehensive education for diverse students and teach to the whole child, purposefully developing skills, knowledge, attitudes, and values. As a result, educational excellence transcends academic performance to also include learning outcomes such as “cultural competence, critical social consciousness, political activism, and responsible community membership” (Gay, 2010, p.33). CRP is multidimensional because its scope extends beyond curriculum materials to account for teacher-student relationships, creating a community-based classroom climate, instructional techniques, and assessment strategies. In this regard, Gay’s (2010) description of CRP as multidimensional strongly resembles Ladson-Billings’ (1994) notion of social relations. A teacher who holds a culturally relevant focus may have high expectations for their students which makes CRP an empowering option. Similar to Ladson-Billings’ (1994) conceptions of self and others, such teachers believe all students are capable of academic success and commit themselves to facilitating this success. The transformative nature of CRP arises from its commitment to confronting oppression, power differentials, and development of social consciousness. Finally, because CRP supports intellectual liberation, it is deemed an emancipatory pedagogy. Gay (2010) argues that not only is knowledge from diverse ethnic populations made accessible, but students are taught how to apply this knowledge to their learning experiences, thus helping “students realize that no single version of ‘truth’ is total and permanent” (p.38).

The foundation of culturally responsive pedagogy (Gay, 2010) in culturally relevant pedagogy (Ladson-Billings, 1994; 1995) is obvious in many respects, while also extending the work of Ladson-Billings (1994) through clearly articulated applications to curriculum and instruction. Together, they provide a rich, evidence-based view of successful teachers of diverse students and an ideal to strive toward in teacher education. Educational scholars have advocated the application of CRP in education (e.g., Sleeter, 2012; Gay, 2010; Howard, 2010; Ladson-Billings, 1995). Within the field of science education, several scholars have utilized these pedagogies as a means to disrupt prevailing conceptions of science, increase underrepresented students' academic success, and engage learners in science practices that lead to social action within the community. Yet, as Sleeter (2012) argued, the research connecting CRP implementation to students' academic success is limited. This may lead scholars to be critical of CRP as a theoretical and pedagogical framework, and rightfully so. However, specific theories on culture, diversity, and learning support assertions within CRP and explain why the education community should not turn its back on this transformative pedagogy.

Why is CRP a Viable Solution?

Sleeter's (2012) call to reject superficial notions of culture acknowledges that communities of individuals are often homogenized and stereotyped according to images portrayed in the media. While it is indeed inaccurate and unethical to assume that all individuals of a certain background will behave and think alike, Gay (2010) asserts that variability in cultures "does not nullify the existence of some core cultural features and focal values in different ethnic groups. Instead, members of ethnic groups, whether consciously or not, share some core cultural characteristics" (p.10).

While commonalities among individuals from different cultural backgrounds can form the basis for negative stereotypes, they can also cause the development of a sense of unity and agency among people who share similar life histories. CRP acknowledges and is sensitive to learners whose cultural and linguistic backgrounds vary significantly from the formal culture of schooling. Aligned with social constructivist and sociocultural perspectives on learning and the notion of cultural border crossing, CRP creates a learning environment that is community-based, affirms diversity, and utilizes students' funds of knowledge in instruction (i.e., community, home, and familial strengths and traditions) (Moll, Amanti, Neff, & Gonzalez, 1992).

Diverse Students' Discourse Patterns Vary From Mainstream Schooling

Discourse patterns vary across cultures and linguistic backgrounds and are often different, sometimes strikingly, from the mainstream culture promoted explicitly (through curriculum and textbooks) and implicitly (from behavioral norms and discourse styles) in formal schooling. For example, lengthy, repetitive talk containing emotional reactions and personal experiences are characteristic of some English Language Learner (ELL) groups (Lee & Fradd, 1998; Valdes et al., 2005).

The canon of science commonly portrayed in schooling includes distinct norms, language, and habits of mind (Calabrese Barton, 2007). Research has documented that certain scientific values, such as curiosity, creativity, persistence, and respect toward nature are found in most cultures. However, other values and attitudes specific to the canon of science are more characteristic of Western science, such as thinking independently, using empirical criteria, openly criticizing, and making arguments based on logic (Buxton, 2006; Lee & Fradd, 1998). Such differences in discourse and daily practices are common in high-poverty schools where diverse students are likely to be enrolled and taught by teachers whose backgrounds differ dramatically (Tate et al., 2008).

The various ways in which diverse students approach and interact with the world are not only undervalued and underutilized in mainstream schooling, they are often misconstrued or perceived as threatening or defiant (Lee & Fradd, 1998; Tutweiler, 2007), directly impacting students' attempts to interact with educational messages (Emdin, 2011) and participate in schooling (Tobin, 2000).

Cultural Border Crossing

Among other theoretical foundations, CRP is grounded in the concept of cultural border crossing. Cultural border crossing is a process in which the ease of transition from a students' home culture to school culture is mediated by the degree of congruency between the two (Aikenhead & Jegede, 1999; Ladson-Billings, 1995). Theoretically speaking, students whose home culture closely resembles that of the norms and behaviors associated with school will experience a relatively smooth transition between the two worlds. In contrast, a student whose home culture is notably distinct from the norms and behaviors associated with school will find border crossing between the two worlds formidable and fraught with psychological harm, as it often means renouncing the values and practices of that student's home (Aikenhead & Jegede, 1999; Costa, 1995).

For example, it has been documented that the practices of schooling cause nonmainstream students (students whose cultural and linguistic norms deviate from those promoted in school) to assimilate to the school culture at the expense of their personal identities. This form of subtractive schooling promotes the loss of students' native language and behaviors during assimilation (Lee & Fradd, 1998; Valenzuela, 2005). CRP acknowledges that disparities exist between the culture and practices of schools and the students they serve, which directly impacts multiple student outcomes including cultural competence (Ladson-Billings, 1995), engagement (Howard, 2001), and achievement (Garza, 2008; Ladson-Billings, 1995; Weinstein, Tomlinson-Clarke, & Curran, 2004).

Culturally Responsive Pedagogy Uses Students' Cultures as Educational Tools

CRP works to bridge the discontinuity and undervaluing of students' cultures – "learned and shared standards for thinking, feeling, and acting" (Erickson, 1986, p. 117) – found in mainstream schooling by affirming students' backgrounds through instruction and curriculum (Lee & Fradd, 1998; Valdes et al., 2005). Additionally, because the process of border crossing is often accompanied by discomfort and tumult, educators who are culturally responsive impart an ethic of genuine care for students, nurturing and supporting them through the high expectations they hold for students' academic success (Rightmyer, 2011).

Research has illustrated the importance of strong relationships (e.g., student-teacher; student-student; family-teacher) in fostering student engagement (Hondo et al., 2008; Stanley & Plucker, 2008; Valenzuela, 2005). In an examination of reasons why students choose to remain in school, meaningful and respectful relationships with educators and peers are high on the list (Lehr, Johnson, Bremer, Cosio, & Thompson, 2004). However, strong relationships are not the only key to student success. Students need to feel that what they are learning is challenging and relevant to their lives (Stanley & Plucker, 2008). This is especially true among diverse students (Ladson-Billings, 1994).

CRP's Epistemological Foundations

The epistemological foundations of CRP lie in sociocultural and social constructivist perspectives (Atwater, 1996). CRP promotes a collectivist view on education versus an individualist model, which pits students against one another in competition. Through its collectivist orientation to learning, CRP contends that students will excel when knowledge is constructed through direct experiences with material, in meaningful and relevant contexts, and occurring in a community of practice.

From its foundation in the social constructivist perspective on learning, CRP positions the learner as the center of knowledge (Patchen & Cox Petersen, 2008), with the process of knowledge construction mediated by culture, language, and social interactions (Atwater, 1996; Rodriguez, 1998). Cultural realities and roles are constructed in concert with social interactions (Ernest, 2010), making the emphasis on what these social interactions look like extremely relevant to the culturally responsive educator. For example, it is important to gauge whether or not social interactions in the classroom support diverse students' academic learning or exclude diverse perspectives and the participation of certain students.

CRP also takes a sociocultural perspective on learning, arguing that student learning occurs in communities of practice via a process of enculturation with associated ways of talking and acting. Therefore, the relationship between learning and larger social, political, and historical influences as well as the role of identities in learning is salient (Calabrese Barton, 1998; Elmesky & Tobin, 2005; Lemke, 2001). Learning is facilitated through the use of signs, symbols, and cultural and educational tools (Howard, 2010; Vygotsky, 1978). Language serves as a learning tool and provides a lens to examine compatibilities and incongruences in cultural practices and ways of learning (Elmesky & Tobin, 2005; Gee, 2008; Lemke, 2001). With its focus on language and enculturation, sociocultural theory provides a lens for examining and understanding how culture contributes to learning (Howard, 2010).

As a theoretical framework, CRP views learning as an active process driven by prior knowledge and social interactions situated within larger historical and political contexts. As such, CRP recognizes that the cultural and linguistic norms of diverse students are often ignored, underutilized, and misinterpreted in mainstream schooling. The process therefore tries to ease the cultural border crossing many diverse students experience on a daily basis by creating a learning environment that is respectful, inclusive, and an extension of their lives at home.

CRP Science ascribes to many fundamental tenets of the paradigm. Yet, because of the Westernized aspects of science frequently portrayed in formal schooling, CRP Science emphasizes aspects not commonly seen in general CRP empirical literature. The next section will characterize CRP Science as it is currently represented in the empirical literature before arguing for a reconceptualization of CRP Science that aligns more closely with the standards-based reform movement and which is capable of increasing diverse students' academic achievement on a wide scale.

CRP Science

CRP Science stands in stark contrast to traditional science instruction. Science instruction that is considered to be traditional features teacher-directed transmission of jargon-heavy concepts and relies heavily on the textbook as a primary source of information (Akkus, Gunel, & Hand, 2007; De Boer, 1991). Furthermore, science as it has been traditionally taught expects that students will learn from teachers as long as content is presented in scientifically-accepted ways (Lee & Fradd, 1998). These practices position science instruction in such a way that it promotes passivity, impedes critical thinking, and overlooks direct connections to student experiences (DeBoer, 1991; Yore, 2001).

Conversely, CRP Science (a) contextualizes instruction in students' lives and experiences (Basu & Calabrese Barton, 2007; Calabrese Barton, 1998; Mensah, 2011); (b) engages learners in reform-based science instruction (Bianchini & Brenner, 2010; Kelly-Jackson & Jackson, 2011; NRC, 2012); (c) occurs in respectful and inclusive learning environments where multiple perspectives are acknowledged (Lee, 2004; Elmesky & Tobin, 2005) and language supports are widely implemented (Lee, 2004; Johnson, 2009); (d) uses science as a platform to uncover negative stereotypes and biases (Brown, 2013; Tate et al., 2008; Laughter & Adams, 2012); and (e) frequently establishes genuine, community-based partnerships to support social action projects (Bouillion & Gomez, 2001; Fusco, 2001) (Appendix A). CRP Science is a targeted approach to science education because it purposefully "…considers the racial, linguistic, cultural, and gendered identities and experiences that students bring to the classroom" (Tate et al., 2008, p.65). Reform-based science education is a component of CRP Science; however, because CRP Science targets students from linguistically and culturally diverse backgrounds, additional structures are required to facilitate academic success.

Characterizing CRP Science According to the CRIOP

Appendix A demonstrates how CRP Science can be characterized in the empirical literature according to the seven pillars of the *Culturally Responsive Instruction Observation Protocol* (CRIOP) (Powell et al., 2012). As indicated in its title, the CRIOP is an observation protocol originally developed to characterize teachers' culturally responsive practices. The decision to use the CRIOP to guide my characterization of CRP Science was based on two premises: the CRIOP (1) represents a synthesis of the vast and timely literature on CRP and (2) in the seven CRIOP pillars, operational definitions of specific CRP tenets are provided, making the occasionally nebulous constructs within CRP more concrete, observable, and directly measurable.

In the decisions made to categorize specific elements of the empirical literature on CRP Science, I recognize the subjective nature of such decisions and that to another individual the elements could be categorized differently. However, my interpretation achieved my goal of providing a concrete and unifying understanding of CRP Science in actual formal and informal learning environments. Additionally, I acknowledge that I imposed categories on studies that may not have previously addressed these goals. In fact, there is currently no use of the terminology “CRP Science.” Rather the following terms are used: culturally relevant science (Johnson, 2011; Kelly-Jackson & Jackson, 2011; Laughter & Adams, 2012; Fusco, 2001; Patchen & Cox Petersen, 2008); equitable science (Bianchini & Brenner, 2010); science for social justice (Calabrese Barton, 2003); inclusive science (NRC, 2012); democratic science (Calabrese Barton, Basu, Johnson, & Tan, 2011); connected science (Bouillion & Gomez, 2001); instructionally congruent science (Lee, 2004); multicultural science (Calabrese Barton, 2000) and other similar terms. The term CRP Science will be used throughout this dissertation to acknowledge the various pedagogies in science education that utilize students’ cultural backgrounds to foster learning.

I imposed the seven CRIOP pillars (Classroom Relationships; Family Collaboration; Assessment; Curriculum/Planned Learning Experiences; Pedagogy/Instruction; Discourse; and Sociopolitical Consciousness) and identified the empirical work as *culturally responsive.* As a result, (1) each of these distinct forms of science education contained multiple elements of CRP as operationalized through

Ladson-Billings (1994; 1995), Gay (2010), and the CRIOP (Powell & Rightmyer, 2011), and (2) my hope is that through a unifying theory of action on CRP Science I can advance the field which currently experiences a nearly absent research base (Kelly-Jackson, 2011; Laughter & Adams, 2012), yet holds great promise for diverse students (Lee & Luykx, 2007; Brown-Jeffy & Cooper, 2011; Patchen & Cox-Petersen, 2008).

Moreover, several works describe CRP Science (often conceptual literature or studies of teacher preparation programs), but they did not lend themselves to characterizing the learning environment according to the CRIOP (e.g., Rodriguez, 1998; Zozakiewicz & Rodriguez, 2007; Lee & Luykx, 2007; Calabrese Barton, 2007; Fusco & Calabrese Barton, 2001). Therefore, although these works will be used to support descriptions of CRP Science, they will not be directly elaborated on in this chapter. The remainder of this section will describe concrete examples of CRP Science.

Parameters of CRP Science Sources

In this literature review of CRP Science I will discuss trends and distinctions among thirteen studies. All of the studies that will be reported on utilized qualitative design methodologies to analyze data and describe findings. As such, each study is small scale with findings most often presented as case studies (e.g., Calabrese Barton, 1998; Patchen & Cox-Petersen, 2008). Among the specific methodological approaches, ethnography/critical ethnography was most commonly employed as a lens through which to view and interpret research questions, data, and findings (e.g., Basu & Calabrese Barton, 2007; Calabrese Barton, 1998; Elmesky & Tobin, 2005). Twelve of the thirteen sources were empirical studies containing research questions, conceptual or theoretical frameworks, and rich descriptions of data sources, analysis, findings, and implications. One particular source, a book chapter (Tate et al., 2008), reports on specific curriculum design features that have demonstrated (in other empirical articles) an ability to target diverse learners.

Among the sources, the focus of investigation was divided equally between teacher and student. Seven studies focused on teacher education, both preservice and inservice, whereas six sources focused on students. Middle school-based studies were overrepresented and comprised six of the thirteen sources (e.g., Basu & Calabrese Barton 2007; Bianchini & Brenner, 2010; Kelly-Jackson & Jackson, 2011; Laughter & Adams, 2012). Elementary and high school studies were relatively equally distributed among the remaining sources, with four elementary-based studies (e.g., Bouillion & Gomez, 2001; Lee, 2004; Mensah, 2011; Patchen & Cox Petersen, 2008) and three high school studies (e.g., Elmesky & Tobin, 2005; Fusco, 2001).

Furthermore, three studies occurred in informal environments (e.g., Basu & Calabrese Barton, 2007; Calabrese Barton, 1998; Fusco, 2001); the remaining sources described teaching and learning in formal learning environments (i.e., the science classroom). While it has been argued that out-of-school contexts provide "a kind of freedom in the learning environment not afforded by schools" (Calabrese Barton, 2007, p.335), findings in this synthesis would suggest otherwise. In my presentation of CRP Science I will organize findings according to CRIOP pillars most and least frequently observed as well as notable exceptions. Because the STARTS PD program contains a focus on developing reform-based science teachers, I will also describe CRP Science by elucidating its relationship to reform-based science education.

Pedagogy/Instruction & Curriculum/Planned Learning Experiences

In general, CRP situates instruction in students' experiences, utilizing their funds of knowledge to support learning (Moll et al., 1992). The teacher acts as a facilitator who scaffolds student learning, provides opportunities for students to engage in the practices of science, and redistributes authority in the classroom by offering students choices throughout instruction. According to the thirteen sources reported on here, the same can be said of CRP Science. I have chosen to organize my discussion of the Pedagogy/Instruction & Curriculum/Planned Learning Experiences CRIOP pillars together as their individual elements were observed in conjunction in all but two of the sources (e.g., Bianchini & Brenner, 2010; Kelly-Jackson & Jackson, 2011). Within these two pillars, the specific CRP elements observed most frequently were students engaged in relevant and meaningful practices of science (Basu & Calabrese Barton, 2007; Elmesky & Tobin, 2005; Tate et al., 2008) and providing opportunities to voice and value diverse perspectives in instruction (Calabrese Barton, 1998; Mensah, 2011), which alludes to the reform-based nature of CRP Science.

Tate, Clark, Gallagher, and McLaughlin (2008) identified and utilized both *general* and *targeted* curriculum design strategies intended to increase diverse student learning and exemplify CRP Science. General strategies treat diversity among students as *any* differences they may bring to the classroom (e.g., prior knowledge, previous academic achievement, interests, or special needs). Examples of general science design strategies intended to bolster the achievement of all students include driving questions and hands-on activities to guide inquiry investigations. On the other hand, *targeted* strategies consider diversity in terms of race, language, culture, and gender. Targeted design strategies politicize the nature of schooling in attempts to remedy inequality. Science curriculum materials containing targeted design features connect students' home life with science, using their cultural backgrounds and funds of knowledge as educational tools in the learning process.

The middle school *Asthma* module described by Tate et al. (2008) utilized both general and targeted curriculum design strategies. For example, when completing the module, students learned about both the physiology of and social implications related to asthma. The module was situated in a community context to allow students to perceive science as a social construction. Furthermore, the notion of science as a source of agency was demonstrated as students analyzed actual data in an attempt to discern which of two programs (either a local diesel reduction program or a neighborhood asthma clinic) would better improve the asthma problem in their community. Students were involved in reform-based science practices as they interacted with dynamic visualizations explaining the physiology of breathing and asthma, examined multiple pieces of evidence that provided explanations about how diesel pollution affects asthma, and considered trade-offs when arguing their position in a debate.

Sociopolitical Consciousness

In their CRP metasynthesis, Morrison, Robbins, and Rose (2008) noted that critical and sociopolitical consciousness occurred least frequently in classroom-based research. They argued that sociopolitical/critical consciousness serves as "the capstone to culturally relevant pedagogy. It is through critical consciousness that students are empowered with the tools to transform their lives and ultimately the conduct of our society" (p.443). While studies of CRP in general education may be limited in examples of sociopolitical consciousness, the field of CRP Science is plentiful with opportunities to include issues important to the community (Bouillion & Gomez, 2001; Fusco, 2001; Mensah, 2011) and confront negative stereotypes, biases, and forms of oppression (Brown, 2013; Calabrese Barton, 1998; Laughter & Adams, 2012). In fact, this was one area in particular in which CRP Science stood out for its ability to empower students through social action projects that transform the communities and lives around them (Fusco, 2001; Bouillion & Gomez, 2001).

In an attempt to identify *bridging scaffolds* that connect science learning with students' day-to-day social experiences in meaningful ways, Bouillion & Gomez (2001) worked with teachers and students in two self-contained fifth grade classrooms, the school's science and technology coordinators, and a bilingual instructor in downtown Chicago to co-design an interdisciplinary STEM problem-based unit around community issues identified by students.

The Chicago River Project (Bouillion & Gomez, 2001) arose out of students' desires to clean up the nearby riverbanks that were polluted with trash. Once teachers and students selected this topic for investigation, they identified an outside organization that shared an interest in the real world problem of polluted riverbanks and helped them reach the goal of riverbank restoration. Throughout the project, students learned about pollution, ecosystem functioning and overall health as they engaged in multiple reform-based science practices, developed a conservancy plan, analyzed data, shared findings with the community, initiated a letter-writing campaign to increase awareness and action, implemented strategies for riverbank restoration, and eventually secured lease rights to the riverbank land.

Sociopolitical consciousness-raising experiences in other CRP Science studies were not organized around projects of the same magnitude as the Chicago River Project (Bouillion and Gomez, 2001); however, they positioned science in such a way that it allowed students to “challenge the existing social conditions in which they live” (Bouillion & Gomez, 2001, p.893). For example, elementary preservice teachers (PSTs) in Mensah’s (2011) research on preparing for culturally relevant science instruction included a community-perspective in their lesson on environmental racism. Specifically, the PSTs connected occurrences and effects of pollution to the East Harlem neighborhoods where students lived, which included discussions of asthma incidences within the community. Additionally, Laughter & Adams (2012) reported on the impact of a three-day earth/space science lesson that used Bell’s (1992) *Space Traders* short story as a platform to discuss potential impacts of extraterrestrial life on humans, scientific bias, and promote the use of academic language. In the capstone lesson event, a discussion-based lab, students wrestled with key earth/space science concepts and social consequences.

CRP Science allows students and teachers to challenge social injustices and use science as a means of critiquing and exploring the world around them. Often, the “world” is locally situated, with attention paid to ameliorating issues closest to home. To achieve this goal, CRP Science utilizes help from family and the greater community.

Family Collaboration

According to Appendix A, the CRIOP pillar *Family Collaboration* would seem to occur least frequently in the works on CRP Science. In fact, it was rare to identify examples of teachers reaching out to parents in non-traditional ways or using parent expertise to guide classroom instruction and student learning (e.g., Bouillion & Gomez, 2001; Fusco, 2001). However, the notion of *community-based science* was prominent within the literature.

In her work with 15 urban teenagers in an after-school program based out of a homeless shelter in New York, Fusco (2001) described a community-based science project that involved students and community members in the design and creation of an urban garden. The original project goal was to transform an empty lot across the street from the shelter into a usable community space. During multiple brainstorming sessions, teens discussed issues that impacted them (e.g., hunger, safety) and ways in which the usable space could alleviate some of these concerns. As their brainstorming sessions became more concrete, teens worked in teams to measure the space, categorize living and nonliving contents within the space, and sketch drawings of the lot to determine the feasibility of their ideas.

Once a decision was made to design a community garden and recreation area, local design professionals (including an environmental psychologist) and other community members were invited to discuss plans and ideas. Engaging in discourse in these communities of practice led to future action, as the group began visiting other community gardens for ideas, writing to organizations for assistance and donations, and implementing design plans. Before deciding upon specific plants to purchase for the garden, teen groups charted the position of sunlight over the course of the day and considered how the season would affect plant survival to determine the most cost-efficient purchases.

Over 50 members from the local community participated in Community Day in which teams laid the foundation for the garden by clearing out garbage, digging holes for fences, painting signs, and planting seeds and seedlings. Community members remarked that a place like the garden would allow people to “get away from all the violence” (p. 871). Community members maintained the lot after the original planting day. Additionally, a nearby local community garden was remodeled and revitalized.

CRP Science is Reform-Based

Reform-based science education engages students in authentic practices of science (NRC, 2012). The reform-based practices of science include asking questions and defining problems; developing and using models; planning and conducting investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; engaging in evidence-based arguments; and obtaining, evaluating, and communicating information (p. 42). Students are expected to become proficient in these practices, as scientific literacy involves both doing and talking science (Lemke, 1990).

Although reform-based science education was not specifically examined in the CRP Science studies reported here, there was evidence of multiple reform-based science practices within CRP Science. In addition to the previously described examples, several CRP Science studies provided descriptions of students engaged in practices of science. For example, in this passage, Basu and Calabrese Barton (2007) describe the experiences of two seventh grade students in an “after-school program focused on invention and exploration” (p. 470). Neil and his friend, Gabriel, engaged in multiple practices of science, including developing and using models and planning and conducting investigations:

> When studying fish behavior, Neil created a series of experiments and observations he wanted to conduct on the fish and often came to visit the fish during recess, lunch, and after-school to gather additional data. Gabriel decided to study the fish by building an anatomical model, both out of clay and aluminum. (p.484)

Kelly-Jackson & Jackson (2011) recount a typical science investigation conducted in the classroom of Sammie, a “sixth grade science teacher in a rural, low socioeconomic, predominantly African American school” (p.408). In this excerpt, the authors articulate how students were engaged in multiple practices of science, including analyzing and interpreting data, constructing explanations, and communicating information:

> During the lab activity, each group was allowed to rotate to eight stations (labeled A-H) to make observations, record data, and draw conclusions… As groups reported their findings to the entire class, they were allowed to defend their positions if not all groups agreed or observed similar changes. (pp. 411-12)

Finally, an excerpt from Lee (2004) regarding teachers of ELL students that were involved in a PD program aimed at supporting their ability to “teach science by using commonalities between their culture and language and their students’ backgrounds” (p. 72). Over time, participating teachers began to involve students in reform-based science practices, such as analyzing and interpreting data in addition to communicating information in multiple ways:

> They encouraged students to discuss ideas, findings, and conclusions in large and small groups. They also encouraged students to communicate ideas through drawings, an activity that helped students make careful observations and descriptions. As students gained experience in using science discourse, teachers promoted the use of written forms of communication, particularly data tables, charts, and graphs. These mathematical representations enabled students to find patterns in data and draw conclusions. (p.81)

In each of the thirteen CRP Science studies there was evidence of students engaged in many reform-based science practices. However, among these sources there is not enough information provided to declare that CRP Science must include the reform-based science practices defined in the *Framework* or those practices that are characteristic of inquiry. Several practices of science articulated in the *Framework* comprise inquiry-based science education in which students first pose a question and then seek plausible explanations to the question (NRC, 2000). The essential features of inquiry-based science include the abilities of learners to be engaged by scientifically oriented questions, give priority to evidence, formulate explanations from evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their explanations (NRC, 2000, p. 25). Again, identifying reform-based science practices was beyond the scope of each study, and therefore I cannot accurately state that these elements were not present. However, inquiry is characteristic of the many practices of science in the *Framework* and their positive impact on student achievement is well documented within the literature (Lee, Hart, Cuevas, & Enders, 2004; Luft, 2001; NRC, 2012). Therefore, it is worth articulating the connection between reform-based science and CRP Science, as it has implications for the design of PD programs aiming to prepare teachers who can provide rigorous and accessible science.

Discourse & Assessment

CRP Science acknowledges that important differences exist in the ways students use language and engage in science as they develop science language proficiency (Lee & Fradd, 1998). ELL students often require many concrete experiences and opportunities to use the language of science in social settings before applying them to academic endeavors (Johnson, 2009). Hands-on, inquiry-based science can provide opportunities for students who are not comfortable with the academic registers of science to use and apply novel terms in their explanation of concepts (Bianchini & Brenner, 2010; Lee & Luykx, 2007).

Specific language supports used to promote linguistic competence and academic conversation were offered in multiple studies and include: providing key science terms in both English and Spanish (Lee, 2004; Tate et al., 2008), providing audio files of science text in Spanish (Tate et al., 2008), providing scaffolded notes during lectures (Bianchini & Brenner, 2010), and strategically grouping students for collaboration (Lee, 2004; Patchen & Cox Petersen, 2008).

However, aside from these specific supports, it was difficult to identify instances where the emphasis in science instruction was on fostering science-based academic registers through the use of discourse associated with science (i.e., describing and applying science terms). In other words, many studies acknowledged the importance of preparing diverse students for thinking and acting scientifically, but very few made explicit the connection between promoting the development of academic registers (Gee, 2008) and the resulting ability to engage in scientific discourse (i.e., “talk” science) (Laughter & Adams, 2012; Lee, 2004).

Furthermore, assessment was another area that CRP Science has yet to adequately address. Although there were several instances of students being able to demonstrate understanding in a variety of ways (e.g., Basu & Calabrese Barton, 2007; Elmesky & Tobin, 2005), missing are artifacts illuminating students’ scientific understanding. In fact, when studies attended to student learning, it was most often characterized through qualitative descriptions (Bouillion & Gomez, 2001; Laughter & Adams, 2012) rather than quantitative measures (Emdin, 2011). For example, to assess student learning, Bouillion & Gomez (2001) reported select passages from student interviews in which students were asked to answer a science question posed by the teacher. The researchers contend that students learned the scientific concepts of water quality, soil erosion, recycling, and water conservation. For example, they provide the following passage from a fifth grader:

> [To restore the riverbank] I would use a lot of flowers. I would use grass, a lot of grass. I would use trees along the border to stop erosion. I would use different types of trees, oak trees and maple trees, and I would use, I would use a lot of big trees 'cause we need shade, and I would use, I would use big trees because the birds also need a place to live. (p.888)

The only example of measuring student achievement on a test was identified by Emdin (2011) in his work charting urban students' use of language, their attempts to transact in class (i.e., participate through the use of specific forms of discourse), and resulting teacher actions. Emdin followed select high school students for four years and wrote of a physical science class that acknowledged and encouraged students' dominant forms of communication. He contrasted student achievement on a unit test by comparing items that assessed conceptual understanding of topics covered in classes that encouraged students' home communication with test score data from topic items that were taught in what he considered a more conventional format. The author reported that students performed better on topics associated with the lessons where they were allowed to use their home language and that they provided greater detail in their explanations of concepts.

CRP Science has demonstrated various ways in which science is used to identify and address social and environmental inequities through the coming-together of students and their community. As democratic and widely beneficial as such endeavors may be, they do not necessarily translate to academic achievement in ways that are measured in the current U.S. educational system. If the CRP Science community intends to transform the face of who can "do" science, then efforts to support the ways in which students talk, act, think, and achieve scientifically need to be moved to the forefront. This is one area where CRP Science has yet to rise to the challenge; however, it is imperative in any real discussion of closing achievement gaps. The lack of assessment is one particular challenge to widespread implementation of CRP Science; unfortunately, this is not the only issue. In the next section I will briefly identify several challenges that impede the wide scale presence of CRP Science. In my focus on solutions rather than merely identifying problems, I will keep this next section brief and devote attention to speculating on areas for future research to address such challenges.

Issues Affecting Widespread Implementation of CRP Science

As already mentioned, a major issue seen among CRP Science studies is a paucity of research connecting its implementation to student achievement. Unfortunately, this is not exclusive to CRP Science alone (Sleeter, 2012). Compounding this issue, CRP Science experiences additional challenges in its attempts at wide-scale implementation, which can be roughly categorized as teachers' resistance to engage in the struggle and lack of resources and support. Although I have categorized these separately to show similar trends, they are not mutually exclusive and frequently occur in tandem.

Teacher Resistance

Rodriguez (1998) identified two forms of resistance enacted by PSTs while being prepared to teach science for diversity and understanding: resistance to ideological change and resistance to pedagogical change. Resistance to ideological change is a result of tensions experienced by PSTs when their ideological orientations collide with those advocated in the teacher education program. Rodriguez found that for the PSTs he studied, resistance to ideological change resulted from feelings of guilt, shame, and defensiveness as they were exposed to critical perspectives, in addition to feeling hopeless and overwhelmed with existing school situations. According to Rodriguez, resistance to pedagogical change pertains to when PSTs revert to teaching science in traditional manners (i.e., direct instruction), despite being introduced to innovative and engaging (i.e., reform-based) science teaching approaches. Reasons for resisting pedagogical change among the PSTs in Rodriguez's study include purposeful decisions to employ practices similar to their cooperating teacher, thereby increasing the chances of completing the practicum; lacking appropriate confidence and support to take risks associated with teaching in novel ways; and feeling that innovative teaching is not feasible within the school system.

In addition to the pedagogical and ideological resistance identified by Rodriguez (1998), teachers' resistance to engage in the struggle of becoming culturally responsive was noted in examples where teachers felt as though underperforming, "urban" students needed to earn the right to participate in inquiry-based labs (Barnes & Barnes, 2005). These teachers then entered a state of benign positive appraisal in which they felt they had already taught in culturally responsive ways in the classroom, despite observations to the contrary (Zozakiewicz & Rodriguez, 2007).

Lack of Resources & Support

CRP Science instructional materials are not widely available (Lee, 2004; NRC, 2012). Thus, teachers who are searching for such resources will likely come up empty-handed unless they know exactly where to look. Moreover, teachers at all stages of their professional journey require ongoing support as they attempt to enact CRP Science in culturally restrictive environments (Bianchini & Brenner, 2010). While certain science teacher preparation programs may offer topics associated with CRP Science, they fall short of the goal of effectively preparing teachers when they lack examples, ongoing support, and curriculum resources (Bianchini & Brenner, 2010; Garet, Porter, Desimone, Birman, & Yoon, 2001).

Becoming a culturally responsive teacher is an uphill battle for those who already desire to engage in the struggle. Combined with an understanding of the ways in which teachers resist the CRP message and its lack of connection to student achievement, one may question why CRP Science has persisted as long as it has. However, as discussed in the synthesis of CRP Science, there are many positive elements to this form of science education, which acknowledges students' backgrounds and incorporates them into learning environments that are academically challenging.

In order to promote the widespread use of CRP Science and CRP in general, research must document its impact on student learning (Sleeter, 2012). Currently, there is limited research that accomplishes this goal. Compounding the issue, the literature base documenting the effect of CRP on student learning consists primarily of small-scale case studies (Cammarota & Romero, 2009; Ladson-Billings, 1995). While there have been several studies that provide rich descriptions of what CRP and CRP Science look like in multiple contexts (Bergeron, 2008; Kelly-Jackson & Jackson, 2011; Mensah, 2011) and connect CRP to student outcomes such as engagement (Howard, 2001; Rodriguez, Jones, Pang, & Park, 2004), these studies postulate that academic learning will follow, yet they stop at student access. In response, Sleeter (2012) argues for two changes: (1) evidence-based research that connects CRP and academic achievement, so a case for its widespread use can be constructed; and (2) research focused on the impact of CRP projects, including how teachers learn to become culturally responsive and enact CRP in their classrooms. This dissertation focuses on the latter charge.

Preparing Culturally Responsive Teachers

Because of the great influence teachers have on student achievement (Abell, 2007; Calabrese Barton, 2007) and the demographic imperative to alter educational inequities through better preparing the teacher workforce (Banks et al., 2005), discussion of educational reform must include teachers. Both Ladson-Billings (1995) and Gay (2010) provided descriptions of culturally responsive teachers who use students' funds of knowledge as tools to engage diverse students in academics. However, Villegas and Lucas (2002) move beyond simply characterizing culturally responsive teachers and offer research-grounded suggestions for preparing today's teacher workforce to educate diverse students.

Villegas and Lucas describe six *fundamental orientations* (i.e., specific knowledge, skills, and dispositions) that culturally responsive teachers must possess in order to effectively educate diverse students: (1) sociocultural consciousness, an understanding that individuals' perspectives differ and shape how we perceive the world; (2) affirming attitudes toward culturally diverse students; (3) acting as agents of change and working for equity in education; (4) embracing constructivist foundations of CRP; (5) learning about students and their communities; and (6) continuously cultivating culturally responsive teaching through a student-centered, critical perspective on education. While Villegas and Lucas (2002) originally targeted formal teacher education programs, their message offers far-reaching utility and is relevant to teachers at all stages of their professional journey who are charged with educating diverse students.

Attributes of culturally responsive teachers abound. Yet, traditional teacher preparation programs vary in their ability to develop culturally responsive educators, leaving many practicing teachers feeling underprepared to educate diverse students (Song, 2006). These teachers struggle to teach in culturally responsive ways (Patchen & Cox-Petersen, 2008; Rodriguez, 1998). To meet the demands of successfully educating a diverse study body, inservice teachers need to feel competent in teaching reform-based science that is meaningful and accessible to all students. Therefore, effective PD is necessary. However, not all PD experiences are created equal.

The STARTS PD framework is a research-grounded program, built from elements of high quality PD in science education and undergirded by theories on teacher change, pedagogical design capacity, and CRP. The STARTS PD program has been designed to support high school life science teachers' development as culturally responsive, reform-based educators who can design CRP Science instructional materials. This next section synthesizes literature on PD in science education to make an argument for features of the STARTS design framework. A section characterizing three distinct PD studies follows this one to highlight several ways in which this dissertation study extends the fields of PD in science education and CRP Science.

Professional Development in Science Education

When Garet, Porter, Desimone, Birman, and Yoon (2001) conducted a national survey of over 1,000 mathematics and science teachers previously participating in Eisenhower-funded PD experiences, they aimed to identify PD features that significantly and positively impacted science and mathematics teachers' self-reported increases in knowledge, skills and changes in practice. Results indicated that PD opportunities providing core features such as active learning experiences, coherence with teachers' daily school responsibilities, and content focus are more likely to produce enhanced knowledge and skills, which in turn positively impacted teachers' practices. Equally important to reported changes in the practice of teachers were structural features such as sufficient time (duration) and collective participation among colleagues.

However, of the participating teachers, 79% reported participating in traditional forms of PD (e.g., workshops, courses, and conferences) versus reform-oriented experiences suggesting that, at the time, mathematics and science education PD activities did not effectively impact teachers' knowledge, skills, or practices. The findings of the study by Garet et al. (2001) significantly impacted the design of science education PD experiences to come, as will be described further in my presentation of PD according to their collective goals, specific supports, outcomes and challenges.

The PD studies discussed in this section spanned three years on average (Bell & Gilbert, 1994; Crippen et al., 2010; Lee, 2004; Zozakiewicz & Rodriguez, 2007), providing participating teachers with sufficient time to apply their developing knowledge and skills to classroom practice (Desimone, 2009: Greenleaf et al., 2010; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Experiences were designed for teachers at all grade levels, K-12, and most often generally across science disciplines. However, units on earth science – weather and water cycle (Lee, 2004), climate change (Crippen, 2012), and seismology (Yerrick & Beatty-Adler, 2011) – occurred most frequently when a discipline-specific subject area was represented.

Goals

Program goals

PD goals varied in several respects. Teachers were supported as they learned about and attempted to implement reform-based science teaching (Bell & Gilbert, 1994;

Luft, 2001), improved their science content knowledge (Crippen, 2012; Diamond et al., 2014), developed a professional learning community (PLC) (Crippen et al., 2010), adapted technology-rich curricula (Davis & Varma, 2008), acted as curriculum designers (Parke & Coble, 1997; Stolk et al., 2011), aligned instruction with earth science content standards through innovative approaches (Yerrick & Beatty-Adler, 2011), used commonalities between their language and culture and that of students in science instruction (Lee, 2004), and implemented culturally responsive (Johnson, 2011) and gender-inclusive practices (Zozakiewicz & Rodriguez, 2007). While PD goals aligned to overarching research aims, there were notable distinctions between the two that are worth articulating.

Research goals

The research goals aimed to understand how PD as an intervention impacted teachers' content knowledge (Crippen et al., 2010), classroom practices (Crippen et al., 2010; Luft, 2001; Parke & Coble, 1997; Zozakiewicz & Rodriguez, 2007), and teachers' reform-minded beliefs (Luft, 2001). Furthermore, research goals sought to characterize how teachers apply their knowledge when engaging in the practices of science (Crippen, 2012), develop as professionals in these contexts (Bell & Gilbert, 1994; Lee, 2004), or discern how teachers manage tensions associated with the change process (Parke & Coble, 1997). Furthermore, multiple studies were interested in examining the impact of a given PD program on teacher practices (Luft, 2001; Johnson, 2011; Parke & Coble, 1997; Zozakiewicz & Rodriguez, 2007).

Supports

The supports provided by the PD in science education experiences were vast and wide-ranging. Specific supports were aligned with the documented effective PD features previously mentioned (Garet et al., 2001), as well as the seven principles of effective PD experiences outlined by Loucks-Horsley et al. (2010): opportunities for teachers to build knowledge and skills; modeling strategies; building a learning community; supporting teachers in leadership roles; continuous assessment; driven by research on teaching and learning; coherence with other features of the education system.

To facilitate discussion of specific strategies, I have categorized supports in the following ways: structured sessions, professional learning communities, observation and reflection, and resources and responsive supports. Other features found to be effective at producing PD goals include analyzing student work (Davis & Varma, 2008; Lee, 2004), informal learning experiences (Crippen, 2012; Yerrick & Beatty-Adler, 2011), and action research (Crippen et al., 2010). These features occurred infrequently enough that they will not be discussed here. However, their ability to facilitate teacher growth should not be overlooked.

Additionally, active learning was present throughout all PD experiences, with teachers continuously engaged in reform-based science experiences such as inquiry. Finally, it is important to note, that just as with CRP Science and reform-based science education, a study's omission within a specific category does not imply that a given PD venture did not include those specific supports, but rather, that they were not explicitly articulated.

Structured sessions

Structured sessions occurred weekly (Bell & Gilbert, 1994), monthly (Zozakiewicz & Rodriguez, 2007), in full-day workshops (Lee, 2004; Luft, 2001), and/or in intense one- or two-weeklong summer institutes (Crippen et al., 2010; Luft, 2001; Zozakiewicz &

Rodriguez, 2007). Often, PD experiences utilized a combination of several or all of these structured sessions to focus on teacher concerns (Bell & Gilbert, 1994; Lee, 2004), build science content knowledge (Crippen et al., 2010; Zozakiewicz & Rodriguez, 2007), or to introduce new activities (Bell & Gilbert, 1994) that were either premade from a specific curriculum (Luft, 2001) or co-designed among teachers (Parke & Coble, 1997). Furthermore, these structured sessions supported PLCs and allowed teachers to troubleshoot as well as brainstorm new ideas.

Professional learning communities

Throughout each of the studies, teachers consistently engaged in meaningful collaboration with one another in PLCs. According to Cochran-Smith and Lytle (1999), PLCs provide a learning environment in which teachers can work together to “identify discrepancies between theories and practices, challenge common routines, draw on the work of others for generative frameworks, and attempt to make visible much of that which is taken for granted about teaching and learning” (p.293).

Depending upon the goals of the PD experience, activities and discussions in these PLCs ranged from elucidating personal beliefs about multiple topics (Lee, 2004; Parke & Coble, 1997) to engaging in reform-based science practices (Crippen, 2012; Crippen et al., 2010). Occasionally, teachers took on leadership roles by facilitating group sessions and engaging participants in making predictions, using evidence to substantiate claims, analyze data from a variety of representations, and create arguments (Crippen, 2012). Additionally, teacher leaders developed collective norms, mediated individual and collective beliefs, and enhanced interpersonal relationships (Crippen et al., 2010). While developing teacher leaders is an intense and time-consuming process, there is great value to be found in the endeavor as teacher leaders experience reduced feelings of isolation, increased professional satisfaction, and continued professional growth (Loucks-Horsley et al., 2010).

Researchers often participated in these professional learning communities to probe further about teachers' changing practices and beliefs (Zozakiewicz & Rodriguez, 2007), address specific issues voiced by teachers (Bell & Gilbert, 1994) introduce new activities (Lee, 2004; Luft, 2001), discuss instruction progression and student learning (Davis & Varma, 2008), and encourage interdisciplinary collaboration (Yerrick & Beatty-Adler, 2011). The collective participation of teachers in PLCs occurred across grade level, and within-and among- schools in a particular district (Garet et al., 2001).

In addition to voicing concerns and brainstorming innovative approaches to science instruction, teachers used PLCs as a space to align their teaching philosophies with current research (Parke & Coble, 1997), analyze problem-based, inquiry lessons (Crippen, 2012; Parke & Coble, 1997), share best practices (Crippen et al., 2010, Lee, 2004), and design assessments that were intended to incorporate the native languages of students (Lee, 2004) and elucidate conceptual understanding (Parke & Coble, 1997).

Observation & reflection

Engaging prior knowledge is essential to facilitating learning, as individuals connect new knowledge to previous experiences. Teachers enter their classrooms with deeply held, tacit beliefs about teaching, many of which are incongruent with reform-based science teaching. Unless critically examined, such beliefs are perpetuated, directly impacting what and how teachers teach as well as students' motivation and potential to learn. Therefore, to empower science teachers as reform-based educators capable of providing rigorous academic experiences, developing teachers as reflective practitioners is required (Schön, 1983; 1987). In their exhaustive review of the literature on inquiry-based PD, Capps, Crawford, and Constas (2012) assert, “without including explicit reflection as part of PD experiences, it is unlikely that substantial teacher learning or change will occur” (p.302). Thus, reflection is a fundamental part of the learning process. It provides teachers with scaffolds to critically examine their beliefs and current practices (Villegas & Lucas, 2002), the impact of their instruction on student outcomes (Howard & Aleman, 2008), and how aligned their practices are with reform-based science teaching (Bell & Gilbert, 1994; Parke & Coble, 1997). An additional benefit of reflective practice is that it furnishes teachers with skills for lifelong learning and continual improvement to their practice (Hammerness et al., 2005). Given the utility of this support to facilitate teacher change through its direct connection to practice, it was not surprising to find reflection as a common thread throughout PD experiences.

Reflection was used to examine changes in the ability of teachers to argue as a result of engaging in modified activities (Crippen, 2012), to elicit their cultural histories (Lee, 2004), and to explore teachers’ learning of a new practice (Bell & Gilbert, 1994; Luft, 2001). Reflection was also used to develop reflexive approaches to collaboration (Zozakiewicz & Rodriguez, 2007), aid curriculum planning and enactment (Davis & Varma, 2008), and was deemed critical to developing teacher leaders (Crippen et al., 2010).

Observations serve as a valuable support in that they provide evidence of teachers’ use of new knowledge and skills and serve as a starting point for teacher reflection (Guskey, 2000; Hewson, 2007). Moreover, observation was occasionally used to provide teachers with another route to monitor students’ learning (Lee, 2004). Several studies employed observations to monitor teachers’ changing practices. Occasionally, researchers visited participating teachers' classrooms to ascertain insight (Lee, 2004). However, teachers were more often involved in observing each other's classrooms and subsequently sharing feedback (Bell & Gilbert, 1994; Garet et al., 2001; Luft, 2001). In one particular study, teachers were even granted four days of release to accomplish this goal (Luft, 2001). However, in all cases in which teacher observation occurred, it was intended to provide an entry point for teacher reflection on changing practices (Lee, 2004; Luft, 2001), to learn from expert teachers (Garet et al., 2001), and glean effectiveness of instructional materials (Davis & Varma, 2008).

Resources and responsive supports

In order for teachers to engage in reform-based science education, they need access to supporting resources such as standards, scholarly articles and books, and physical materials (Loucks-Horsley et al., 2010). Resources within these studies were identified as ongoing support from researchers/facilitators (Davis & Varma, 2008; Zozakiewicz & Rodriguez, 2007), innovative activities (Bell & Gilbert, 1994), web-based management systems (Crippen, 2012), video-conferencing (Crippen, 2012), technology-based tools (Davis & Varma, 2008; Penuel et al., 2007), and modeling reform-based instructional strategies (Davis & Varma, 2008; Lee, 2004; Zozakiewicz & Rodriguez, 2007). Additionally, teachers examined state and national science education standards as they attempted to align instruction with reform-based science (Lee, 2004; Parke & Coble, 1997; Zozakiewicz & Rodriguez, 2007).

Teachers found these resources valuable to different degrees throughout their PD experiences. For example, in Zozakiewicz and Rodriguez's (2007) PD program to prepare fourth through sixth grade mathematics and science teachers to teach in multicultural and gender-inclusive ways, only 30% of the participating teachers mentioned access to equipment as valuable. However, greater than 80% of the teachers actually used one or more pieces of equipment during classroom instruction. In contrast, Davis & Varma (2008) found that, when providing PD to support the use of technology-based science modules, technology support, modeling effective teaching, and co-facilitating instruction were perceived by all participating teachers as the most valuable supports.

PD opportunities were responsive to teachers' needs in several ways, although the only overt responsiveness to students was through the integration of students' lives and linguistic backgrounds with science instruction (Lee, 2004; Yerrick & Beatty-Adler, 2011; Zozakiewicz & Rodriguez, 2007). Experiences changed in conjunction with the changing needs of teachers. For example, in Lee's (2004) work with bilingual elementary teachers, she found the most prominent theme at PD onset to be teachers' lack of confidence in their science content knowledge and pedagogical knowledge. In response, an initial area of emphasis in PD sessions was reform-based science instruction, which included rich hands-on inquiry opportunities where teachers learned to convey and apply key science concepts associated with the water cycle and weather. As teachers gained knowledge and confidence, the focus then turned to incorporating students' language and culture into science instruction.

Teacher voice was prominent in studies that articulated responsiveness, demonstrating how professional developers viewed teachers as intelligent and capable professionals (Crippen et al., 2010; Davis & Varma, 2008). During weekly collaboration sessions, teachers negotiated PD content and strategies for executing activities (Bell & Gilbert, 1994) and actively participated in the design, adaptation and implementation of a five-day instructional module (Davis & Varma, 2008). Through responsive supports such as those mentioned here, facilitators were able to develop professional trust with teachers that enabled open and constructive dialogues about their practice (Zozakiewicz & Rodriguez, 2007).

Outcomes and Challenges

Changes in beliefs and practice

Within the multiple studies examining the impact of PD on teachers' practices, the focus on specific aspects of teacher practice under examination varied. For example, Zozakiewicz & Rodriguez (2007) examined the impact of PD on teachers' classroom practices with respect to multicultural, gender-inclusive science education, whereas others focused on how the PD program impacted teachers' reform-based science instruction (Crippen et al., 2010; Luft, 2001; Parke & Coble, 1997).

Studies demonstrated increases in teachers' science content knowledge (Crippen, 2012; Lee, 2004), inquiry practices (Crippen et al., 2010, Lee, 2004: Luft, 2001), and multicultural practices (Lee, 2004; Zozakiewicz & Rodriguez, 2007), albeit in different ways. For instance, in the case of Luft's (2001) work preparing teachers to implement inquiry-based instructional modules, both beginning and experienced teachers showed statistically significant changes in their inquiry practices. However, beginning teachers were found to change their beliefs more than their practices, indicating that their beliefs about teaching were pliable, whereas the converse could be said of experienced teachers in this study.

Multiple studies reported changes in teachers' beliefs (e.g., Lee, 2004; Luft, 2001). For instance, teachers in Lee's (2004) study initially saw minimal relationship between students' languages and cultures and science learning. However, over the course of the PD program, teachers came to realize the “power and impact of merging” students’ cultures and languages with science instruction (p.73). Teachers became more comfortable with science as inquiry and gained confidence in their ability to meet their students’ learning needs. In this particular study, adequate content knowledge and pedagogical knowledge were requisite for establishing this form of instruction, which indicates that, for elementary teachers who originally had low self-efficacy with teaching science, building science pedagogical knowledge is a gatekeeper to teaching in culturally responsive ways.

Student performance

With the high premium placed on PD to yield increases in student achievement (No Child Left Behind [NCLB], 2001; National Science Teachers Association [NSTA], 2006) and charges that PD in science education is lacking in this connection (Garet et al., 2001), research on PD must make explicit connections between teachers’ participation and the impact on student achievement when possible. Yet, only four PD initiatives examined the impact on student performance (e.g., Crippen et al., 2010; Lee, 2004; Luft, 2001; Parke & Coble, 1997). Furthermore, only one study demonstrated a positive impact on student achievement on standardized tests (Crippen et al., 2010), demonstrating that students of participating teachers were more than twice as likely to pass the state science exam compared to a control sample. Participants in Parke and Coble’s (1997) five-phase PD model for transformational science demonstrated improved student attitude and interest when participating in teacher-created curriculum materials. However, students’ science achievement as measured by state tests was merely maintained.

While Luft (2001) demonstrated that students of participating teachers improved their reform-based science skills (e.g., the ability to develop researchable questions, design and conduct investigations, and effectively communicate investigation results), missing was a direct link to student achievement. Students' ability to successfully engage in the practices of science is certainly valuable. Nonetheless, in order to reduce academic disparities, such changes must translate to increased student achievement. Moreover, of the two studies related to PD for CRP Science (Lee, 2004; Zozakiewicz & Rodriguez, 2007), neither documented improvements of student achievement, echoing arguments made by Sleeter (2012) and Lee and Luykx (2007) that a research base demonstrating connection among PD, CRP Science, and student learning is still largely absent and much needed.

Challenges

Because of the complexity associated with PD, such endeavors will be met with challenges at some point in time or another. Pertaining to the studies discussed here, multiple challenges arose. In some instances, teachers abstained from using abundant available resources in favor of external resources when finding evidence to support an argument (Crippen, 2012). Additionally, time constraints (Crippen et al., 2010) and teacher resistance (Bell & Gilbert, 1994; Crippen et al., 2010; Parke & Coble, 1997; Yerrick & Beatty-Adler, 2011) were noted.

In all cases reported, resistance arose when teachers' beliefs and professional identities were challenged. In the case of Crippen et al. (2010), it was reported that teachers who decided to leave the PD program were unwilling to examine their beliefs about teaching and practice in deep ways. Furthermore, when reform-based approaches to science teaching conflicted with teachers' beliefs, teachers were unwilling to incorporate these approaches into their belief system (Parke & Coble, 1997). Specifically in instances of working with diverse learners, teachers' beliefs about education impacted their perception of (and participation within) the PD program, as well as their ability to meet diverse students' needs (Yerrick & Beatty-Adler, 2011). Bell and Gilbert (1994) noted that teachers had to first perceive a need for change and then identify a plan for specific change before their practice was impacted.

PD in science education is a complex venture (Hewson, 2007). Supports are wide-ranging and depend on the goals of the program. Professional developers must design for the specific teachers experiencing the PD, the larger context, as well as the processes participants undergo. In research-grounded PD experiences, such as those shared in this discussion, attention must be paid to how teachers develop during a given intervention and how that intervention impacts specific outcomes (e.g., teachers' knowledge, skills, and dispositions).

Furthermore, challenges within PD ventures are inevitable. For the studies discussed in this chapter, resistance to change was linked to teachers' beliefs and professional identities, much like Rodriguez (1998) found with the PSTs in his study. Teachers' resistance to reform messages presented within PD pose serious constraints on program success and therefore should be identified and addressed when possible.

In the following section, several frameworks that inform the design of the STARTS PD program will be discussed.

Guiding Frameworks on Teacher Change

In addition to CRP, CRP Science and PD in science education literature, several conceptual frameworks guide the STARTS program design. These frameworks include conceptions of teacher as learner (Hammerness et al., 2005; Loughran, 2007; Lortie, 1975; Borko & Putnam, 1996), teacher change/development (Bell & Gilbert, 1994; 1996), and teacher as designer/adaptor (Brown & Edelson, 2003; Davis & Varma, 2008; Remillard, 1999; Squire, MaKinster, Barnett, Luehmann, & Barab, 2003). To better understand these additional theoretical underpinnings of the STARTS PD program, each will be described in the following section.

Teacher as Learner

Teacher learning is distinct from student learning in many ways, although overlap is noted among the two, especially with regards to social influence (Borko, 2004). In general, teachers hold greater agency over their learning (Davis & Krajcik, 2005). After their initial preparation, teacher learning can be sporadic (Wilson & Berne, 1999), whereas students are responsible for attending school and learning through formal experiences. While both students and teachers are expected to possess a strong command of the subject matter they study (or teach), teachers also require solid pedagogical content knowledge (Abell, 2007; Magnusson, Krajcik, & Borko, 1999; Shulman, 1986) and the ability to flexibly apply their knowledge to make sound pedagogical decisions (Davis & Krajcik, 2005).

How and what teachers learn in teacher preparation programs is strongly mediated by their prior knowledge and experiences (Borko & Putnam, 1996), particularly their experiences as students (Lortie, 1975). Influences such as these can lead teachers to superficial or faulty conceptions of teaching, absent fundamental pedagogical knowledge and skills (Hammerness et al., 2005). For example, when preparing science teachers, Barnes and Barnes (2005) note that "[e]ven after years of their own science courses and formal instruction, prospective and inservice teachers often have never been immersed in authentic inquiry themselves" (p.62). Without sufficiently challenging teachers' preexisting notions about teaching, these conceptions will likely remain intact and reproduce the same teaching practices they experienced as students.

When challenging preservice and inservice teachers' beliefs about teaching, the reform message needs to be compelling enough and create sufficient dissonance so that a *need to know* (Dana, McLoughlin, & Freeman, 1998) is created, which increases the likelihood of deep processing and true accommodation when teacher motivation and ability are sufficient (Gregoire, 2003). To support teacher learning, teacher educators must create states of cognitive dissonance (discomfort resulting from simultaneously possessing conflicting conceptions) in which teachers' knowledge, skills, and dispositions are challenged. For example, when preparing culturally responsive teachers, Villegas & Lucas (2002) argue it is fundamental to induce change in teachers' knowledge, skills, and dispositions regarding themselves as cultural beings, the role of schooling, the value of diversity, and the nature of learning. However, this challenge must not occur in isolation, but rather in a supportive and respectful environment (Dana et al., 1998) with the proper supports to accommodate conceptual change.

In the realm of science teacher education, science teacher learning involves the construction (and reconstruction) of science pedagogies (Loughran, 2007; Borko & Putnam, 1996). The professional growth of science teachers can be supported with specific PD structures such as: (a) opportunities for teachers to build their knowledge and skills, (b) modeling instructional strategies, (c) a learning community (Loucks-Horsley et al., 2010), (d) opportunities for enhanced communication among university and school faculty (Zozakiewicz & Rodriguez, 2007), and (e) ongoing support, as well as (f) opportunities for active learning and collective participation of teachers from the same subject area (Garet et al., 2001). With regard to inservice science teacher education, these supports have been effective at producing teacher learning in the following areas: multicultural and gender inclusive instruction (Zozakiewicz & Rodriguez, 2007), instructional congruence (Lee, 2004), learning to teach science as inquiry (Crippen et al., 2010) and incorporating technology into instruction (Davis & Varma, 2008).

Teacher learning is a process distinct from student learning in multiple ways. These distinctions require the use of specific supports to promote teacher learning in both content knowledge and pedagogical knowledge. However, the presence of high-quality PD supports does not guarantee teacher learning. For teacher change to unfold and progress, a closer examination of mediating factors and mechanisms undergirding the process is necessary.

Teacher Change/Development

As teachers learn new subject matter and pedagogical content knowledge they develop and change. Clarke and Hollingsworth (2002) identified six perspectives on teacher change, each of which position the teacher as learner in clearly distinguishable ways. The STARTS PD program is designed with two particular models of teacher change in mind that most closely align with Clarke and Hollingsworth's notions of teacher change as personal development, local reform, and adaptation. In the following section the model of teacher development presented by Bell and Gilbert (1994; 1996) will be described.

Teacher Development According to Bell and Gilbert (1994; 1996)

Bell and Gilbert (1994; 1996) acknowledge that teachers experience frustration when they attend PD experiences (e.g., workshops, coursework, inservice courses), and leave feeling unable to implement new pedagogies, curriculum materials, or content knowledge that improve student learning. Over time, experiences like this may lead teachers to adopt a cynical perspective on PD opportunities and calls for PD that effectively supports teacher change. Moreover, when teachers perceive reform to pose a serious challenge, there is a risk of retreat to traditional forms of teaching once the program has ended (Bell & Gilbert, 1994; Loughran, 2007).

The model of teacher development proposed by Bell & Gilbert arose from findings of a three-year research project in New Zealand (*Learning in Science Project*) that investigated the development of 48 primary and secondary science teachers as they learned constructivist-oriented approaches to teaching science. Findings indicated that teacher development occurred along three dimensions - personal, social, and professional – and in three phases (Figure 2-1). Generally speaking, the *personal development* domain pertains to attending to teachers' feelings and concerns associated with the change process and the reconstruction of what it means to be a science teacher; the domain *social development* is related to collaboration among teachers and with students as notions of science education are renegotiated; and the *professional development* domain concerns changing knowledge, skills, and dispositions about science education and instruction.

Initial development

Prior to implementation, Bell and Gilbert's research team conducted a teacher survey discerning attitudes, expectations, and efficacy among participants. Results indicated that participating teachers commonly experienced some level of professional dissatisfaction and chose to engage with the PD because they saw it as an avenue for overcoming this dissatisfaction (personal development). Additionally, teachers who felt a sense of isolation in the classroom before the program onset enrolled in the PD because they anticipated great benefits from collaboration (social development).

Teachers' initial professional development began with the message that teaching is problematic and full of dilemmas. A focus on *learning about* practices rather than *solving* problems of practice (Loughran, 2007) came to the forefront. Viewing teaching as problematic enabled participating teachers to engage in the reform message and allowed them to try out new activities without their professional identities being immediately challenged at program onset, thus providing a safe and respectful learning environment. Teachers who had not undergone these first phases of development were not as likely to engage in the PD or its reform message.

Second phase of development

Over the course of PD, teachers entered what Bell and Gilbert categorize as a second phase of development. During this time, teachers' *personal development* included reconstructing their visions of a science teacher and addressing concerns regarding reform-oriented teaching, such as losing control in the classroom, the amount of teacher-directed instruction needed, covering ample traditional curricular materials, and meeting assessment requirements.

During the initial social development phase teachers felt isolated from others and perceived collaboration to be valuable. At this second stage of social development, meaningful collaborative experiences among teachers and facilitators established a sense of trust and credibility within the program. Teachers felt more comfortable contributing to activities, providing supportive and critical feedback to others, and reflecting on their own practices. Bell & Gilbert found that collective participation that is truly supportive, builds trust with one another, and offers and receives critical feedback about practice in nonjudgmental ways facilitates the social development of teachers and ushers in teachers' professional growth.

Stronger interaction between teachers' cognitive development and classroom practice than that previously seen characterizes the second phase of PD. Through continual reflection, teachers showed growth in their abilities to elicit student thinking and connect it in to instruction in meaningful ways. Teachers refined and applied their ideas about science and science education as they reflected on the roles of teachers, learners, the curriculum, and practices of science aligned with constructivist approaches to learning.

Third phase of development

As teachers experienced success as learners and teachers in a supportive, collaborative environment, they expressed feelings of empowerment and responsibility for their own development. Concerns from the second phase of personal development (losing control, covering curriculum, meeting assessment requirements) decreased during this final phase of personal development as teachers repeatedly evaluated and learned to trust the reform-oriented style of teaching over time. Moreover, teachers began to develop trust in their students' abilities as they witnessed indicators of learning and success during implementation of the new curriculum and no longer felt incompetent if they were not the center of instruction.

As teachers developed socially they began to actively seek out collaboration outside of structured PD time and with teachers from other content areas. During interviews, teachers expressed feeling like they had a network of colleagues with whom they could collaborate and voice concerns. In the final phase of the professional development dimension, several participating teachers took initiatives to pursue subsequent professional development opportunities. These teachers took on the role of leaders as they facilitated future PD experiences and introduced colleagues to new classroom activities while supporting them in implementation. Additionally, they applied for positions within the Ministry of Education to serve as professional development facilitators at the regional level.

Interactions among the dimensions and phases

The process of teacher development observed in the *Learning in Science Project* can be characterized as one in which personal, social, and professional development occurs in an interwoven fashion. Bell and Gilbert (1996) acknowledge that addressing and resolving teachers' concerns throughout the professional development experiences had both cognitive and affective aspects. Furthermore, they note, "[i]t appeared. . . that it was most crucial to address affective dimensions if teacher development was to continue" (p.25), as many of the concerns had personal, social, and professional development elements.

Ultimately, as Bell and Gilbert (1994) worked with teachers and observed their learning progression, data supported their conclusion that teachers' personal development was pivotal in the change process in that "personal development preceded professional development, the pace of personal development influenced the pace of professional development and the personal development was often influenced by factors outside the professional and teaching work of the teacher" (p.494).

Supports

The strength of Bell & Gilbert's model is that it not only identifies specific dimensions and phases of teacher development and how they are interconnected, but also elucidates specific supports that foster professional growth and permits teachers to persist in the challenges associated with changes in knowledge and practice. Teachers' professional dissatisfaction and recognition of the need for change in practice does not necessarily mean they will implement reform-based practices (Loughran, 2007; Veal, 1999). To support true conceptual change, deep processing of the reform message must occur (Gregoire, 2003) and systematic processing can be promoted with specific, high-quality supports throughout all phases of development (Bell & Gilbert, 1996). For the teachers in Bell and Gilbert's (1994; 1996) study, feedback and reflection became the two greatest supports.

Personal, social, and professional concerns were attended to in each of the weekly sharing sessions. Teachers voiced their concerns and perceived constraints in learning communities. Collaboratively, along with the facilitator, participants gave and received feedback while working toward solutions. When concerns were known ahead of time, they were also addressed in specific workshop activities. Of additional importance was reflection on and discovery about how teachers themselves have learned over time. Thus, metacognition played a central role in facilitating change. Throughout the professional development program, teachers tried out small activities in their classrooms and reflected on the experience from both teaching and student learning perspectives. This allowed participants to critically reflect on aspects of their teaching while also experiencing success in small steps. Teachers' validation of themselves as competent professionals was essential to continuing the change process.

To recap, the model of teacher development proffered by Bell and Gilbert (1994; 1996) contends that teacher learning and growth occurs along personal, social, and professional dimensions and in distinct, yet interrelated phases. Hence, development in one area will not progress in meaningful and lasting ways unless concerns in other areas are attended to and addressed with specific supports. For the 48 teachers in this study, the most effective supports facilitating teacher growth were reflection and continuous feedback.

Professional developers who utilized effective supports to facilitate science teachers' development of reform-based science practices (e.g., Crippen et al., 2010; Parke & Coble, 1997) and CRP Science (e.g., Rodriguez, 1998; Zozakiewicz & Rodriguez, 2007) experienced teacher resistance. The Bell and Gilbert (1994; 1996) model offers powerful insight into dimensions and phases of teacher development as well as suggestions for why teachers either embrace or resist reform messages at specific phases of the PD journey.

Challenges associated with teaching in reform-based ways must be addressed and overcome if teacher change aligned with PD goals is to occur. This becomes especially salient when involving teachers in the process of creating instructional materials in addition to changing their practices, as the impact on student performance is intensified. Developing teachers' pedagogical design capacity requires the utilization of specific supports and knowledge of larger contextual influences on curriculum and instruction (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Squire et al., 2003).

Yet, undertaking a process such as developing science teachers' abilities to design instructional materials builds capacity for sustaining the positive impacts of PD and is especially critical to enacting CRP Science, as most science instructional materials currently in use are not culturally responsive (Lee, 2004; Lee & Luykx, 2007; NRC, 2012; Tate et al., 2008; Zozakiewicz & Rodriguez, 2007).

Teacher as Designer/Adaptor

PD experiences that are ongoing and connected to teachers' daily practices improve science teachers' knowledge and practices (Crippen et al., 2010; Zozakiewicz & Rodriguez, 2007). However, PD often focuses on supporting the implementation and adaptation of premade curriculum materials (Bell & Gilbert, 1994; Davis & Varma, 2008; Loucks-Horsley et al., 2010). In contrast, few reported models aim to directly alter teachers' practices by supporting them through the development of innovative instructional materials (Parke & Coble, 1997; Zozakiewicz & Rodriguez, 2007). Such opportunities build capacity for sustainable change by empowering science teachers with the tools and support necessary to create instructional resources that are contextualized to student and classroom needs. The challenge, then, involves designing PD with specific supports that enhance teachers' pedagogical design capacity (Brown & Edelson, 2003) by aiding them in the construction of CRP Science instructional materials.

Pedagogical Design Capacity

According to Brown and Edelson (2003), the practices of a teacher can ultimately be viewed as engaging in design. When planning for instruction, teachers must first attend to and interpret existing resources, evaluate any classroom constraints, devise strategies and balance tradeoffs. As a result, teachers – as designers of learning environments – possess a pedagogical design capacity. Brown and Edelson (2003) define *pedagogical design capacity* (PDC) as a teacher's "ability to perceive and mobilize existing resources in order to craft instructional contexts" (p.6). The PDC a teacher possesses enables them to use curriculum materials in a variety of ways, including offloading, adapting, and improvising. When teachers offload, they rely on premade curriculum materials for instruction, contributing little of their own PDC during enactment. Teachers who adapt curriculum materials adopt specific elements of preexisting instructional resources (e.g., student worksheets, lab activities), but utilize their PDC when they contribute their own design decisions. PDC is exercised greatly during the process of improvisation. When improvising, teachers do not rely on curriculum materials at all; instead, they design the instruction themselves. Adapting and improvising are the two areas that the STARTS PD program targeted as teachers were supported in their design of CRP Science instructional materials. Thus it was essential to support expanding PDC for teachers through program activities.

By exploring teachers' PDC, professional developers stand to gain a better understanding of how teachers gain access to and adapt appropriate instructional materials. Teachers adapt curriculum materials to meet contextual needs (Ball & Cohen, 1996; Squire et al., 2003). However, teachers who have not had opportunities to strategically analyze instructional materials often make counterproductive (Beyer & Davis, 2012) or superficial (Lloyd & Behm, 2005) modifications to instruction.

To develop the PDC of a teacher, professional developers must provide adequate opportunities for teachers to critically explore resources and successfully integrate them into classroom practices to meet contextual and student needs. Davis, Beyer, Forbes, and Stevens (2011) argue that PD should support teachers in learning more about their students, students' backgrounds, their ideas about science, and the larger school context, as "understanding and leveraging context is a critical aspect of pedagogical design capacity. . . and would help teachers be better positioned to make productive changes to the curriculum materials" (p. 808). Additionally, teachers must be supported through the process of making instructional goals explicit and linking them to specific curriculum features (Beyer & Davis, 2012; Brown & Edelson, 2003). However, teachers enter PD experiences with various PDCs. Therefore, they may require multiple resources depending on their knowledge and practices. For example, teachers who possess a well-established PDC may benefit from open-ended resources rather than more explicit and structured strategies for linking instructional materials to pedagogical goals (Brown & Edelson, 2003).

In their work developing the capacity of elementary PSTs as reform-based science curriculum designers, Beyer and Davis (2012) note that participants initially emphasized effective modifications to instruction, such as making science fun, providing hands-on activities, and promoting cooperative learning. Similar to Lee (2004) and Abell (2007), the authors noted that participants lacked science content knowledge, pedagogical knowledge, and confidence when they began the course. However, as teachers gained confidence by the end of the course, over 70% of the participants modified curriculum materials according to reform-based science teaching criteria such as regular check points to assess student understanding, eliciting student ideas through specific prompts, and uncovering students' prior knowledge through effective questioning.

Several factors influenced PSTs' expanding PDC and confidence: (a) learning about reform-oriented criteria and applying them to lesson plan analysis; (b) repeated practice critiquing lessons; and (c) observing mentor teachers as they modified instructional materials. Yet, the authors also found that PSTs understood the need to modify curriculum materials for students' and teachers' benefits but not necessarily *why* practitioners modify materials. This led Beyer and Davis (2012) to assert that beginning teachers may be more inclined to productively critique instructional materials if they are provided with rich opportunities to learn about research-based theory on science teaching and analyze examples consistent with reform-based practices via specific guiding criteria.

To best explore an educational intervention's influence on the progression of CRP Science teachers and constructors of innovative instructional materials, a design-based research (DBR) approach is warranted. DBR studies are distinct from other research designs in that they are primarily concerned with examining a designed intervention, associated learning outcomes, and the mechanisms undergirding their progression, all with the goal of enhancing future design iterations (Barab, 2006; Edelson, 2002; Kelly, 2004; Shavelson & Towne, 2002). In this next section the field of educational design research will be surveyed.

Design Studies in the Literature

General Trends

At the core of design studies are (1) the design, enactment, and refinement of an educational intervention (i.e., tool); and (2) identifying and understanding learning progressions, their mechanisms, and mediators when an intervention is enacted (Edelson, 2002; Confrey, 2006; McKenney & Reeves, 2012). These educational tools are designed to facilitate learning and are studied in classroom settings where multiple dependent variables are involved and acknowledged, rather than controlled for. Additionally, many stakeholders are involved in the design and ongoing analysis to bring a wealth of expertise to the table (Barab & Squire, 2004).

Of the STEM education-focused design research studies discussed in this synthesis, seven were conceptual pieces (e.g., Barab & Squire, 2004; Kelly, 2004; Confrey, 2006, Edelson, 2002) and six reported on empirical studies utilizing DBR as a methodology (e.g., Confrey & Lachance, 2000; Songer, 2006; Squire et al., 2003). Three design studies were in science education, two focused on mathematics education, and one on STEM education. Four design studies were conducted in middle school classrooms and two in elementary school. One particular study enacted a designed curriculum with multiple grade ranges – middle, high, and undergraduate (Squire et al., 2003). However, this was the only instance in which high school and postsecondary education were areas of focus. Time immersed in study settings ranged from four days (Squire et al., 2003) to three years (Confrey & Lachance, 2000).

All studies utilized a mixed methods approach. However, findings were ultimately presented qualitatively, most often in case studies (e.g., Brown & Edelson, 2003; Hjalmarson & Diefes-Dux, 2008). Educational tool design, use, and refinement were observed in all cases. Although the tool was frequently a designed curriculum, there was an example of additional instructional materials (e.g., outlines and rubrics) as tools to support learning (Hjalmarson & Diefes-Dux, 2008).

Also representative of DBR, researchers were actively involved in their studies on multiple levels (Barab & Squire, 2004). All researchers served as participant observers, providing suggestions and support during curricular enactment and, occasionally, serving as "customer service representatives" (Squire et al., 2003, p.474). Further, all but one research team (Hjalmarson & Diefes-Dux, 2008) operated as curriculum designers. Finally, in two studies, curriculum designers also acted as teachers during curriculum enactment (Confrey & Lachance, 2000; Joseph, 2004). In this synthesis, I chose to present the empirical literature according to categories of features characteristic of DBR: research goals; iterative cycles and the process of design refinement; methodological rigor; and outcomes and future directions.

Research Goals

Theoretically, design studies are primarily concerned with characterizing a designed intervention, associated learning outcomes, and the mechanisms undergirding their progression (Barab, 2006; Edelson, 2002; Kelly, 2004; Shavelson & Towne, 2002). Of the DBR studies discussed in this chapter, research goals can be roughly categorized as concerned with characterizing learning progressions (Confrey & Lachance, 2000), identifying and understanding various mediators of learning (Joseph, 2004; Songer, 2006) and curriculum adaptation (Brown & Edelson, 2003; Squire et al., 2003). They can also be used to describe how teachers design educational supports and for which purposes (Hjalmarson & Diefes-Dux, 2008).

Occasionally, studies with multiple overarching research goals attended to several DBR facets. For instance, Songer (2006) and her research team designed, implemented, and revised a science inquiry-based curriculum, *The Kids' Inquiry of Diverse Species* (*BioKIDS*), with sixth-grade students over the course of a year to explore how to best develop students' complex reasoning skills through specific scaffolds and redesign existing data-rich technologies so they translate to educational tools appropriate for student learning. Through this series of research endeavors, Songer (2006) focused on the design of specific learning environments as well as the translation of existing technologies to promote student learning.

Iterative Cycles & the Process of Design Refinement

Constant comparative analysis is not exclusive to DBR. However, in design studies, the purpose for concurrent data collection and analysis is to refine tools to better understand and impact the learning progression (Confrey & Lachance, 2000; Joseph, 2004). Therefore, a salient feature of DBR is the process of design refinement occurring in iterative cycles of development. Although some studies clearly articulated iterative design throughout the course of a given study (e.g., Joseph, 2004) for others this was not so clear (e.g., Brown & Edelson, 2003; Squire et al., 2003). However, in each of these instances the iterative nature was demonstrated through discussions of how the team's previous research had contributed to the current investigation (Confrey & Lachance, 2000; Songer, 2006; Squire et al., 2003). This was best explicated in Confrey and Lachance's (2000) work on developing mathematical abilities in elementary students via empirically grounded instructional materials.

Confrey and Lachance (2000) developed a conjecture on splitting as a mathematical construct that arose from a series of previous research endeavors and theories of learning. According to Confrey (1994), "'splitting can be defined as an action of creating simultaneously multiple versions of an original, an action often represented by a tree diagram' (p. 292)" (cited in Confrey & Lachance, 2000, p. 237). Thus, splitting moves multiplication beyond repeated addition. Guided by the splitting conjecture, they devised a three-year design study with 18 third graders to design for students' learning of mathematical constructs (e.g., multiplication, division, ratio) via activities that support the splitting conjecture. Both researchers taught mathematics to these students throughout the three years, outlined a progression of tasks to bolster students' understanding of interrelationships among relevant mathematical concepts, and concurrently refined emerging theory and the original conjecture.

To prepare for each instructional session, a set of tasks were designed and implemented. Students were then observed during activities, and artifacts were collected. Through informal interviews with students during class time, Confrey and Lachance captured interactions around key tasks the intervention was designed to foster. Of critical importance to understanding how ratio reasoning developed via the splitting conjecture-supported activities were the opening and closing of each class session, where groups recapitulated the day's events and presented findings (i.e., progress reports). Furthermore, the curriculum was refined and redesigned over time through preliminary data analysis based on student responses from various phases of the intervention. Final data analysis occurred post-intervention and was devoted to constructing and refining the conjecture and resulting theory (Confrey & Lachance, 2000).

From their work, two additional features of DBR are illuminated: its intensity and embeddedness. Design studies occur in naturalistic settings where context plays a large role in that multiple variables are present and cannot be controlled for (Barab & Squire 2004; Fishman et al., 2004). Moreover, in the case of the work by Confrey and Lachance (2000), they were embedded in the setting for an extended period of time, serving as researchers, curriculum designers, and teachers. While some may applaud design researchers for their endurance throughout the course of investigation, these same features lead others to approach DBR findings with skepticism. For example, by not controlling multiple variables, design studies run the risk of not being able to tease out complex interactions and establish causality (Kelly, 2004). Therefore, a charge among design researchers is to make evident a study's methodological rigor. In the cases presented here, multiple approaches were taken to achieve this goal.

Methodological Rigor

Design researchers attempt to establish methodological rigor through the collection and analysis of a variety of data (Confrey & Lachance, 2000; Joseph, 2004), triangulation (Hjalmarson & Diefes-Dux, 2008; Squire et al., 2003), and collaboration among teams of experts (Brown & Edelson, 2003; Songer, 2006). Each of the studies utilized these approaches to establish methodological rigor. However, the role of collaborators varied slightly (e.g., designer; analyst) according to overall research aims.

Numerous data sources were collected and analyzed, including interviews with teachers (Brown & Edelson, 2003; Hjalmarson & Diefes-Dux, 2008) and students (Confrey & Lachance, 2000); observation and field notes (Squire et al., 2003); learner-created (Joseph, 2004; Songer, 2006) and teacher-created artifacts (Hjalmarson & Diefes-Dux, 2008); and audio and video recordings (Confrey & Lachance, 2000; Joseph, 2004). In a given study, multiple data sources were triangulated to exhibit trustworthiness, reliability, and adequate external validity (Confrey & Lachance, 2000; Squire et al., 2003).

Demonstrating methodological rigor throughout iterative stages of design and analysis is no small task. Such an endeavor requires careful attention to all elements under investigation and thorough simultaneous data collection and analysis. One example of establishing rigor throughout all phases of the design study was Joseph's

(2004) work designing classroom activities and communities that allow elementary students to learn in a cognitive apprenticeship setting. Joseph (2004) and her research team constructed two curricula during the course of this investigation. For the first curriculum, the design team chose the theme of flight because they thought it would be interesting to students. Prior to enactment, multiple small-scale activities were designed around this theme and students participated in pre-interviews to elicit interests and prior content knowledge. Curriculum enactment occurred once a week over the course of a five-week summer program.

Post-interviews and student learning artifacts yielded disappointing results for the flight curriculum. Joseph and her team did not observe outcomes aligned with design goals, such as students' extended engagement with activities, which led them to posit that the theoretical link between learner goals and curriculum theme was not salient. Based on the lackluster performance of the first curriculum, the team developed candidate explanations for its failure – too much time between lessons (once a week), insufficient "motivational affordances" beyond a link to the theme– and they also redesigned the second curriculum to directly address these issues.

Because students participating in the original flight curriculum were not interested in the theme or activities, the research team designed the second curriculum for motivation in learning. Then, Joseph and her research team created a design theory (the Interest-Driven Learning (IDL) framework) based on their findings from the first curriculum as well as relevant literature, and tested out the theory's ability to predict and explain motivation with a new group of elementary students.

A new theme was chosen for the second curriculum, this time based on surveys of children's interests and observations about how students choose activities. Further, motivation profiles were developed for each of the students to predict engagement with various curriculum features. While enacting the second curriculum, the team found that students were passionate about either video making, featuring aspects of themselves in videos, or social interaction. However the students grappled with project issues in similar ways, despite their motivational profiles. While the second curriculum met the desired design aims, there were still challenges. However, because of the methodological rigor undertaken through all phases of design, Joseph was able to provide multiple, informed implications for the work and future directions.

Outcomes & Future Directions

Design studies are ultimately intended to be practical endeavors producing usable knowledge that provide solutions to educational problems experienced by teachers and learners (Kelly, 2004). Therefore, Edelson (2002) argues that three outcomes of DBR should be the generation of theory, design framework, and design methodology. This discussion will devote special attention to the usability of design study outcomes. Furthermore, while DBR studies design for effective learning environments, success was not always an outcome of a given design (e.g., Squire et al., 2003). This left researchers with a great responsibility to provide a rationale and suggest future directions. For this reason, a discussion of both outcomes and future directions follows.

Usable knowledge abounds within design studies, ultimately reinforcing the pragmatic nature of DBR. Design study outcomes led to construction of effective curriculum materials (Joseph, 2004; Songer, 2006), design frameworks (Hjalmarson &

Diefes-Dux, 2008), and data-driven theory (Brown & Edelson, 2003; Confrey & Lachance, 2000). For example, based on findings of teachers' adaptation, offloading, and improvisation of designed instructional materials, Brown and Edelson (2003) devised the notion of *pedagogical design capacity* to describe a teacher's ability to utilize preexisting curricular materials to design effective learning environments. From this, a loose set of PD guidelines was produced to best support teachers' ability as curriculum designers.

Moreover, Confrey and Lachance (2000) developed a model for approaching mathematical concepts (e.g., multiplication, division, fractions, geometry) through the splitting conjecture and aligned modeling activities in the curriculum with theory. Their work yielded innovative mathematics curriculum material supporting students' development of mathematical reasoning. Lastly, findings from the examination of mathematics teachers' design and use of tools supporting model-eliciting activities by Hjalmarson and Diefes-Dux (2008) resulted in a framework elucidating teachers' purposes for tool construction and use. However, as mentioned earlier, the designed interventions were not always successful at producing desired outcomes. In both cases of lackluster performance, such outcomes were attributable to the absence of student voice in curriculum design (Joseph, 2004; Squire et al., 2003) as well as insufficient connection between theory and original design (Joseph, 2004).

For instance, findings from the study by Squire et al. (2003) exploring teachers' use of a curriculum in various contexts indicated that learners did not perceive the curriculum's over-arching question to be relevant, were unable to detect project goals, and chose to explore only the challenge questions they found personally meaningful.

Additionally, findings demonstrated that regardless of curriculum design, teachers adapted instructional materials according to their pedagogical beliefs, the classroom culture, and student interest.

The authors ultimately contended that curriculum adaptation is mediated by context, student, and teacher needs. The researchers then speculated on future directions. First, future curriculum materials need to be designed with students' goals and teachers' strengths in mind. Moreover, the designers' role should be more indirect, providing adequate voices for teachers as well as educational innovations that are adaptive to local needs/constraints, while offering support for teachers as design decisions are developed.

DBR is an emerging paradigm that aims to address educational problems and produce usable knowledge through the design, implementation, and refinement of educational innovations. Guided by theory-driven conjectures, design studies are responsible for generating design frameworks, methodologies, and advancing theory that ultimately enables innovations to be adopted by others and adapted to new contexts. This dissertation study aims to utilize a DBR approach to design, implement, and refine the STARTS PD framework through findings yielded from concurrent data collection and analysis.

Extending the Fields of PD in Science Education and CRP Science

The STARTS PD program is research grounded and features several hallmarks of high quality PD experiences aimed at developing teachers' CRP Science knowledge and practices. In this section, I will elucidate the various ways in which the STARTS program and dissertation research agenda extend the current work in PD in science education and CRP Science. Specifically, I will present examples of how this dissertation extends empirical literature on (a) PD in science education for instructional material design reform; (b) PD for CRP Science; and (c) DBR exploring PD for the design of instructional materials.

PD for Supporting the Design of Instructional Materials

Jackson and Ash (2012) reported the results of a three-year PD initiative implemented in two low-performing majority minority elementary schools in Texas. The intervention was designed to support elementary teachers in the purposeful planning of inquiry science instruction highly aligned to state standards. Additionally, there was heavy emphasis on creating multi-sensory word walls as a targeted approach to increasing the science achievement and language development of ELL students.

As teachers worked in grade level teams, they studied science standards and purposefully planned 5-E instruction (Bybee et al., 2006) around those standards to increase reform-based science teaching. As teachers engaged in purposeful planning, they focused specifically on state standards and district-mandated guidelines. Additionally, teachers were given time to interact with the science content vertically (across K-5 grades) to identify what they should already know by the time students enter their classrooms.

Because the authors were looking specifically to connect PD experiences with student outcomes, they analyzed the state science assessment scores for all 5th grade students at the two schools where this school-wide intervention occurred. Although there was a ceiling effect for White students at one school (i.e., no statistically significant room for improvement), the remainder of the difference-in-proportions analyses indicated a significant increase in the passing rate of students over the course of the intervention. Overall results showed improved science learning outcomes and narrowed achievement gaps among ethnically diverse groups of students.

When exploring the impact of the PD on teachers' practices, the authors reported results of teacher-completed surveys. Teachers indicated that purposeful lesson planning helped them vertically align their science instruction, K-5, as well as initiate a common science instruction planning time that has been sustained. Additionally, teachers began to utilize more science language development strategies in their classrooms, such as interactive word walls and inquiry-based instruction.

According to Jackson and Ash (2012), teachers cited the most effective PD activities as "opportunities to exchange ideas, 5-E lesson plans that they could use as examples to write their own lessons, and alignment of instruction with grade level [state standards]" (739). This study was one of the first to link underrepresented students' science achievement to teachers' PD experiences through teacher-created instructional materials that incorporated students' linguistic needs. Furthermore, by explicating purposeful planning activities, Jackson and Ash provided specific guidelines for implementing this form of PD in new settings.

Jackson and Ash (2012) described the primary goal of this PD venture as ensuring that "every aspect of instruction was aligned to the TEKS [Texas state science education standards] with fidelity" (p.726). While the STARTS PD program did not share this goal as its primary emphasis, it would be counterproductive to design and implement a PD program that does not take into account the realities of today's science classrooms. Thus, several of Jackson and Ash's PD features were present within the STARTS PD program. Specifically, STARTS teachers examined state and national science education standards to discern their intent when designing reform-based science instruction. Teachers also reviewed the lessons they designed for the CRP Science units to identify the degree to which they aligned to state and national standards. Moreover, the STARTS PD program extended the PD initiative presented by Jackson & Ash (2012) in its approach to support students' science language development through the use of the *Growing Awareness Inventory* (GAIn) (Brown & Crippen, in review) and CRP Science instruction, which may include interactive word walls. However, an emphasis of the STARTS PD program was bridging the disconnect between students' home lives and their school lives, as opposed to force-fitting instructional strategies that are designed specifically with "teaching to the test" in mind. Furthermore, teachers' changing knowledge and practices were documented in this dissertation in a much more rigorous manner than self-reports alone. Rich data sources such as repeated classroom observations, multiple STARTS PD program artifacts, and group interview transcripts were utilized as the basis for claims about STARTS participating teachers' CRP Science knowledge and practices.

PD for CRP Science

The empirical literature on PD for CRP Science is limited. Of those, few articles explicate the structure required to effectively implement PD with such a focus. In this article, Zozakiewicz and Rodriguez (2007) present findings from their three-year Project Maxima initiative. The Maxima intervention was built from sociotransformative constructivist principles (Rodriguez, 1998) and designed to support fourth- through sixth-grade teachers in establishing more inquiry-based, culturally relevant, and gender-inclusive science instruction. The authors modeled CRP Science and invited critique of their practices as a way to assist teachers in establishing culturally relevant classroom environments. Structured reflection times were planned during monthly meetings and summer institutes where participants and authors discussed how modeled activities were multicultural and gender inclusive. Participants were also asked how they might further modify such activities to fit a particular grade level and context. Additionally, the research team made themselves available to teachers as they struggled with implementation, providing both ongoing support and the use of science equipment. Participants reported that modeling CRP Science was one of the most influential factors affecting their practice. Additionally, teachers viewed ongoing support as a valuable resource as they began teaching in reform-oriented ways and with new instructional materials. The authors noted that, despite Maxima's successes, they still encountered teacher resistance.

To challenge entrenched teaching practices and advance CRP Science, Zozakiewicz & Rodriguez (2007) suggest, "making teaching for diversity a central construct in teacher professional development" (p. 422). Effective PD structures – such as modeling innovative pedagogies, critical exploration, and ongoing support – were featured in the STARTS PD program, as it is clear from the paucity of CRP Science instructional materials that this form of instruction must be modeled, openly practiced, and constructively critiqued by STARTS participating teachers.

The authors noted that, despite Maxima's successes, they still encountered teacher resistance. However, they omitted any discussion about teachers' reasons for resisting the reform message or what actions were taken to directly address this resistance. The STARTS program will further expand on this study by identifying and challenging teachers' resistance during program implementation, as well as pinpointing salient PD features supporting teachers as they encounter such challenges.

DBR of PD for Supporting Curriculum Design

In this DBR study, Stolk et al. (2011) involved teachers in designing context-based science curriculum materials. The overarching research goal was to use existing theory on how teachers internalize actions to investigate the effectiveness of their designed PD model. Specifically, the authors were interested in investigating "how to elaborate the framework into a PD programme, and to acquire insight into the contribution of the programme activities to the process of professional development" (p.374).

Stolk et al. refined their existing PD framework by first identifying, and then designing for specific cognitive and affective goals, which they based on the internalization of actions theory (Galperin, 1992). Furthermore, the authors made explicit their theory-guided expectations for the function of the PD program, from which they subsequently derived hypotheses. Stolk et al. (2011) contend that these expectation-driven hypotheses should enable researchers to observe where the actual PD trajectory deviates from what's expected and to feed directly into framework design.

During the PD program, participating teachers first learned about an example context-based science unit, including its underlying general model. The researchers led participants through the actual unit, where teachers participated as students would. Then, each teacher enacted this educative context-based science unit in their classrooms. Based on their experiences, participants reflected on their teaching experiences during the lesson. Finally, teachers then designed an outline for a new context-based science unit.

Findings indicated that, although all teachers successfully taught the first unit, they experienced difficulties when applying the same teaching strategies to new situations. Therefore, teachers did not apply the context-based unit-design model while constructing their outlines. They also reported difficulties motivating students, as the content was not deemed as relevant to students as expected, nor did it provide students with the proper scaffolding to make deep conceptual connections. Furthermore, although not specifically addressed, it was noted that several participants engaged in what Gregoire (2003) would consider *heuristic processing*, with teachers refusing to engage with the reform challenge.

While elements of DBR were present in this study (e.g., elucidating design framework from existing literature; connecting conjectures to expectations for learning outcomes), missing was an in-depth discussion of the ways in which findings were applied to model revision. For example, implications were vague, and did not seem to reflect this specific design ("in designing an outline of a new context-based unit, teachers should have access to more resources other than a well-known chapter from a textbook" (p.385)). This dissertation study expands on Stolk et al.'s (2011) DBR study by clearly articulating the ways in which methodological rigor was established throughout all phases of design and refinement, as well as generating an in-depth design framework and local theory on teachers' progressions as CRP Science teachers and designers of CRP Science instructional materials.

Remarks

The literature on PD for CRP Science is scarce. Of such studies, the focus is often on teachers' perceptions of the value of the program. There is a lack of connection to instructional material design and student outcomes. When PD does focus on the design of instructional materials, it is often solely on promoting inquiry-based instruction or alignment with state and national standards. Moreover, the same can be said of in-depth DBR studies on PD in science education. Yet, to establish both local impact (through effective intervention design) and general relevance (through local theory generation), research on PD for CRP Science must attend to all of these challenges. Hence, this dissertation study expands on the existing empirical literature in several ways. The purpose of this dissertation was to produce local impact and general relevance by: (1) characterizing the progression of culturally responsive knowledge and practices in a group of six high school life science teachers who engaged in the STARTS PD program, thereby describing their journey as CRP Science educators and constructors of culturally responsive, academically rigorous instructional materials; (2) identifying STARTS design elements associated with supporting the professional growth of these teachers; and (3) generating local theory, a design framework, and set of accompanying design principles based on these findings.

Summary

High-quality PD in science education has made prominent the need to prepare science teachers capable of educating students through research-based conceptions of science teaching. PD ventures have positively impacted teachers' inquiry-based practices and have begun to connect PD programs with student achievement. On a much smaller scale, PD initiatives have also focused on preparing science teachers to provide students with equitable learning opportunities through culturally sensitive instruction. Yet, much work in the area of PD for CRP Science still remains. Academically challenging curriculum materials must be created; teachers must develop a set of knowledge, skills, dispositions, and practices associated with both scientific inquiry and CRP Science; and programs need to be directly linked with student achievement.

The STARTS PD program utilized research grounded supports to guide science teachers' personal, social, and professional development through ongoing, job-embedded experiences. STARTS teachers participated in a modified lesson study as they learned to examine the impact of their practices on student outcomes. They critically reflected on multiple aspects of their practice over time and analyzed student data when making pedagogical design decisions. Ultimately, empowering STARTS teachers as creators of CRP Science instructional materials in PLCs is intended to sustain the positive impacts of this PD for CRP Science. This dissertation and the STARTS program contribute to the research and development base in the growing field of CRP Science.

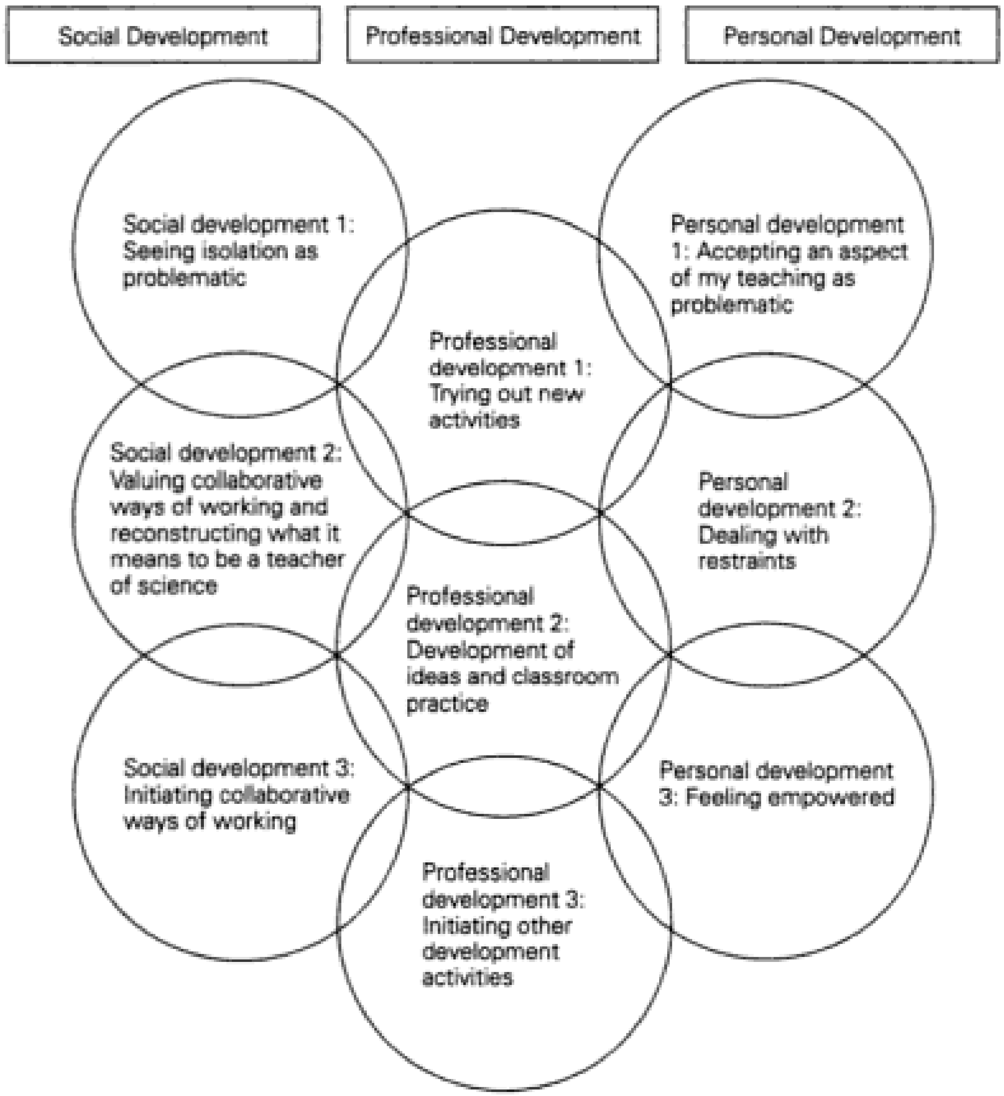


Figure 2-1. The model of teacher development
Reprinted by permission from Bell, B., & Gilbert, J. (1994). Teacher development as professional, personal, and social development (Page 485, Figure 1). *Teaching & Teacher Education*, 10(5), 483-497.

CHAPTER 3
RESEARCH METHODS

Overview

The STARTS (Science Teachers Are Responsive To Students) professional development (PD) program was designed to prepare culturally responsive, reform-based high school life science teachers who create and implement novel CRP Science (culturally responsive pedagogies in science education) instructional materials. Although the STARTS program provided a research grounded PD experience for science teachers, it was above all else a design-based research (DBR) endeavor. Characteristic of other DBR studies, this dissertation study was primarily concerned with describing a designed intervention, associated learning progressions, and the mechanisms undergirding these progressions (Barab, 2006; Confrey & Lachance, 2000; Edelson, 2002; Kelly, 2004; Shavelson & Towne, 2002).

Specifically, this qualitative study utilized grounded theory analysis (Charmaz, 2006; Strauss & Corbin, 1998), typological analysis (Hatch, 2002), and matrix analysis (Averill, 2002; Miles & Huberman, 1994). These methods were used to (1) explore potential relationships between teachers' participation in the STARTS PD program and changes in their CRP Science knowledge and practices over time; (2) discern in what ways, specifically, STARTS PD features supported this professional growth; (3) construct a grounded theory of high school life science teachers’ progression as CRP Science educators; and (4) present an empirically grounded design framework and principles to guide the design of PD of this magnitude.

To this end, the following questions framed the study:

1. For high school life science teachers participating in an explicit PD program on CRP Science, what defines the process of becoming culturally responsive educators?

   a. As teachers participate in the STARTS program, how does their CRP Science knowledge progress over time?

   b. As teachers participate in the STARTS program, how do their CRP Science practices change over time?

2. What features of the STARTS design framework can be associated with supporting the changes in CRP Science knowledge and practices of high school life science teachers?

Prior to elucidating the research design for this study, I will first present the STARTS PD program as a research-grounded intervention. Following the intervention explication, I discuss the study design, including the setting, participants and selection procedures in detail. The processes of data collection and analysis will then be articulated. The chapter concludes with a discussion of the evaluation criteria that were employed to establish trustworthiness. In the following section I describe the STARTS PD program according to its central mission, overarching features, further theoretical grounding, and major activities.

The STARTS PD Program

Central Mission and Overarching Features

The STARTS PD program was designed for use with high school life science teachers working in five ethnically and linguistically diverse public schools throughout a large school district in the Southeastern United States. The overall aim of STARTS was to prepare high school life science teachers working in these diverse schools to best meet their students' academic needs through culturally responsive, inquiry-based science instruction. To accomplish this goal, the program was grounded in multiple bodies of research including: effective PD methods for CRP Science (Johnson, 2011; Zozakiewicz & Rodriguez, 2007), inquiry-based science instruction (Capps et al., 2012; Loucks-Horsley et al., 2010), and online teacher PD (Dede, 2006); teacher change via PD experiences (Bell & Gilbert, 1994; 1996); and supporting teachers as instructional designers (Parke & Coble, 1997; Stolk et al., 2011). Aimed at increasing science teacher efficacy on multiple levels, the STARTS program offers practicality as it features dual emphasis on developing pedagogical knowledge and content knowledge (Crippen et al., 2010). STARTS was situated within district-implemented pacing guides and was designed to empower teachers by providing them with the proper tools and support to continually integrate their innovative instructional materials with existing textbooks and educational resources.

The STARTS PD program was based upon the premise that through job-embedded, ongoing PD that is responsive and contains a dual-focus on science content and pedagogy, teachers' knowledge and practices will be transformed, specifically into a more culturally responsive, inquiry-based form. Furthermore, central to the STARTS program design was the argument that teachers of culturally and linguistically diverse students must be aware of the influence of culture on learning (Aikenhead & Jegede, 1999; Emdin, 2011), their beliefs about students and science teaching, the political nature of schooling (Darling-Hammond, 2010; Jackson, 2009), the importance of relationship-building between teachers and students (Hondo et al., 2008; Valenzuela, 2005), and effective subject-specific CRP strategies (Brown, 2013). Hence, building responsive classroom environments, connecting students' backgrounds with science instruction, and enhancing culturally congruent discourse were among program foci. To further situate CRP Science within existing classroom practices, the use of several reform-based science practices such as asking questions, analyzing and interpreting data, constructing explanations from evidence, and communicating scientific information (NRC, 2012), were also features of the program.

Further Theoretical Grounding

In addition to the extensive theoretical grounding presented in Chapter 2, the literature-based rationale behind additional STARTS PD features deserves attention. In this section, the job-embedded, web-supported, and responsive nature of the STARTS program is justified.

Job-embedded professional learning

Job-embedded PD improves teaching and learning by grounding learning tasks directly in teachers' daily practices (Croft, Coggshall, Dolan, Powers, & Killion, 2010; Putnam & Borko, 2000). Additionally, job-embedded approaches promote reflective practitioners who, through the careful analysis of student data, can offer informed solutions to specific problems of practice. Unlike more traditional forms of PD, job-embedded tasks are knowledge-centered, learner-centered, assessment-centered, and community-centered. In other words, job-embedded PD is discipline-specific as opposed to providing general pedagogical knowledge (knowledge-centered), personalized for teachers' needs (learner-centered), allows teachers to receive feedback on new approaches (assessment-centered), and occurs in collaborative environments (community-centered) (Coggshall, Rasmussen, Colton, Milton, & Jacques, 2012). One particular form of job-embedded PD contained within the STARTS program is lesson study (Loucks-Horsley et al., 2010).

Web supported

Online teacher professional development (oTPD) programs ease burdens commonly associated with traditional PD ventures such as limited time to implement reform pedagogies, lack of ongoing support, and disconnect from daily practice (Dede, Ketelhut, Whitehouse, Breit, & McCloskey, 2009). Since their inception, oTPD programs have been used to introduce new curricula, enhance relationships between school and community, and alter teachers' beliefs and instructional practices (Dede et al., 2009; Whitehouse, Breit, McCloskey, Ketelhut, & Dede, 2006). In the case of science education in particular, oTPD has been successfully used to enhance science teachers' subject matter knowledge, instructional practice, and attention to students' ideas (Doubler & Paget, 2006) as well as facilitate participant discussion (Luft, 2001), manage participant materials (Crippen, 2012), and support communication through videoconference (Crippen et al., 2010).

Like any other PD venture, oTPD program elements should be driven by specific goals and purposes (Dede, 2006; Loucks-Horsley et al., 2010). The STARTS program utilized specific oTPD features in combination with face-to-face learning opportunities that created a coherent PD experience and further connected content with teachers' practices. Specifically, STARTS teachers enrolled in a six-month-long PD course in which they shared lesson study products, completed Professional Growth tasks, and participated in a professional network to expand their culturally responsive and reform-based pedagogies in a variety of ways (Loucks-Horsley et al., 2010).

Responsive to students and teachers

Aligned with guiding principles of CRP (Gay, 2010; Ladson Billings, 1995; Villegas & Lucas, 2002), the STARTS program employed an asset-based orientation of teachers and students. STARTS was designed to continually uncover and incorporate teacher voice throughout the PD program. For example, participating teachers completed a survey in which they identified their initial professional needs and beliefs about science teaching and learning. Findings from the survey were directly integrated into the PD design to both acknowledge the constraints teachers experience and to build on their strengths.

During the first face-to-face Saturday Collaboration Session, teachers also generated ideas about CRP and reform-based science teaching practices they were already implementing through a self-assessment survey and small group discussions. This approach valued teachers as professionals and recognized the strengths they already possessed, unlike many multicultural teacher education programs (Furman, 2008; Mensah, 2011). Additionally, teachers continually used the CRIOP self-assessment (Mallory & Saccysyn, 2012) as a guide to discern aspects of their practice needing improvement, rather than simply receiving feedback from this researcher.

Recognizing the myriad restraints imposed on science teachers, the STARTS program was designed to be cognizant of district mandated pacing guides, state and national standards, required textbooks, and biology End of Course exams. These contextual factors were accounted for when designing PD experiences that increased teachers’ content knowledge, pedagogical knowledge, and supported them as designers of CRP Science instructional materials (Loucks-Horsley et al., 2010). Teacher voice weighed heavily in decisions over which core science ideas and crosscutting concepts to focus on throughout the program.

To promote CRP Science and student responsiveness, teachers completed a series of *Growing Awareness Inventory* (GAIn) tasks (Brown & Crippen, in review). The purpose of the GAIn was to develop cultural responsiveness in teachers through the completion of specific tasks that are student-centered and aligned with key tenets of CRP (Gay, 2010; Ladson-Billings, 1995; Powell et al., 2011; Villegas & Lucas, 2002). The GAIn tasks structured the integration of students' backgrounds into science instruction, thereby scaffolding teachers' design of CRP Science instructional materials. Additionally, while participating in STARTS, teachers focused in on their students at two levels. The first level of focus was classroom-specific. Teachers were asked to select one of their class periods to follow throughout the program. It was expected that teachers would connect instructional decisions and insights to interactions and outcomes in this classroom. The second level of focus was student-specific. Within the selected classroom, teachers were asked to choose 4-5 "focus group" students to follow closely. Analyses on and input from these students were used to gauge the effectiveness of the lesson study research lesson, to hone in on during the GAIn tasks, and to connect data analysis and resulting suggestions with instruction. The selections were up to the teacher and included choosing students who had "promise," students who were more eager to communicate with the teacher, and students who were disengaged.

STARTS Program Activities

As an ongoing, job-embedded PD program, STARTS provided participating teachers with multiple opportunities to enact and reflect on CRP Science in their daily practices (Coggshall, et al., 2012; Desimone, 2009). As teachers learned reform-based, CRP Science knowledge and practices, their professional growth was supported in a blended environment. Ongoing support occurred face-to-face in regular Saturday Collaboration Sessions as well as in online environments (Dede, 2006; Loucks-Horsley et al., 2010). Teachers engaged in six major activities during STARTS: lesson study, *Curriculum Topic Study*, GAIn tasks, *Professional Growth* tasks, CRP Science unit construction, and Saturday Collaboration Sessions. Each activity will be detailed according to its ability to facilitate the STARTS PD program goals. A timeline of the program is presented in Figure 3-1.

Lesson study

Learning how to teach requires practice and study. As teachers design, enact, and subsequently analyze lessons, their teaching will likely improve. However, this is dependent upon several factors, including careful observation of effective elements and critical reflection on strategies needing improvement. Lesson study fosters teacher growth through collaboration in professional learning communities (PLCs) where developing knowledge for teaching is a major focus (Shimizu, 2002). Originating in Japan as an innovative PD approach (Isoda, 2010), a major focus of lesson study is the development of research lessons intended to meet specific student learning goals. As a result, lesson study features teachers working collaboratively to identify target goals for student learning and to construct corresponding high-quality lessons. Teachers participating in PLCs engage in a cycle of reflective practice with the aim of constructing, analyzing, and revising a research lesson (Loucks-Horsley et al., 2010). Long-term student learning goals based on a specific theme are identified; lessons aligned with these goals are devised and implemented while team members observe and collect data on student learning. Finally, debriefing and revision based on analysis and feedback occurs (Lewis et al., 2006; Mutch-Jones, Puttick, & Minner, 2012;

Shimizu, 2002).

The structure of lesson study offers opportunities to improve teachers' practices, thereby developing them further as professionals. Components critical to teachers' development are lesson enactment, reflection, and refinement. As colleagues observe teachers implementing a "research lesson" (Lewis et al., 2006, p.3) they experience the lesson as learners would. Due to the collaborative nature of lesson study, teachers are able to discuss lesson content and confusions first hand as they refine instruction (Mutch-Jones et al., 2012). Furthermore, through critical reflection and analysis, teachers better comprehend how and why lesson elements promoted student learning, thus increasing their pedagogical design capacity.

Lesson study was the first major activity teachers engaged in during the STARTS program. The lesson study cycle was intended to help teachers begin to learn about their students' learning needs, reflect on the impact of their practice on student outcomes, and identify areas for professional growth that may not have been previously articulated. During this modified lesson study cycle, teachers worked in pairs to first identify one class period apiece to focus on. They then identified target student outcomes, and constructed a science lesson intended to address learning goals specifically for their classes. Because teacher pairs often taught at different schools, each teacher then video-recorded the lesson, focusing closely on a group of 3-4 students who were of special interest to the teacher. Teachers then observed one another's recordings and provided feedback through the use of a structured feedback guide that was managed in the STARTS online course system. To complete the lesson study cycle, teachers met face-to-face during the second Saturday Collaboration

Session, debriefed the entire process, and brainstormed ideas for lesson redesign based on findings.

***Growing Awareness Inventory* (GAIn) tasks**

The GAIn tasks are a series of three reflective practice protocols that provide STARTS teachers with structured support as they learn to identify and meaningfully incorporate students' cultural and linguistic backgrounds into reform-based science instruction (Brown & Crippen, in review). The GAIn has been designed to develop the abilities of CRP Science teachers as they complete specific tasks, each of which are student-centered and aligned with key tenets of culturally responsive pedagogy (CRP), such as affirming students' backgrounds, sociocultural awareness, and building a community of learners (Gay, 2010; Ladson-Billings, 1995; Villegas & Lucas, 2002). The GAIn tasks were intended to transition teachers from first exploring their practice from a classroom-centered perspective to connecting instruction to beyond-the-classroom factors (i.e., students' home lives). For example, the first GAIn task focused on information teachers learned about their students' needs during class time. In the final GAIn task, this focus moved to learning about students' needs outside of the classroom and school. The GAIn tasks were designed to help STARTS teachers critically examine the implicit messages conveyed by their classroom environments, relationships between teacher and students, students' preferred communication patterns, and to allow them to speculate on ways to incorporate CRP Science into classroom instruction. The GAIn tasks also served as the primary structure for organizing information that was learned about students that would then be integrated into the capstone project, the CRP Science unit.

Through the GAIn tasks, STARTS teachers were expected to gain experience connecting students' backgrounds and interests to reform-based instructional strategies and assessment practices that build on these strengths. Though the GAIn does not represent an exhaustive picture of CRP Science, it provides a starting point for teachers to more deeply understand students' cultural backgrounds and connect this knowledge to instruction in meaningful ways, which is uncharacteristic of traditional science classrooms (Martin, Mullis, Gonzalez, & Chrostowski, 2004).

In a previous study exploring the impact of GAIn tasks on secondary mathematics and science preservice teachers' (PSTs) lesson planning for CRP, Brown and Crippen (in review) found that facilitating PSTs' awareness of, and eventual lesson planning for, effective mathematics and science pedagogy requires: critically reflecting on field experiences, collaborating with PSTs across disciplines to design lessons, directly connecting these lesson plans to course teachings and structured observation findings, and evaluating lesson impact according to specific student outcomes. Further, the authors identified distinct forms of reflection that best support PSTs through each of the processes. These findings were then developed into a domain-level theory of action (Figure 3-2). For example, during the Observation process (Reflection-A), PSTs identify resources in cooperating teachers' classrooms that are reflective of and/or could be translated into CRP-based science and mathematics instruction. While completing the GAIn task (prior to Collaboration), PSTs reflect on interactions between students and the cooperating teacher and speculate on potential CRP connections, as well as ideas for student-centered instruction. The GAIn tasks were then redesigned to reflect these findings. During the STARTS program, teachers completed the second iteration of GAIn protocols.

Curriculum Topic Study

When practitioners engage in *Curriculum Topic Study* (CTS) (Keeley, 2005) they do just that, study a science curriculum topic. The CTS process is systematic and in-depth, utilizing a set of resources and strategies designed to bridge research and practice in ways that improve science teaching and learning (Keeley, 2005). The teacher identifies a science topic (e.g., cells; rocks and minerals) and a CTS guide then identifies readings that support teachers' development of knowledge on the topic (e.g., *Benchmarks for Science Literacy*, American Association for the Advancement of Science [AAAS], 1993; *Science for all Americans*, AAAS, 1990). The six sections being developed include: (1) identifying adult content knowledge, (2) considering instructional implications, (3) identifying concepts and specific ideas, (4) examining research on student learning, (5) examining coherency and articulation, and (6) clarifying state standards and district curriculum (Keeley, 2005, p.20). Through CTS, teachers focus on their science content knowledge, explore research on students' conceptions of the topic, examine effective instructional strategies, and align this to science education standards, which are essential to promoting student learning (Borko, 2004; Bransford, Brown & Cocking, 2000).

CTS provides structure and guidance for teachers to explore core science ideas and the progression of crosscutting concepts, better preparing them to engage students in authentic inquiry experiences that replicate science practices. Furthermore, CTS provides teachers with resources to learn about research on student learning. Educative materials such as the CTS enable teachers to learn about and participate in the practices of science. Such scaffolds are necessary, given that many science teachers have never been involved in authentic inquiry throughout their formal schooling experiences (Barnes & Barnes, 2005). During the STARTS program, teachers collaboratively conducted a CTS for the specific science topic featured in their innovative, culturally responsive science unit.

STARTS teachers worked in teams to conduct a CTS as a way to foster reform-based science teaching by deepening their knowledge of the science content to be featured in their CRP Science unit. They also examined research on student learning and suggested instructional strategies for their topic, explored the progression of crosscutting concepts for this topic, elucidated relevant state and national science education standards, and provided a structured way to support the design of their CRP Science units. The resulting document became the foundation for the reform-based science portion of teachers' CRP Science units and was later integrated with GAIn findings, which formed the culturally responsive portion of the unit. Adamson, Santau, and Lee (2013) argue that "to effectively teach science, teachers must not only master science content, but also be familiar with how students learn science" (p. 556). By engaging in CTS, teachers can accomplish both of these goals.

Professional Growth tasks

Professional Growth (PG) tasks arose out of the need for PD programs to continually be responsive to teachers' needs and to connect to their daily practices. The PG tasks began about halfway through the STARTS program as a result of emergent findings, including new professional goals articulated by teachers, as well as trends from classroom observations. The teachers selected three topics on which they wanted to learn more (e.g., making student thinking visible, effective collaboration/student grouping, and connecting families & science). To further assist STARTS teachers in achieving their professional goals, the PG tasks prompted teachers to identify key features of effective CRP Science and reform-based science practices (from the literature, through video recordings of STARTS teachers exemplifying a practice, or by analyzing sample lesson plans), and then considering how to modify and apply these practices for their classroom contexts.

Certain PG tasks were designed to increase teachers' use of discourse-fostering and assessment strategies in the classroom, as these became areas of professional growth identified by teachers. For example, in the *Making Student Thinking Visible* PG task, teachers were asked to consider how questioning techniques could be used as a way to elucidate students' understandings of science concepts during whole-class discussion. They then watched a video clip of a STARTS teacher executing these strategies with her biology students, speculated on ways to increase the use of similar questions in their classroom, and made an action plan for this.

Saturday Collaboration Sessions

The Saturday Collaboration Sessions became the primary forum for collective participation. Teachers met monthly in these face-to-face, all day Saturday Collaboration Sessions where they brainstormed lesson ideas, completed major tasks, voiced concerns, and designed innovative instruction. The Saturday Collaboration Sessions were also a time for the researcher, and, eventually, STARTS teachers, to model reform-based, CRP Science instructional strategies. The collective participation of teachers from similar subject areas, schools, and/or grade levels is fundamental to fostering professional growth. Through collective participation, teachers collaborate with one another in a meaningful way in PLCs. According to Cochran-Smith and Lytle

(1999), PLCs provide a learning environment in which teachers work together to "identify discrepancies between theories and practices, challenge common routines, draw on the work of others for generative frameworks, and attempt to make visible much of that which is taken for granted about teaching and learning" (p.293).

In the PD literature, researchers often participated in PLCs to probe further about teachers' changing practices and beliefs (Zozakiewicz & Rodriguez, 2007), address specific issues voiced by teachers (Bell & Gilbert, 1994) introduce and model new activities (Lee, 2004; Luft, 2001), and discuss instruction progression and student learning (Davis & Varma, 2008). The collective participation of teachers in PLCs occurred across grade levels, within-and among- schools in a particular district (Garet et al., 2001). In addition to voicing concerns and brainstorming innovative approaches to science instruction, teachers used PLCs as a space to align their teaching philosophies with current research (Parke & Coble, 1997), analyze problem-based, inquiry lessons (Crippen, 2012; Parke & Coble, 1997), and share best practices (Crippen et al., 2010, Lee, 2004). During the STARTS PD program teachers and the researcher met in a PLC for all of the purposes cited above.

CRP Science units

As the capstone project of STARTS, the CRP Science units were intended to bridge together science content and students' interests and learning needs, thereby creating meaningful and challenging science instruction that is truly student-centered. Teachers were assisted through the process of creating their CRP Science units in multiple ways. First, as part of each major activity (e.g., lesson study, CTS, GAIn and PG tasks), teachers were provided with a series of scaffolds leading them to reflect on salient elements of each task and their current practices, enabling them to speculate on ways to connect what was learned to instruction, and then allowing them to implement trial lessons utilizing their suggested connections. Second, teachers worked collaboratively in both face-to-face and online environments to brainstorm potential connections and instructional strategies. Finally, teachers voiced their interest in learning more about specific topics (e.g., effective collaboration in the science classroom, making student thinking visible). These topics were included in the STARTS program with specific tasks designed to support teachers in learning about research-based strategies, critically observing their colleagues practicing these strategies, and then speculating on potential connections to their CRP Science unit.

The STARTS program contained many hallmarks of high-quality PD. To support science teachers' content knowledge and reform-based, CRP Science pedagogical knowledge, participating teachers engaged in six major activities over the course of several months. The next section explains the research design utilized to examine teachers' progression as CRP Science teachers, and the salient features of the STARTS framework capable of supporting this professional growth.

Research Design

This dissertation study produces both local impact and general relevance through the generation of a research-grounded design framework, a set of accompanying design principles, and local theory (Edelson, 2002). To understand the progression of high school life science teachers as teachers of CRP Science within the context of the STARTS PD program, the study applied a qualitative approach to address guiding research questions. Data were simultaneously collected and analyzed to provide a deeper understanding of the impact of the STARTS program on high school life science teachers' development as well as to explore PD framework elements supporting participants' professional growth and the ways in which these effective elements mediate teacher change. I begin the research design description with the rationale for selecting biology, and the life sciences more generally, as the subject area of interest.

Subject Area Selection

Students' disengagement in science begins in middle school (NRC, 2012; Riegle-Crumb, Moore, and Ramos-Wada, 2011), and solidifies during high school, when they are making concrete decisions about future career aspirations (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001). These aspirations are predictive of educational attainment, as adolescents' course and activity choices are guided by such desires (Bandura et al., 2001; Riegle-Crumb et al., 2011). Because enrollment in biology classes is often mandatory and occurs during this highly influential time period, efforts to enhance students' engagement with and achievement in science must begin here. Furthermore, because the biology classes in this Southeastern state contain a high stakes standardized exam, there are additional constraints and added stresses placed on both students and their teachers. Therefore, the high school life science disciplines were chosen because of the desire to enact effective PD experiences in the presence of such contextual factors.

Research Setting

The STARTS PD program took place in five diverse high schools in a large school district in the Southeastern United States (Table 3-1). The program was situated within a larger, district-funded STEM reform initiative which aimed to increase the rigor and accessibility of K-12 STEM education. The district student body is racially and linguistically diverse, with approximately the same percentage of Black, Hispanic, and White students (Hispanic, Black, and Other Race students are classified as "minority" by the district). One of the five high schools from this study mirrored the district's racial demographics, three schools enrolled greater than 75% racial minority students, and one school was predominantly White (Table 3-1). The three schools serving the largest minority student populations were also receiving Title I funds. Among all five high schools, an average of 65% of the student body had achieved proficiency on the state biology End of Course exam, which is required for graduation. To pass the exam, students must demonstrate proficiency by earning at least three out of five possible points. A score of four or five indicates mastery. On average, 12% of the entire student body from these five schools had achieved mastery.

Participant Selection

Six life science teachers from throughout these five high schools participated in the study. Participating teachers were purposefully selected because of their ability to contribute to theory development (Charmaz, 2006; Creswell, 1998). I began working with and recruiting the six participants from a total population (n=13) of life science teachers from this school district who participated in a separate weeklong, content-focused summer PD institute, the *Summer Science Institute* (SSI). Teachers from this particular district were of interest because of the larger STEM Initiative, through which the STARTS PD program was funded. During SSI, I presented an overview of the STARTS PD program to the life science teachers from the district. Institutional review board informed consent forms (Appendix B) were distributed to the total population. Six teachers gave their permission to participate in the STARTS PD program and the research study. When asked to explain their desire to participate in this program through an initial survey, teachers' responses ranged from general (i.e., the program would enhance their teaching abilities) to specific (i.e., they could develop strategies to incorporate students' cultures into science instruction).

Participant Descriptions

All teachers' names used in this study were self-selected pseudonyms, as were the names of their high schools. All participants were female, but represented various races and ethnicities as well as varied years of teaching experience (Table 3-2). During the study, the teachers all taught some form of high school life science subject, but ranged in the level (e.g., General, Honors) and focus (e.g., Biology with a concentration on English for Speakers of Other Languages [ESOL Biology]). In several cases participating teachers also taught additional subject areas at this time, but chose to focus on one particular class period. To best portray each teacher, excerpts from their autobiographies accompany my descriptions.

Christina Joy was a lively and charismatic teacher. A skilled teacher with 14 years of experience, Christina Joy was the only teacher who did not teach a biology course at the time of this study, though she had in the past and regularly mentored beginning biology teachers. Christina Joy taught zoology as well as anatomy and physiology for the medical magnet program. She was selected to serve as the district's Marzano (teacher accountability system) (Marzano, Pickering, & Pollock, 2001) liaison and was well-regarded in her school, where she also tutored students after hours. In fact, during one classroom visit, I met Christina Joy's principal who, when speaking of the Marzano system, told me that "she taught me everything I need to know" (personal conversation, 10/15/13). Christina Joy described herself as an over-achiever and was simultaneously pursuing a specialist's degree in educational leadership at the local university at the time of the study. Not long after the STARTS PD program concluded, Christina Joy received the district's award for educational excellence. Here is how Christina Joy described her K-12 schooling experience and how it impacted her as a teacher:

> When I reflect on my learning experience in Kindergarten through twelfth grade many things come to mind. First and foremost, something that should be divulged at the onset, is that I attended private, Christian schools my entire life until college. Overall, my experiences were positive and I would not change much if the opportunity existed to do so. Rules were present and followed, and I was not one to really test the waters in that area, for the most part anyway. I was never a rebel or one to go against the grain. I was a go-with-the-flow, conservative and polite student, always aiming to please the teacher. At the time, I never understood the rational {sic} for the kids who did not follow the rules and seemed to antagonize the "system" whenever possible. . . my teachers and educational experiences in K-12 have clearly defined who I am as a teacher today, as well as impacted my educational philosophy. I cherish those days; sometimes they feel like a lifetime ago and sometimes they feel like yesterday. Luckily, I get to carry the torch on in my own classroom, hoping to impact my students the way these teacher influenced me. (Autobiography, 9/13)

Claudia was a sweet, strong-willed teacher. She often spoke of how she was known through the district for her tendency to fight for teachers' rights and was even interviewed by the local news station to speak out on teacher accountability. In addition to her strong content knowledge, Claudia was fluent in both English and Spanish. As a result, she served as the biology teacher for ESOL students, teaching her biology classes in both languages. Claudia had been teaching for 22 years at the time of the study. She taught in both the United States and Costa Rica, where she lived for several years. During the STARTS PD program, Claudia lost several family members and close friends which took an obvious toll on her personally and professionally. Still, Claudia remained actively involved in the program. As a child and adolescent, Claudia moved frequently. She recounts this in her autobiography:

> I went to kinder garden in Nicaragua for a year, a private, catholic, girls school, i have very few memories about it. . . we moved to my mom's home town. . . in Costa Rica, and i went the another private, catholic school during first and second grade. . .Then we moved to San Jose. . . i also went to private catholic schools, only for girls, until 5th grade. . . In 6th grade, i went to another school, perhaps one of the best in the country. . . [after graduating from high school and university]… i applied for a teaching position at the British School of Costa Rica, was teaching 6th grade science in English and Spanish, 7-8-9-10 grade in English, and 11th grade biology in Spanish only. . . i was offered a job at the European school in Costa Rica, so i moved there, i was in charge of the whole science department, and i was very successful. . . [in 2001] i applied to come to work to USA on a program that they hire teachers from all over the world. . . I got a job at a middle school, a title one school. . . [in 2007] . . . i transferred to a high school [and] In 2009, the superintendent hired a new chief academic officer who changed the way schools system was, there was too many aggravations, harassment, and a hostile environment in the schools. . . i used to speak in front of the school board almost every month until, i was on the news, newspaper called me to interview me. . . i became an admiration for many parents and members of the community, for being a foreigner, a teacher and speaking on behalf of teachers and students. As I always began my speeches: "My name is [Claudia], i am here exercising the freedom of speech in order to defend the dignity of our profession and the education of our children." (Autobiography, 9/13)

Kate was a second-year teacher at the time she participated in the research study. Though she had the least experience of all STARTS participating teachers, it did not show. Kate consistently provided authentic and academically rigorous science experiences for her biology and anatomy and physiology students (I observed her teaching both subject areas). Kate was a friendly and reserved person who connected with several other STARTS teachers during the program. This was the first time Kate had ever taught anatomy and physiology, so she often found great value in her relationship with Christina Joy. Through STARTS, Kate consistently exhibited great insight about her practices and students' needs. Here Kate describes the influence of innovative teaching on her own science teaching style:

> The first class that comes to mind when I think of educational impact on me is my fourth and fifth grade gifted level class. The number of students involved in the gifted program around the county was low, so once a week we were all bused to one school for a few hours to go to “gifted class.” I remember a bit of pride and novelty of getting to ride a bus with only 6 of my best friends, to go to a class where a very small number of us got to work on advanced projects. . . I remember one day when our teacher taught us the fundamentals of algebra by moving manipulatives around the equal sign. It was so simple! After all that I had heard about how hard algebra was from my older sister in middle school, I was so shocked at how easy it was to understand. Looking back now, I see the positive results of inquiry-based learning. Once I understood this basic concept, it was so easy for me to add the little twists that came when I finally did take algebra later on. . . I think that the fact that I can’t remember much about my school experience is because in middle and high school, I just passively absorbed everything. I remember one day mindlessly copying vocabulary in my Biology class and thinking, “I don’t know what any of this means!” The things that I do remember are things that really challenged me or gave me an opportunity to step up and figure stuff out, especially when it was together with my friends. . . I teach my students how I enjoyed being taught, by utilizing small groups and inquiry or challenge-based lessons. (Autobiography, 9/13)

Lorelei, a biology teacher of 8 years, came into education after being a scientist. During the first interview she conceded, “My background was science; my major was in biology. I never had education classes so I was thrown into being a teacher. . . knowing the material but not necessarily knowing why I was teaching it a particular way” (Group interview 1). Like the other STARTS teachers, Lorelei was also an over-achiever. She often set extremely high personal and professional goals and worked tirelessly to achieve them. She often emphasized the meaningful, respectful relationships she was building with her Honors Biology students, and was sensitive to their need for perfection. Lorelei consistently provided her students with caring and challenging learning experiences.

> I can recall school days being a fun social event with learning sprinkled in. My parents owned a small wholesale distribution business during this time. I really appreciated the fact my parents had a flexible work schedule and could always be there, especially, to greet me after school with a

> snack; my favorite was apples with peanut butter. . . My favorite teacher was Ms. [favorite teacher] who I didn't have until high school. Ms. [favorite teacher] had the largest impact on my future decision to major in Biology. My dream of studying biology started at the young of 14 while attending [local] High School which was shortly after meeting Ms. [favorite teacher]. . . I could recall as a youngster always wanting the more challenging teacher because I knew I would learn more. . . To this day, I enjoy a challenge and always try to exceed expectations…I was happy to go along with what my teachers and parents asked of me. . . My class schedule only reflected advanced placement in science and math, not all subject areas so I was stuck in regular classes. School became mundane and I was rarely challenged. . . Throughout high school, I could not wait to go to college and begin my dream. I was in love with the idea of working in a lab all day and being surrounded by like-minded people. I continued to play soccer and pursued the sport intensely while playing on the [local high school] team, in a recreational league, and several invitation-only leagues as well (all stars & commissioner's cup events). I graduated top of my class and through dual enrollment received an early taste of what college would be like as a junior. (Autobiography, 9/13)

Natalie was an outgoing teacher who was very engaged in her school. Though she was teaching biology when I began working alongside her, Natalie had previously taught integrated science and environmental science. In addition to teaching biology, Natalie also coordinated the Student Government Association (SGA). She was often involved in organizing homecoming and fundraising events, accompanied students on SGA-related weekend trips, and frequently remained at work until 7pm. While participating in the STARTS PD program, Natalie was simultaneously pursuing an online graduate degree in educational leadership from the state's land-grant university. She was very accommodating to her students, often working one-on-one with them and speaking in English and Spanish to facilitate academic conversations.

Natalie and Lorelei taught at the same high school, where they collaborated with one another to devise activities and lessons. Natalie always had a penchant for teaching, which she explained in her autobiography:

> When I was just 4 years old, my single mother had to place me in day care in order to go to work. She needed to provide for my brother and I, and needed us to go to school. . . When I was in first grade, my older brother and I began riding the bus after school to a public, all-grades school where there was aftercare until 5 pm when my mother could pick us up… My mom always knew what kind of teachers I had because I would go home and act just like them when I was playing "school" . . . I attended a public middle school [that] fed into one of the worst high schools in [one] County at the time. My mother knew she could not afford to put us in private school, so we moved counties just before my brother reached 9th grade; I was in 8th grade. My mother always made our moves in the summer so we never had to switch schools mid-year. . . I entered 8th grade into a different public school in [another] County. This was a very different school than I was used to. I was one of the only Hispanic students in my classes. . . I joined SGA when I was a sophomore and that was it; I was hooked. I met my SGA advisor and created such a connection with her. . . She changed my life for the better. She brought out leadership qualities in me that I never knew I was capable. She molded me into the leader I am today. I graduated high school knowing that I wanted to be a high school teacher just like Mrs. [SGA advisor]. Here I am today, 10 years later, fulfilling my dream. Although this has been my dream, I never anticipated it being this difficult. (Autobiography, 9/13)

Zane had been teaching science in the United States since 2005, though she had previously taught and served as an educational leader in Haiti for seven years. Zane taught both general and advanced placement biology at the time that she participated in the study. She was very active in her church and connected with students and their families there. Zane was pursuing an online graduate degree in educational leadership while participating in STARTS, which she often cited as reason for her sporadic engagement with the PD program. She worked diligently to prepare instruction, creating new lessons when she already had existing materials. In her autobiography, she explained:

> I was born in Haiti and raised by my Grandmother who exposed me to literacy at an early age while she was reading her Bible. . . After high school, I entered college of education and started teaching at the same time as an elementary teacher. It was possible in my country considering the scarcity of human resources in the education field. After three years, I moved up to become a secondary teacher and I taught almost every

> branch of science. . . I left the classroom for four years to work as a manager of an education project that trained and supervised teachers in the Southwest area in Haiti. . . In August 2005, I got my first full time position as a middle school science teacher [in the United States]. I spent six years teaching middle school students and moved into High School in 2011 as a Biology Teacher. . . [this is] the first year I'm not teaching a ELL (English Language Learner) class. . . I'm a constant learner and my students play a major role shaping me as the teacher I am today. My students are my patrons. I work with and for my students. As a leader in the classroom, I listen to them. I pay attention to where they are, where they are expected to go. I promote mutual respect and collaboration among them and between us. . . My dream would be to have the opportunity to go back and help reform our school system in my [home] country. I would love to start somewhere and help one teacher at a time improve his/her professional practice. Until then, I'm striving to be the best teacher I can and have a life-long impact on my students. (Autobiography, 9/13)

Table 3-3 depicts the guiding research design for the study, including the data sources and analytic approaches according to each research question. The following sources were collected with the aim of gathering sufficient data to reach theoretical saturation (Creswell, 2009) about teachers' progression as CRP Science educators and to satisfactorily inform the STARTS design framework. An overview of the stages is presented first, followed by a description of each data source according to its type.

Data Collection

Data were collected in multiple stages accompanied by concurrent analysis (Table 3-4). According to Charmaz (2006), grounded theory data are "detailed, focused, and full. They reveal participants' feelings, intentions, and actions as well as the contexts and structures of their lives" (p.14). To produce rich descriptions of teachers' CRP Science knowledge and practices over time, numerous data sources were collected in five stages, with ongoing analysis supporting the theoretical sampling of new data sources (in addition to pre-established data sources). In addition to these data sources, supplemental data were collected to determine the ability of the STARTS PD framework features to support teachers' professional growth. To document all design decisions and revisions, an ongoing reflexive journal (Lincoln & Guba, 1985) was maintained throughout all stages of the STARTS research and development program.

The Saturday Collaboration Sessions demarcated each data collection stage. In between each Saturday Collaboration Session, teachers were engaged in various STARTS activities and their classrooms were observed. At each stage the data were read holistically, open coded by incident, and preliminary patterns and trends in their CRP Science knowledge and practices, as well as any explicit connections between the STARTS activities and teachers' professional growth, were recorded in the reflexive journal. Journal entries were connected to an ongoing Design Decisions Report (DDR) in which any PD activity decisions were revised based on emergent findings. For example, as the program progressed, teachers consistently abstained from establishing partnerships with students' family members. Though connecting science content with families' funds of knowledge had been discussed previously, a PG task specifically devoted to practical ways to connect science with families was designed and implemented during the third stage. Appendix C contains an excerpt from the DDR. During the first stage of data collection and analysis, teachers completed the preliminary *Beliefs About Reformed Science Teaching and Learning* (BARSTL) questionnaire (Sampson, Enderle, & Grooms, 2013), engaged in lesson study, and participated in the first Saturday Collaboration Session. In addition, their classroom practices were observed for the first time. In the second stage, teachers' completed GAIn 1 tasks, autobiographies, and RWPs were examined.

Next, the first group interview, second Saturday Collaboration Session, and second observations were held. These three sources were video-recorded and transcribed. In the third stage, STARTS activity artifacts such as the GAIn 2, PG tasks, CTS working document, and RWPs were collected and examined. At this time, a third round of classroom observations was conducted. Teachers also attended the third Saturday Collaboration Session in which they engaged in another group interview, completed a mock teaching session, and provided feedback on the session. All activities were video-recorded and transcribed.

During the fourth stage, teachers completed all PG tasks, the third GAIn task, and their CRP Science unit templates. Teachers presented their CRP Science units during the final Saturday Collaboration Session and also participated in a STARTS redesign session in which they provided feedback about the structure and nature of the major activities. Both the CRP Science unit presentations and STARTS redesign session were video-recorded and transcribed verbatim. There was also a final concurrent data collection-analysis stage after the fourth Saturday Collaboration Session. This allowed additional time for any remaining teachers to enact their CRP Science units as well as any additional data collection associated with theoretical sampling, which were often responses to clarification questions via email and phone correspondences.

Classroom Observations

Observations enable the researcher to record data as it naturally occurs in a given context (Plano-Clark & Creswell, 2011). To the non-participant observer, observations provide a chance to produce “social reality from an external perspective” (Flick, 2009, p. 225). When conducting grounded theory research in particular, the researcher heavily attends to action and interaction during observation. Through this attention, the researcher can then focus on the conditions under which a phenomenon occurs.

The classroom practices of each teacher were observed six times, once a month during the second through fourth months, and on three occasions during CRP Science unit implementation. One teacher (Zane) did not complete her CRP Science unit. Thus, five teachers were observed as they enacted their CRP Science units. Each observation was video-recorded, transcribed, and field notes produced. Observations lasted an entire class period. The duration depended on whether the teacher taught in block schedule format (90-110 minute range) or shorter class periods (50-minutes). However, Corbin and Strauss (2008) warn of potential drawbacks to observation. The authors state, “[a] researcher may give meaning to action/interaction based on observation without checking out that meaning with participants. It is always beneficial to combine observation with interview or leave open the possibility to verify interpretations with participants” (Corbin & Strauss, 2008, p. 30). Thus, when possible, a debrief session followed the observation. If this was not permissible, the teacher and I communicated through email and phone later that evening. During each observation for which I was physically present, I took on the role of nonparticipant observer to be as minimally disruptive to normal classroom functioning as possible. In the event that it was not always possible for me to be present during the CRP Science unit implementation, teachers video-recorded their three lessons, transferred the recordings to a storage device, and mailed them to me.

During each observation, I recorded field notes. Adhering to the suggestions posed by Charmaz (2006) and Hatch (2002), field notes contained a chronological breakdown of individual and collective actions, statements to capture participants' language use, and discernable feelings, as well as summaries describing significant processes that were characteristic of CRP, CRP Science, and reform-based science teaching. My initial interpretations and analyses were recorded as well, though they were clearly bracketed from raw field notes. Field notes of my second observation of Christina Joy's classroom practices are found in Appendix D.

To assist the examination of teachers' reform-based and CRP Science practices, I used the *Culturally Responsive Instruction Observation Protocol* (CRIOP) developed by the Collaborative Center for Literacy Development (CCLD) (Malo-Juvera, Powell, & Cantrell, 2013; Powell et al., 2011) (Appendix E) and the *Reformed Teacher Observation Protocol* (RTOP) developed by the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) project (Piburn & Sawada, 2000) (Appendix F). After the observation was complete for the day, I viewed the video recording and completed a CRIOP and RTOP for each teacher. I entered the CRIOP and RTOP scores into an Excel spreadsheet and wrote summaries of each teacher's observation according to CRP Science and the CRIOP as well as reform-based science teaching and the RTOP.

CRIOP

The CRIOP contains 25 indicators across seven pillars: Classroom Relationships, Family Collaboration, Assessment Practices, Curriculum/Planned Learning Experiences, Pedagogy/Instructional Practices, Discourse/Instructional Conversation, and Sociopolitical Consciousness. The CRIOP represents a synthesis of the vast and timely literature on culturally responsive pedagogy (CRP) and provides operational definitions of specific CRP tenets in the seven CRIOP pillars. In these pillars, operational definitions of specific CRP tenets are provided, making the occasionally nebulous constructs within CRP more concrete, observable, and directly measurable. For example, the Classroom Relationships pillar was designed to capture elements of the classroom environment, such as respectful learning atmosphere, high teacher expectations, and productive student collaboration. Family Collaboration measures the extent to which the teacher reaches out to family and establishes partnerships. The Assessment Practices pillar represents teachers' use of formative assessment practices and student self-assessment. Curriculum/Planned Learning Experiences focus on the degree to which the curriculum utilizes students' prior knowledge, experiences, and diverse perspectives. Inquiry-based practices, teacher scaffolding, and developing academic vocabularies are all contained within the Pedagogy/Instructional Practices pillar. The inclusion of culturally congruent discourse and instructional strategies that promote academic conversation are encapsulated in the Discourse/Instructional Conversation pillar. Finally, Sociopolitical Consciousness pertains to the ways in which the curriculum includes opportunities for students to explore issues important to the local context and confront stereotypes and bias. Performance on each indicator ranges on a scale from 1 (not at all) to 4 (to a great extent). Each pillar is scored holistically; therefore, the total possible points vary for each pillar depending upon the number of indicators contained within each pillar.

Reliability of the CRIOP was measured using Cronbach's alpha, which indicates internal consistency (i.e., intercorrelations among CRIOP items). Analysis yielded an alpha value of 0.94 (α = 0.94), illustrating strong reliability among CRIOP instrument items. After the sample size was determined large enough for factor analysis, an exploratory factor analysis was conducted on classroom observation data between 2008-2009 (N = 78) to identify underlying CRIOP components. Results indicate that the CRIOP is a consistent assessment for culturally responsive teaching (Malo-Juvera et al., 2013).

RTOP

The RTOP was designed to measure the reform-based practices of science and mathematics teachers. Designed through a constructivist lens, the RTOP operationalizes mathematics and science education reform constructs so they can be observed and measured. This constructivist-oriented, reform-minded characterization of mathematics and science education emanates from three major mathematics and science education reform sources: (1) National Council Teachers of Mathematics (NCTM) reports (1991; 1995; 2000); (2) National Academy of Sciences (NAS), National Research Council (NRC) reports (1996; 2000); and (3) AAAS Project 2061 reports (1990; 1993).

The RTOP consists of 25 items divided among three major subsets: (1) Lesson Design and Implementation; (2) Content; and (3) Classroom Culture. The subset of Lesson Design and Implementation items were created to capture reform-based, constructivist lessons. For example, the degrees to which instruction recognizes students' prior knowledge and utilizes student-generated ideas are measured.

The second category, Content, measures science and/or mathematics content as well as the process of inquiry. This is further broken down into two subscales, one focused on capturing propositional knowledge (e.g., fundamental concepts are explored) and the other focused on procedural knowledge (e.g., student reflection). The Classroom Culture items subset measures how often students are encouraged to actively participate, to communicate their ideas, as opposed to teacher-directed instruction. This category is divided into two subscales, communicative interactions (e.g., high proportion of student conversation) and student-teacher relationships (e.g., teacher as a resource person). Performance on each item ranges on a scale from 0 (never occurred) to 4 (very descriptive). The maximum points for each subscale is 20 points (5 items for each subscale). The total possible points equaled 100. However, high school science teachers typically average a score of 42, which is the lowest score among all comparison groups (middle school, community college, and university students) (Piburn & Sawada, 2000).

To determine instrument reliability, a best-fit linear regression was conducted on observation data from 153 middle school, high school, and college-level math and physics classrooms during Fall 1999 (N = 287). The reliability estimate, $R^2 = 0.954$, is a robust value that indicates strong overall consistency among the instrument items. Additionally, reliability of the RTOP subscales were also calculated. These results are presented in Table 3-5. Reliability was also calculated for observations occurring in eight biology classrooms during Fall, 1999. Reliability was determined to be very high ($R^2 = 0803$), indicating high internal reliability among the instrument items throughout multiple science classrooms as well as in the mathematics classrooms. Construct validity and predictive validity were calculated to assess instrument validity. Construct validity measures the degree to which the test items accurately measure an operationalized theoretical construct (in this case, inquiry-oriented instruction)

(American Education Research Association [AERA], 1999). Correlational analysis yielded high R^2 values across all subsets, as seen in Table 3-5. Results indicate strong construct validity.

I first trained on the RTOP through the online training videos and I also participated in a full-day training session with a graduate student. Additionally, I trained on and helped revise the original CRIOP at the CCLD during the summer of 2012. During the face-to-face training session with the graduate student, we observed and evaluated two videos of science and mathematics classrooms that were unrelated to the project, according to the RTOP and CRIOP. We discussed our scores and came to consensus for items from both observation protocols. Additionally, during the first Saturday Session, the STARTS teachers observed and evaluated the same two videos with the RTOP and CRIOP. We then discussed their results and came to a group consensus. After each observation I engaged in member checking by providing teachers with field notes and RTOP and CRIOP scores.

Focus Group Interviews

Two semi-structured focus group interviews were held with participating teachers at the second (10/13) and third (11/13) Saturday Collaboration Sessions to gain insight into their experiences with STARTS activities, their professional growth, and relationships with students. Sample questions from these two interviews are found in Appendix G. Interviews contained questions intended to advance theory about the process of developing as a CRP Science teacher via PD (Creswell, 2009). Interviews reveal pertinent information to both the researcher and the participant. Corbin and Strauss (2008) state that, “the interview process provides participants an opportunity to talk in depth about issues that they hadn't talked much about before, giving them additional insights into their own behavior" (p.28).

The formal interviews lasted approximately 60 minutes. During the first focus group interview, questions were organized around teachers' perceptions of CRP Science, their students, and STARTS experiences thus far. Further, the initial interview questions pertained to concepts from the literature (Corbin & Strauss, 2008), such as areas of CRP Science teachers were struggling with. At the time of the second interview, questions focused on teachers' practices, how they connected what they were learning about students to instruction, and the process of designing CRP Science instructional materials. Both interviews were audio-recorded and transcribed verbatim.

STARTS Artifacts

Beliefs about Reformed Science Teaching and Learning (BARSTL) instrument

The BARSTL instrument (Sampson, Enderle, & Grooms, 2013) was developed to measure the degree to which preservice elementary teachers' beliefs about science teaching and learning reflected reform-based orientations. The instrument contains 32 statements divided across four subscales: How people learn about science; Lesson Design and Implementation; Characteristics of Teachers and the Learning Environment; and The Nature of the Science Curriculum (Sampson et al., 2013, p. 6). Items were informed by several reform documents (e.g., AAAS, 1993; NRC, 1996). Each subscale contained eight items, with four items representing reform-based science education orientation and the remaining four capturing traditional perspectives. The instrument employs a four-point Likert-type scale in which teachers indicate the degree to which they disagree or agree with a statement. Higher scores reflect more reform-based beliefs about science education.

The BARSTL was administered to participating teachers during the first stage of data collection/analysis as part of a larger questionnaire to discern their initial beliefs about science education as well as their professional needs. Through item results, I was able to more thoroughly design PD experiences that account for and were responsive to teachers' existing strengths and needs.

Lesson study documents

Lesson study documents were collected and preliminarily analyzed during the first stage as participating teachers submitted them. Lesson study documents included group goal selections, the research lesson, observation and analysis documents, and revised lessons. In addition to structuring the lesson study experience for teachers, these documents aided constant comparative analysis (Strauss & Corbin, 1998) by allowing me to compare (a) the CRP Science knowledge and practices of teachers and (b) their views of students at different time periods.

GAIn tasks

The GAIn tasks required teachers to identify CRP Science practices in the literature and, subsequently, their classrooms. Teachers reflected on the relevance of such practices for their students and speculated on plans to integrate responsive strategies with their repertoire of instructional practices. Teachers' GAIn tasks were collected as participants completed them and subsequently analyzed for potential trends. This occurred during the first, second, and third stages of data collection/analysis. These GAIn tasks served to promote dialogue between teacher and researcher through my provided feedback as well as providing a source of constant comparison.

CTS working document

The completed CTS working documents of the teachers were collected and examined during the third stage of data collection/analysis. Much like the GAIn tasks and lesson study documents, the CTS working document served two primary roles. During the STARTS PD program, the CTS document structured teachers' experiences with a major task. It also scaffolded the incorporation of reform-based science teaching into the CRP Science unit. From a research standpoint, the CTS working document was a data source to be examined for teachers' CRP Science knowledge and practices at a given point in time. By constantly comparing the CTS working documents across teachers and other STARTS artifacts, I was able to explore shifts in CRP Science knowledge and practices over time.

CRP Science unit

The CRP Science unit template structured the integration of responsive teacher instruction (via GAIn findings) with reform-based science (via CTS findings). The instructional units were collected and examined during the fourth stage. The CRP Science units served as a source of triangulation between intended and observed practices.

Reflective Writing Prompts

Structured reflection can positively impact changes in teachers' practice and their professional, social, and personal development (Bell & Gilbert, 1996). Participants continually reflected on their practice and progression throughout the course of STARTS. To aid the collection of rich data, I created Reflective Writing Prompts (RWPs) to accompany STARTS activities. Teachers completed nine RWPs in all. An RWP topic varied depending on the particular activity in which teachers were engaged. For instance, topics included: reflecting on how well a particular activity supported teachers' professional growth, comparing teachers' CRP Science and reform-based practices with examples from the literature, and connecting PG content to classroom practice. The RWP data were used to examine how teachers described their own professional development, as well as any mediating factors. While the RWPs had practical value in that they structured PG tasks and teachers' reflections, from a research standpoint they enabled me to seek answers to questions that arose during preliminary analysis, thereby serving as an additional source for theoretical sampling (Charmaz, 2006).

Saturday Collaboration Session artifacts

The Saturday Collaboration Sessions served as the main structure for teachers to brainstorm new lesson ideas, enact novel CRP Science strategies, and receive feedback on their practices. Teachers participated in a mock teaching feedback session (third Saturday Collaboration Session, 11/13) and STARTS redesign session (fourth Saturday Collaboration Session, 1/14) in which they were asked to provide feedback on the effectiveness of specific STARTS activities as well as suggestions for structural redesign of the program. At the fourth Saturday Collaboration Session (1/14), each teacher also presented their CRP Science units. Each of these activities were video-recorded and transcribed verbatim. These data sources were examined to determine potential relationships between STARTS PD activities and their professional growth as CRP Science teachers.

Clarification Questions

The Clarification Questions data were constructed after the completion of the STARTS PD program in response to emerging theoretical categories during the systematic process of open coding (Strauss & Corbin, 1998). Certain categories and their properties (i.e., attributes) remained unclear. Thus, as a form of theoretical sampling, I posed additional Clarification Questions to the participating teachers that were focused specifically on weak but developing categories. Charmaz (2006) defines theoretical sampling as, “seeking pertinent data to *develop* your emerging *theory*. . . you conduct theoretical sampling by sampling to develop the properties of your category(ies) until no new properties emerge” (p. 96, italics in original). Teachers’ responses to these focused Clarification Questions were collected during the fifth and final stage of data collection/analysis. The data were used to further develop theoretical categories.

Data Analysis

This dissertation study utilized multiple qualitative approaches to data analysis, including: grounded theory (Charmaz, 2006; Strauss & Corbin, 1998), typological analysis (Hatch, 2002), and matrix analysis (Averill, 2002; Miles & Huberman, 1994). Though there was overlap between the qualitative analysis methods employed to answer the guiding research questions for this dissertation study, each question was addressed through a distinct application of these methods (refer to Table 3-3). Thus, this section consists of a detailed account of the data analysis process according to each research question.

Teachers’ Progression as CRP Science Teachers

To understand the process of becoming a CRP Science educator for the six high school life science teachers participating in the STARTS PD program, I utilized grounded theory analysis methods. Grounded theory is appropriate for examining interactions between individuals or among persons within specific contexts (Charmaz, 2006; Strauss & Corbin, 1998), particularly when a weak literature base exists. Specific attention is paid to process, action, and the structure within which these are situated, thereby providing rich data sources for later constructing theory from participants' views (Creswell, 2009; Strauss & Corbin, 1998). Grounded theory analysis techniques include open, axial, and selective coding, with the overall aim to move from concrete to abstract through theory generation. Researchers utilizing grounded theory familiarize themselves with existing theories and concepts to develop sensitivity to potential meanings within the data. However, as Charmaz (2006) warns, "such approaches preclude ideas from emerging as you code events" (p. 48). Thus, theories should be set aside as data are initially explored for categories. To reduce the potential for distorting messages within the data, I also engaged in the process of constantly comparing data sources to each other.

According to Strauss and Corbin (1998), grounded theory analysis begins with open coding, in which "categories are discovered in data and developed in terms of their properties and dimensions" (p.102). First, I organized the data sources in HyperRESEARCH (qualitative data management software) as they were collected. I examined my reflexive journal entries to identify any potential emerging codes around teachers' progression in CRP Science knowledge and practice. Student grouping and student-teacher interactions were two areas of initial focus, as I had observed changes to this end over time in classroom observations. I also paid special attention to any data passages related to family connections and sociopolitical consciousness-raising, as these were areas infrequently exhibited by teachers in their practices. At the end of the first four stages of data collection and analysis, I conducted a more systematic approach to open coding than the incident-by-incident approach previously employed. I began line-by-line coding the group interview transcripts. Like Charmaz (2000), I broke data into single, sensible units and then labeled the actions and meanings portrayed in each unit. Appendix H presents the complete list of initial codes and their potential associated categories. Table 3-6 contains a list of preliminary codes including *perceiving that grouping promotes better work*, *getting better means new activities and practices,* and *building relationships with students*. As I progressed through open coding, potential categories began to emerge. These categories were based on either (1) frequency of related codes, (2) multiple representations/facets of a certain process (i.e., properties of codes, Strauss & Corbin, 1998), or (3) potential categories from my reflexive journal. Examples of early potential categories included*: student grouping, teacher scaffolding, family collaboration,* and *sociopolitical consciousness*. I also kept memos of possible conceptual categories as a way to manage the data as I coded them, which were added to my journal.

I then engaged in axial coding to further develop categories according to their properties and dimensions. The related codes were consolidated in Hyperresearch according to their similarity in meaning or relation to the categories (Strauss & Corbin, 1998). To explore progression and not just action in a given time period, I also looked across the codes over time. Therefore, I further grouped the coded passages and their emerging categories according to the time in which they occurred (ex: the first group interview occurred several months prior to the CRP Science unit presentations). This resulted in chunks of open codes associated with a developing category over a timeline. Examples of developing categories during this stage of analysis included: *professional growth* (as process), *awareness* (as a state of being), *connecting science with students* (as an action), *teacher satisfaction* (as a state of being and an outcome), and *toolbox* (as an object supporting teacher change). These categories were compared across the teachers and over time periods.

To further develop the categories, I went back to their associated codes to identify properties (i.e., attributes) and dimensions (i.e., range of properties of a category) (Strauss & Corbin, 1998). At this time, I explored which codes were outliers, and which codes were more distantly and more closely related to one another, if at all. Codes that no longer appeared relevant to the data were removed.

I constructed Cartesian planes for each category at this point to visually represent the dimensions along which a category ranged. Figure 3-3 illustrates a Cartesian plane for the developing category, *toolbox*, which contains the properties *new topics* and *new strategies*. At this phase of analysis, the dimensions ranged from favorable to unfavorable conditions for the incorporation of a new strategy or relevant science topic to existing instruction. For example, in the top left quadrant are conditions in which it was favorable for STARTS teachers to apply relevant topics to existing science content in the curricula, such as when the topic was combined with a previously used instructional strategy. In the bottom right quadrant are instances in which the application of a new strategy was unfavorable, including the need to cover content and prepare students for the End of Course exam. By articulating the range along which categories existed, I was better able to discern the conditions (where, when, how, and why) associated with a category (Strauss & Corbin, 1998). Additionally, I engaged in theoretical sampling (Charmaz, 2006) to seek pertinent data for emerging categories that still had ambiguous dimensions (e.g., *repositioning students*). To develop these dimensions further, I sought pertinent data from participating teachers, largely through phone and email correspondences. As I developed richer understandings of the categories, I revised their labels as needed (ex: *connecting science with students* was merged into *instructional change*) and wrote detailed memos describing their properties, all of which were supported with evidence passages. Because the codes were now consolidated according to source (and, therefore, relative time), I looked for relationships, additional properties/dimensions of a code, and where they could be further consolidated.

Once salient categories were identified, I utilized selective coding to integrate and refine them further. Many of these categories and their associated properties/dimensions were repetitive among data sources, including those obtained through theoretical sampling, thus indicating that theoretical saturation had been attained. This resulted in six themes associated with high school life science teachers' progression as CRP Science teachers, which are listed in Table 3-6. I wrote statements that articulated the observed relationships between themes. Finally, I created a narrative reflecting the temporal progressions of these themes and their supporting relational statements. In the narrative, I looked closely for shifts in teachers' CRP Science knowledge and practices, paying special attention to describe these shifts according to their defining properties. The resulting narrative further allowed me to articulate dimensions of the categories.

STARTS Framework Features Supporting Teachers' Progression as CRP Science Teachers

In order to discern the relationships between teachers' progression as CRP Science teachers and the STARTS PD features capable of supporting this professional growth, data were analyzed in multiple stages using qualitative analysis approaches, including methods for typological analysis (Hatch, 2002), matrix analysis (Averill, 2002; Miles & Huberman, 1994), and constant comparative analysis (Strauss & Corbin, 1998). Before identifying features of the STARTS PD framework that influenced teachers' professional growth, I first sought to determine any trends and patterns in teachers' shifting CRP Science and reform-based knowledge and practices over time. To do this, I employed typological analysis methods (Hatch, 2002) to examine the classroom observations, field notes, and teachers' completed STARTS artifacts.

The first step in typological analysis was to read through the data and divide sections by predetermined categories/typologies. The typologies I was interested in were the various elements of CRP Science and reform-based science teaching, which were identified and operationalized according to the CRIOP and RTOP, respectively. First, I coded all classroom observations according to the CRIOP and RTOP scales. These were recorded as evidence of either CRP Science or reform-based science classroom *practices*. In addition to direct observation of practices, I was also interested in teachers' CRP Science and reform-based science teaching *knowledge*. Therefore, I also coded various teacher artifacts according to the CRIOP pillars and RTOP subscales. These data sources included teachers' completed GAIn and PG tasks, lesson study documents, CTS documents, and RWPs.

The next step in the analysis was to compile the main ideas associated with each typology in a summary sheet for all six teachers. The summary sheets were organized in HyperRESEARCH and contained information for each teacher's CRP Science and reform-based knowledge and practices according to the typologies. I isolated the codes by each teacher, and wrote a descriptive summary of their reform-based and CRP

Science knowledge and practices, which condensed the large data set. Following the construction of summary sheets, the next step in typological analysis is discerning any emerging patterns, relationships, or trends (Hatch, 2002). Because I was ultimately interested in understanding how their culturally responsive and reform-based science teaching knowledge and practices developed over time in the STARTS program, I isolated the coded instances per teacher across a timeline, demarcated by the various STARTS activities. I then broke the summaries for each participant into four categories: CRP Science *knowledge*, CRP Science *practices*, reform-based science teaching *knowledge*, and reform-based science teaching *practices*. I repeated this step, now looking for connections and patterns across the teachers. Through this I could then examine patterns in developing knowledge and practices over time, such as similarities, differences, and correspondences among the categories. My goal for engaging in these steps was to determine to what degree teachers' practices were reflective of CRP Science and reform-based science teaching over time. Through this process, I now had an empirical basis for exploring which STARTS PD features were capable of supporting shifts in teachers' CRP Science and reform-based knowledge and practices.

Once there was an empirical foundation for exploring the ways in which STARTS activities supported teachers' development as reform-based, CRP Science educators, I employed methods for matrix analysis (Averill, 2002; Miles & Huberman, 1994) and constant comparative analysis (Strauss & Corbin, 1998) in an attempt to identify relationships between STARTS activities and teacher outcomes, which were represented by the six progression themes identified through the grounded theory analysis. Miles and Huberman (1994) state that a matrix involves "the crossing of two or more main dimensions or variables. . . to see how they interact” (p. 239). The authors suggest the use of a descriptive effects matrix to determine what changes a particular program elicits in its participants. The resulting matrix provides a visual display of the relationship between structural elements (in this case, the STARTS PD activities) and changes in practice.

To better isolate relationships between STARTS activities and outcomes, the six themes of teachers’ progression as CRP Science teachers were expanded to seven outcomes, with *instructional changes* becoming *new topics* and *new strategies*. I then examined the data and isolated instances in which a teacher made a direct connection between one of the outcomes and a specific STARTS activity. For example, in the passage below, Lorelei refers to an article she read for a PG task on collaborative learning as the source of new instructional strategies she utilized:

> The student grouping article was the one I learned the most from and utilized these strategies in the classroom. I also plan on continuing the use of the strategies detailed. . . I will continue to use the strategies discussed in the student grouping article and plan on early implementation next year. (Lorelei, RWP Evaluation)

If no direct connection was reported, it did not necessarily mean that the particular activity did not assist in multiple dimensions of professional growth. Rather, the results indicated that there was no direct reporting of the connection in data sources. Across the data sources I identified 171 such direct connections. Because “one event often leads to another, and then to another. . . making the relationships among events very difficult to sort out” (Strauss & Corbin, 1998, p. 184), I constructed a matrix containing cells populated with the format *STARTS Activity -> Teacher Outcome*. This activity-outcome matrix enabled me to discern the degree to which the various STARTS activities accounted for each outcome, and thereby to locate the phenomena of professional growth in context (Strauss & Corbin, 1998). In the matrix (Table 3-7), the STARTS activity is one dimension and the specific outcome is another. For example, one column might contain information for *Lesson Study -> Views of Students*. The corresponding cell contains the total number of isolated evidence passages for a direct connection between the STARTS Activity, lesson study, and the outcome theme, community building. In the instance of *Lesson Study -> Views of Students,* the total number of isolated evidence passages is one. The total of all connections identified between any STARTS activity and a given outcome were then summed for that outcome. For example, there were 38 instances of a direct connection among all six STARTS activities and the outcome *Views of Students*. To represent the degree to which a given activity was associated with a particular outcome, I then divided the actual instances of a connection between *Activity -> Outcome* by the total instances and represented this as a percentage. In the *Lesson Study -> Views of Students* example, there were six instances of a direct connection between the lesson study (activity) and views of students (outcome). Thus, lesson study was associated with changing views of students in 16% of all instances.

Through the matrix I could now begin to visualize the relationship between structure (STARTS activity) and process (teachers' progression) (Strauss & Corbin, 1998). According to Averill (2002), "[t]he visual impact of a matrix display can draw the reader's attention to overall trends or points of emphasis across categories as he or she reads the supporting explanation" (p. 858). Thus, to further assist in visually representing this relationship, I constructed one figure for each activity containing the seven teacher outcomes and their associated connections to that particular activity. These figures are presented in Chapter 5 alongside their associated activities.

This qualitative study applied grounded theory analysis, typological analysis, and matrix analysis methods to explore high school life science teachers' process of becoming CRP Science teachers and the STARTS PD features supporting shifts in their knowledge and practices. In the following section I articulate the criteria for evaluating the rigor of qualitative research by establishing trustworthiness.

Establishing Trustworthiness

To establish "experience-near significance and experience-distant relevance" (Barab & Squire, 2004, p.6), design studies are intended to produce usable knowledge about a given educational tool while also advancing theory. Therefore, specific outcomes of DBR should include the generation of local theory, design frameworks, and accompanying design principles. However, the quality of such products should be well established through specific criteria. Design researchers are responsible for demonstrating methodological rigor in both the internal processes of research and the designed intervention's potential impact on teaching and learning. To establish trustworthiness, design-based researchers provide a variety of evidence about the research process and the intervention's potential impact on practice.

Lincoln and Guba (1985) noted that establishing trustworthiness of qualitative research is one way to evaluate the quality of the work completed. The criteria Lincoln and Guba (1985) provided to evaluate the trustworthiness of a qualitative inquiry include credibility, transferability, dependability, and confirmability. Charmaz (2006) suggests a similar set of expectations for evaluating grounded theory studies. Because of the central importance of grounded theory to this dissertation study, these criteria were used to establish trustworthiness and evaluate impact of the findings. They include: credibility, originality, resonance, and usefulness. These constructs will be examined in the following sections and the ways in which they were preserved within this study will be illuminated.

Credibility

Credibility is analogous to the construct of internal validity within a quantitative research paradigm. Guba (1981) states that credibility pertains to the “truth value” of a qualitative inquiry, how a researcher establishes “confidence in the ‘truth’ of the findings of a particular inquiry for the subjects. . . with which and the context in which the inquiry was carried out” (p. 79). In other words, credibility is evaluated to determine the degree to which the study examines what it was designed to examine in a particular setting and with a specific group of individuals (Lincoln & Guba, 1985). To demonstrate credibility, according to Charmaz (2006), the grounded theorist must have achieved “intimate familiarity with the setting or topic. . . categories [that] cover a wide range of empirical observations. . . [and] strong logical links between the gathered data and your argument and analysis” (p. 182).

To establish credibility, I engaged in persistent, repeated observation, peer debriefing after each classroom observation and Saturday Collaboration Session, and member-checking when appropriate (teachers reviewed my field notes and CRIOP and RTOP scores after each observation, confirming and/or revising as needed). I achieved triangulation by constant comparison across multiple data sources (e.g., classroom observation transcripts, field notes, focus group interview transcripts, STARTS activity artifacts completed by each teacher) and an audit trail through my reflexive journal which contained raw data passages, summaries of preliminary analytical notes, and methodological notes such as design decisions.

Originality

Because the outcome of a grounded theory study consists of generation of novel theory (or extension of existing theory in an innovative manner), the product should be original. Originality arises from "fresh" categories that offer "new insights"; they identify the theoretical and social significance of the research as well as "challenge, extend, or refine current ideas, concepts, and practices" (Charmaz, 2006, p. 182). By undertaking a careful review of the literature prior to the study, I was aware of the existing theories on cultural responsiveness, cultural relevance, and cultural congruence – both generally within education and specifically within science education. Furthermore, I was aware of the perspectives on teacher change and supporting teachers as curriculum designers within the context of PD posited in the empirical literature. Hence, I was knowledgeable about the ways in which findings of this study extended existing theories in addition to providing new insights on the process of becoming a CRP Science teacher.

Moreover, I produced a conceptual model of high school life science teachers' progressions that arose from relational statements about the major concepts and their properties. This in itself is not present within the literature on CRP Science and therefore resulted in original findings. By connecting teachers' professional growth to specific PD features that best support their development, I've attempted to demonstrate the theoretical and practical significance of this work.

Resonance

According to Charmaz (2006), categories that "portray the fullness of the studied experience" result in resonance (p. 182). In this study, theoretical saturation was achieved when gathering new data from participants no longer revealed new properties of the six theoretical categories. Grounded theorists also strive for resonance through demonstrating that the resulting theory is sensible to participants. Member checking was employed regularly throughout this study to ensure sensible findings that represented participants' experiences. First, participating teachers received a copy of my field notes and CRIOP and RTOP scores after every classroom observation. We then discussed these documents through debriefing, which occurred in person or via email and/or phone correspondences. Finally, throughout the later stages of analysis (i.e., axial and selective coding) emerging findings were communicated to participants in electronic documents and via phone/email correspondences. The participants were asked to confirm and/or revise my interpretations of the data.

Usefulness

The notion of usefulness aligns to criteria for evaluating the impact of design studies proposed by Confrey and Lachance (2000), particularly the compelling nature, adaptability, and generativity of a designed intervention. Compelling nature pertains to how well the intervention convinces practitioners to act with urgency to implement reform. The intervention must move beyond being viewed as interesting and compel practitioners to change, without haste. A designed intervention is considered adaptable when it can be flexibly applied to multiple educational settings while expecting similar outcomes. Generativity relates to the degree to which the conjecture undergirding a designed intervention helps practitioners reconceptualize classroom interactions and practices. This last criterion relates most closely to the robustness and practicality of a local theory and design framework.

Charmaz (2006) suggests that, “a strong combination of originality and credibility increases resonance, and the subsequent value of the [scholarly] contribution” (p. 183). Grounded theory and the products of qualitative inquiry are useful if they offer interpretations that can actually be used by people, spark additional research, and contribute to the relevant knowledge base. Through the construction of a localized grounded theory (chapter 4), design framework, and set of design principles (Chapter 5), I aimed to address these criteria and, ultimately, the usefulness of this qualitative study.

Statement of Subjectivity

Acknowledging subjectivity is essential to the qualitative research paradigm. Because of the pervasive influence a researcher’s subjectivity has on the entire research program – from data collection, interaction with participants, analysis, to theory construction – the values and beliefs possessed by the researcher must be acknowledged (Guba & Lincoln, 1989). This is especially true when an end goal of research is the generation of theory, as “we do not gain an autonomous theory, albeit one amenable to modification. Rather we are *part* of our constructed theory and this theory reflects the vantage points inherent in our varied experiences” (Charmaz, 2006, p. 149). As a researcher, I hold several beliefs that perpetually influenced my actions and decisions. As a designer, these beliefs further shaped the design and implementation of the STARTS PD program, including my role as facilitator. Though the program was built from the relevant literature, the way in which I applied theory to practice was highly influenced by my beliefs about science education for diverse learners and PD. I begin by declaring these salient beliefs and conclude by articulating the ways that I confronted and questioned these taken-for-granted assumptions through a reflexive approach that ultimately enhanced the trustworthiness of the study.

I entered this study with specific beliefs about how science should be taught, especially to diverse students who are historically underrepresented. In the classroom, science should validate and reflect students' backgrounds through relevant topics of importance to students. Science knowledge emanating from different ethnic groups should be made accessible and treated as worthy of the same respect as canonical science. Through this, students build cultural competence in the presence of science and are more likely to forge identities of themselves as scientists. Science should also be explored through a critical lens and used as a platform to uncover the existing forms of oppression that impact diverse students. Students should have opportunities to engage in social action, applying their science knowledge to remedy community issues when appropriate. Thus, science for diverse learners should be culturally responsive, transformative, emancipatory, and connected to the community.

Furthermore, I believe that in order to best foster the academic success of diverse students in the current educational system and prepare them for postsecondary success, should that be their next step, culturally responsive science education must occur in conjunction with reform-based science education, such as the practices of science (NRC, 2012), including inquiry (NRC, 2000). For diverse students in particular, being scientifically literate in the ways recognized in national reform reports enables them to acquire the culture of power more readily by making those practices explicit.

I also hold specific beliefs about the teachers with whom I worked during this study. Because of the manner in which I met them (they chose to spend a week away from their families and home during the summer to attend the SSI program), I assumed that these teachers were motivated to continue growing professionally and also had the resources to capitalize on this opportunity. Because they were informed of the nature of the STARTS PD program before deciding to participate, I believed that they genuinely desired to learn how to better connect with their students through culturally responsive approaches to science instruction. I also believed that the teachers entered the program with many strengths, several of which I planned to utilize to further their professional development. However, I assumed that they likely hadn't critically explored the nature of schooling and science instruction as it is presented in the district curricula. Furthermore, I believed they had limited experience with integrating students' backgrounds with science.

Lastly, I hold beliefs about the nature of PD as well as the specific school systems in which teachers operate. These beliefs are influenced by my own experiences as a science teacher for both high school and elementary students who was required to engage in PD on a regular basis. Because teachers chose to participate in the STARTS PD program, as opposed to being required to do so, it was essential that the program continually be responsive to their needs (on personal, classroom, and school levels) while admittedly forwarding a CRP Science agenda.

The beliefs I declared have affected several aspects of the research and design program. Alongside the guiding theoretical frameworks, they influenced what I attended to during observations and other data collection sessions, which PD experiences and readings I selected for teachers, and how I interpreted the data. Therefore, to bolster the trustworthiness of the study, I employed multiple techniques for assuring the methodological rigor of qualitative research, including numerous data sources, multiple stages of analysis, frequent and repeated observation, prolonged engagement, member checking, and an audit trail (Creswell, 2009; Guba & Lincoln, 1989). Additionally, I maintained a reflexive memo-writing journal (Charmaz, 2006) throughout the program, which included reflective notes after each Saturday Collaboration Session, my preliminary analyses, and suggestions for upcoming STARTS activity content based on teachers' emerging needs. To ensure quality in internal process I also maintained an ongoing Design Decisions Report (DDR) in which any PD design decisions were revised based on emergent findings.

Summary

The STARTS PD program was designed to support changes in teachers' CRP Science knowledge and practices as well as their ability to construct innovative CRP Science instructional materials. To do so, six major activities formed the corpus of the program: lesson study, GAIn tasks, CTS, PG tasks, CRP Science unit construction, and Saturday Collaboration Sessions. Six high school life science teachers from throughout a culturally and linguistically diverse school district in the Southeastern United States participated in the STARTS PD program and the research investigation. This study applied a qualitative design to characterize the professional growth process of these six teachers and identify salient PD framework features that influenced their progression as CRP Science educators in this context.

To explore teachers' progressions over time, numerous data sources were collected, including two focus group interviews at Saturday Collaboration Sessions, repeated classroom observations, researcher's field notes, and multiple STARTS PD artifacts. These data were analyzed through grounded theory methods (Charmaz, 2006;

Strauss & Corbin, 1998). To identify PD features capable of supporting teachers' professional growth as CRP Science educators, the same data sources were examined. However, they were analyzed through distinct qualitative methods, such as typological analysis (Hatch, 2002) and matrix analysis (Averill, 2002; Miles & Huberman, 1994). Through concurrent data collection and analysis, a local theory elucidating participating teachers' progression over the course of STARTS was generated. Furthermore, STARTS design framework and design principles were revised based on the grounded theory and explicated to establish local impact and general relevance.

The results of this study are useful in that they extend theory about high school life science teachers' progression as CRP Science educators and directly connect this progression to structural features of a research-grounded PD program. Therefore, the results hold implications for the design of PD ventures of this magnitude, which are sorely needed.

Structure of the Findings

The findings of this study are presented in Chapters 4 and 5, which have been prepared in manuscript format. Chapter 4 presents the findings of the grounded theory study, including a conceptual model depicting participating teachers' professional growth as CRP Science educators in the context of the STARTS PD program. Chapter 5 details findings of the typological and matrix analyses through which specific STARTS framework features that supported teachers' professional growth were identified and later revised. While relevant implications for the findings are discussed at the conclusion of each chapter, they are also further explicated in Chapter 6, alongside the limitations of this study.

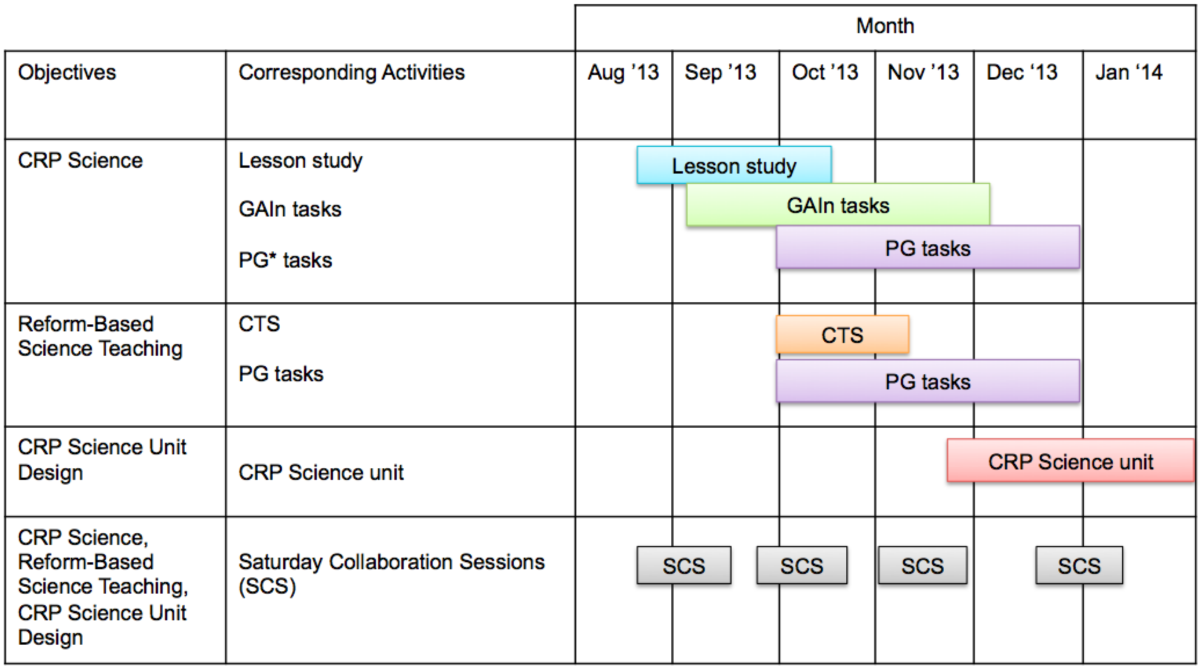


Figure 3-1. STARTS PD program timeline.

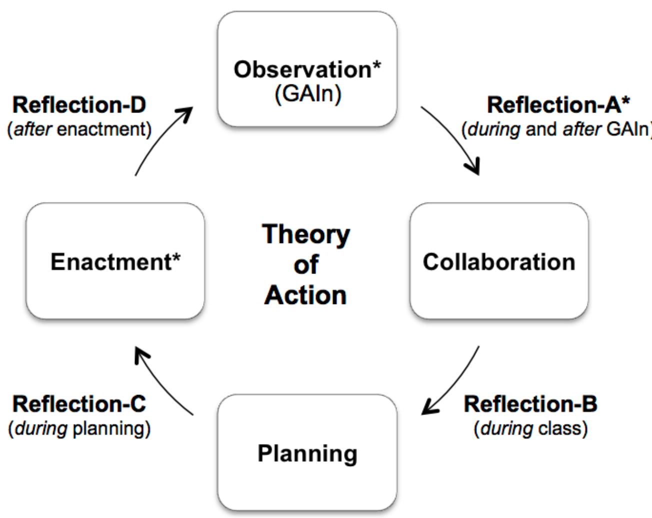


Figure 3-2. Theory of action for the GAIn within a STEM teacher education course that includes a field placement.

Note: *Activities that occur during the field placement.

Reprinted by permission from Brown, J.C. & Crippen, K.J. (in review). The Growing Awareness Inventory: Building capacity for culturally responsive STEM with a structured observation protocol (Page 20, Figure 2). Submitted to *School Science and Mathematics.*

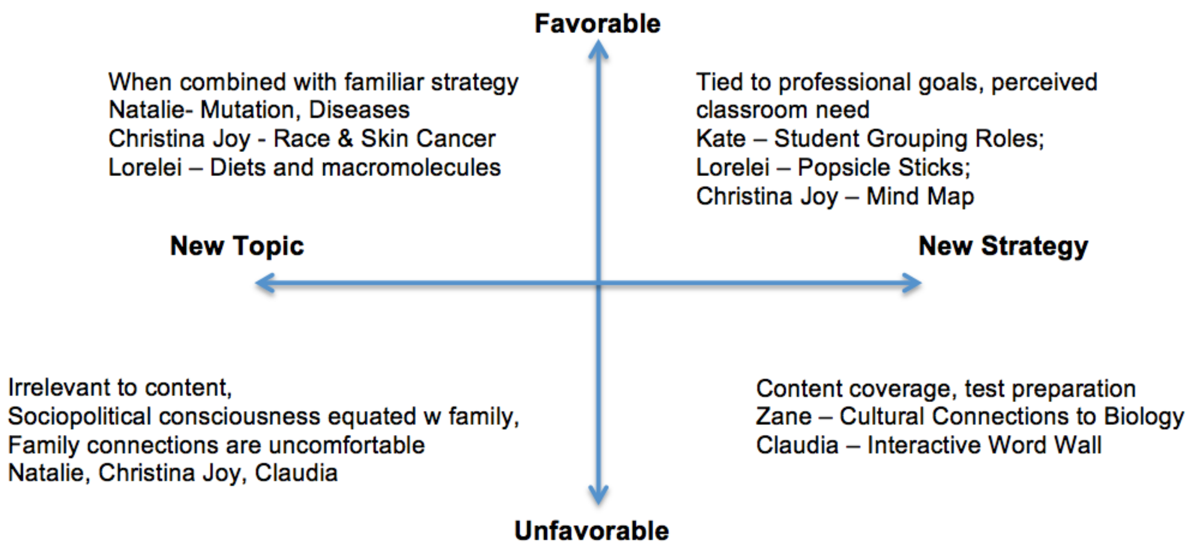


Figure 3-3. Cartesian plane diagram illustrating dimensions of the category, *Toolbox*, which contains new strategies and new topics.

Table 3-1. School demographics.

School	Free and reduced lunch population (%)	Racial minority population (%)	Biology End of Course exam proficiency, mastery (%)
Golf Ridge	64	72	55, 8
Seaside	77	83	52, 7
Palm View	21	33	91, 21
Stars Hollow	34	57	78, 16
Socrates Academy	75	88	52, 6

Table 3-2. Participant demographics.

Teacher	Ethnicity/Race (self-reported)	Years of experience	Subject area(s) taught	School
Christina Joy	White	14	Anatomy & Physiology*, Zoology	Golf Ridge
Claudia	Hispanic	24	ESOL Biology*, General Biology	Seaside
Kate	White	2	Anatomy & Physiology*, Honors Biology	Palm View
Lorelei	Peruvian-American	8	Honors Biology*	Stars Hollow
Natalie	Latina	4	General Biology*	Stars Hollow
Zane	Haitian-American	16	General Biology*, Advanced Placement Biology	Socrates Academy

Note: * asterisk denotes subject area for focus class period.

Table 3-3. Guiding research design.

Research question	Data sources	Data analysis
For high school life science teachers participating in an explicit PD program on CRP Science, what defines the process of becoming culturally responsive educators?	Focus group interviews Classroom observations Field notes STARTS PD artifacts: - BARSTL questionnaire (Sampson et al., 2013) - GAIn tasks - Professional Growth tasks - Reflective Writing Prompts - Mock teaching feedback transcript - STARTS Redesign transcript - CRP Science unit presentations transcripts Focus group interviews Classroom observations Field notes Design Decisions Report	- Grounded theory (Charmaz, 2006; Creswell, 1998; Strauss & Corbin, 1998) - Constant comparison (Strauss & Corbin, 1998)
What features of the STARTS design framework can be associated with supporting the changes in CRP Science knowledge and practices of high school life science teachers?	STARTS PD artifacts: - BARSTL questionnaire - Lesson study document - GAIn tasks - CTS document - Professional Growth tasks - Reflective Writing Prompts - Mock teaching feedback transcript - STARTS Redesign transcript - CRP Science unit presentations transcripts	- Typological analysis (Hatch, 2002) - Matrix analysis (Averill, 2002; Miles & Huberman, 1994) - Constant comparison (Strauss & Corbin, 1998)

Table 3-4. Data collection/analysis stages during the STARTS research and development project.

Data Sources	Project Timeline Data Collection Stage								
	Stage 1		Stage 2	Stage 3	Stage 4			Stage 5	
	Aug ‘13	Sep ‘13	Oct ‘13	Nov ‘13	Dec ‘13	Jan ‘14	Feb ‘14	Mar ’14,	April ‘14
BARSTL questionnaire	X								
Classroom observations*		X	X	X	X	X			
Group interviews			X	X					
Reflective Writing Prompts	X	X	X	X	X	X			
Lesson study documents		X							
Autobiography			X						
GAIn tasks			X	X	X				
CTS document				X					
PG tasks				X	X				
CRP Science units					X	X			
Saturday Collaboration Session artifacts		X	X	X		X			
Clarification Questions (email, phone correspondence)							X	X	X

Note: *The Dec ’13 and Jan ’14 classroom observation dates depended upon when teachers implemented their CRP Science units. Field notes accompany each classroom observation. Design Decisions Report was maintained throughout.

Table 3-5. RTOP subscale reliability estimates; subscales as predictors of RTOP scores.

Subscale	R-squared
Subscale 1: Lesson Design and Implementation	0.915
Subscale 2: Content – Propositional Pedagogic Knowledge	0.670
Subscale 3: Content – Procedural Pedagogic Knowledge	0.946
Subscale 4: Classroom Culture – Communicative Interactions	0.907
Subscale 5: Classroom Culture – Student/Teacher Relationships	0.872
Predictor	R-squared (as predictor of total)
Subscale 1	0.956
Subscale 2	0.769
Subscale 3	0.971
Subscale 4	0.967
Subscale 5	0.941

Reprinted by permission from Piburn, M., & Sawada, D. (2000). Reformed Teaching Observation Protocol (RTOP) reference manual (ACEPT Tech. Rep. No. IN00-3) (Page 10, Table 1; Page 12, Table 2). Tempe: Arizona Collaborative for Excellence in the Preparation of Teachers

Table 3-6. Becoming CRP Science teachers.

Selective codes	Axial codes	Open codes
Views of students	Awareness Sociopolitical elements	Perceiving the classroom environment as not natural, Being forced to think of students and not just content
CRP Science conceptions	Awareness Teacher satisfaction Teacher progression	Acknowledging importance of relevance in instruction, Being culturally responsive means engaging activities Being culturally responsive is rare
Toolbox	Topic vs strategy Family connections	Getting better means new activities and practices, Identifying new techniques, It's natural to build from preexisting lessons
Community building	Creating safe spaces Care	Care is required for students to trust, Care is responsible for positive St-T relationships
Repositioning students	Student grouping Student outcomes	Believing in her students, Perceiving that grouping promotes better work
Instructional changes	Professional growth Connecting science with students Assessment	Seeing old way of questioning as invasive, Gaining deeper understanding of *why* to make instructional strategies

Table 3-7. STARTS activity-outcome matrix.

Activity-outcome	CRP Science conceptions	Views of students	Teaching practices	Community building	Student repositioning	New topic	New strategy
Lesson Study	1 (6%)	6 (16%)	11 (20%)	0 (0%)	0 (0%)	1 (8%)	1 (3%)
GAIn	15 (88%)	29 (76%)	31 (55%)	5 (63%)	0 (0%)	6 (50%)	7 (18%)
CTS	1 (6%)	1 (3%)	9 (16%)	0 (0%)	0 (0%)	2 (17%)	12 (31%)
PG tasks*	0 (0%)	0 (0%)	3 (5%)	2 (25%)	1 (100%)	0 (0%)	9 (23%)
CRP Science Unit	0 (0%)	2 (5%)	1 (2%)	1 (13%)	0 (0%)	1 (8%)	0 (0%)
Sat. Collab. Session**	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	2 (17%)	10 (26%)
Total	17 (100%)	38 (100%)	56 (100%)	8 (100%)	1 (100%)	12 (100%)	39 (100%)

Note: *Professional Growth tasks, **Saturday Collaboration Sessions.

CHAPTER 4
FROM AWARENESS TO PRACTICE: CONCEPTUALIZING HIGH SCHOOL SCIENCE TEACHERS' PROGRESSION AS CULTURALLY RESPONSIVE EDUCATORS

Introduction

As the United States experiences population growth greater than any other industrialized nation (El Nasser, 2006; El Nasser & Overberg, 2011), unequal increases among populations have transformed the nation's demographics. The U.S. population is now more diverse than ever before. Simultaneously, the notion of education as the great equalizer has been challenged, as achievement disparities stratified by race and socioeconomic status persist across all academic disciplines and grade levels (Kelly-Jackson & Jackson, 2011; National Center for Education Statistics [NCES], 2010; National Assessment of Educational Progress [NAEP], 2009). Black and Hispanic students consistently underperform on national science assessments, and this trend spills over to the science, technology, engineering, and mathematics (STEM) workforce, which remains largely exclusive in terms of race (NSF, 2011).

Current U.S. educational practices leave a significant portion of the nation's citizens undereducated (Howard, 2010). A majority of STEM professions require some form of postsecondary or advanced degree. This further constrains the workforce population, as higher education attendance rates for students from these underrepresented racial groups are lower when compared to White and Asian students (Aud et al., 2011). With a growing number of 21st century occupations requiring scientific literacy, the exclusion of diverse populations from the STEM workforce constricts economic opportunities, making it considerably more difficult to pursue liberties such as access to quality housing, healthcare, and education (Aud et al., 2010; Bullard, 2001). Accordingly, there are both social and economic implications for this trend.

In an attempt to address the persistent achievement gap in science by race and socioeconomic status (NAEP, 2009), the National Research Council's (NRC) (2012) most recent science education reform report, *The Framework for K-12 Science Education*, has made prominent a desire to achieve Science for All through curriculum and instruction. A growing research base argues for the integration of students' cultures with science instruction as a way to bridge incongruences between home and school, thereby making science more accessible and meaningful to students that are traditionally underrepresented in the discipline (Aikenhead & Jegede, 1999; Calabrese Barton, 1998; Lee, 2004).

Culturally responsive pedagogy (CRP) (Gay, 2010; Ladson-Billings, 1994; 1995) aims to strengthen the academic performance of diverse students by "using the[ir] cultural knowledge, prior experiences, frames of reference, and performance styles" (Gay, 2010, p.31) to make learning opportunities more equitable and effective. When implemented, CRP bolsters the academic achievement (Ladson-Billings, 1995; Weinstein, Tomlinson- Clarke, & Curran, 2004) and engagement of diverse students (Gay, 2010; Howard, 2010). Despite the potential of CRP to ameliorate current academic trends, it is not widely enacted (Bianchini & Brenner, 2010; Patchen & Cox-Petersen, 2008). Teachers report feeling underprepared to educate diverse students (Song, 2006) and struggle with teaching in ways that are culturally responsive (Patchen & Cox-Petersen, 2008). Because of the great influence teachers have on student learning and the promise of CRP to positively impact underrepresented students' academic performance, the development of teachers as culturally responsive science educators must be supported. Few professional development (PD) initiatives have aimed to support teachers' professional growth in this manner; yet, to foster educational equity for diverse students, such programs are an imperative.

The STARTS (Science Teachers Are Responsive To Students) PD program was created as a response to this imperative. As such the program was designed to prepare teachers to enact culturally responsive pedagogies in science education (hereafter referred to as CRP Science) and design and implement academically rigorous instructional materials that meaningfully incorporate students' backgrounds. This grounded theory study seeks to address the research question: *for high 1983ool life science teachers participating in an explicit PD program on CRP Science, what defines the process of becoming culturally responsive educators?* In this paper I present a local theory of high school life science teachers' progression as CRP Science teachers in the context of the STARTS PD program. According to McKenney and Reeves (2012), "local theory is produced when limited manifestations of a certain phenomenon are studied. . . this kind of work results in understanding of learning within specific ecological contexts (and not across a wide range of settings)" (p.35). To describe participants' progression as CRP Science teachers, I present a conceptual model and articulate the relationships among six themes characteristic of their professional growth over time. Accompanying the teacher progression model and supporting temporal narratives are descriptions of the program activities at each phase, thereby advancing knowledge about potential relationships between the process of teachers' professional growth and PD structures.

Theoretical Framework – Culturally Responsive Pedagogy

The foundations of CRP Science are grounded in Ladson-Billings' (1994; 1995) theory of culturally relevant pedagogy and Gay's (2010) scholarship on culturally responsive pedagogy. In this section I will detail the work of Ladson-Billings (1994;

1995) and Gay (2010), paying specific attention to the characteristics of teachers who enact CRP before presenting a description of CRP Science that is grounded in the relevant literature.

Stemming from her work with successful teachers of African American students, Ladson-Billings (1994) first described culturally relevant teaching as assisting students in “the development of a ‘relevant black personality’ that allows African American students to choose academic excellence yet still identify with African and African American culture” (p.17), thus promoting cultural competence. According to Ladson-Billings (1995), culturally relevant teachers create learning environments that affirm students’ identities and backgrounds, thereby providing a means for students to “maintain their cultural integrity while succeeding academically” (p.476). Culturally relevant teaching emerged at a time when much of the work regarding African Americans and education was approached from a deficit perspective, often describing the academic underperformance of African American students as a result of what they lacked in terms of educational resources and support. In contrast, CRP positioned education from an asset-based mindset and focused on empowering students intellectually, emotionally, and politically. Ladson-Billings (1994) found that teachers with culturally relevant practices embodied three distinct attributes: conceptions of self and others, social relations between teacher and student, and conceptions of knowledge.

Teachers with culturally relevant conceptions of self and others hold their students and their profession in high regard. These teachers view teaching as an art, believe all students can succeed, see their profession as a way to give back to the local community, and recognize "*who* students are and how they are connected to wider communities" (p.49, italics in original). Culturally relevant teachers organize fluid and equitable social relations in their classrooms, encourage collaborative learning, demonstrate connections with all students, and emphasize community. A teacher who espouses culturally relevant conceptions of knowledge "attempts to help students understand and participate in knowledge-building" from a critical perspective (Ladson-Billings, 1994, p.81). Teachers who enact CRP are passionate about the content they teach, view knowledge as dynamic and shared by students and teachers, and act as facilitators.

When Gay (2010) first wrote of culturally responsive pedagogy, she suggested it was a compilation of various pedagogies that make use of students' cultures in the process of learning, including the work of Ladson-Billings (1994; 1995). Gay (2010) identified several characteristics of CRP, describing it as validating, comprehensive, multidimensional, empowering, transformative, and emancipatory.

Culturally responsive teachers validate students by acknowledging their cultural heritages, using these backgrounds as a bridge between school, and home, and incorporating multicultural resources in the curriculum, regardless of content area. Teachers who enact CRP provide a comprehensive education for diverse students in that they teach the whole child, purposefully developing skills, knowledge, attitudes, and values. As a result, educational excellence transcends academic performance to also include learning outcomes such as "cultural competence, critical social consciousness, political activism, and responsible community membership" (Gay, 2010, p.33).

CRP is multidimensional because its scope extends beyond curriculum materials to account for teacher-student relationships, creating a community-based classroom climate, instructional techniques, and assessment strategies. In this regard, Gay's (2010) description of CRP as multidimensional strongly resembles Ladson-Billings' (1994) notion of social relations. The unrelentingly high expectations a culturally relevant teacher holds for her/his students are the basis for CRP as empowering. Similar to Ladson-Billings' (1994) conceptions of self and others, such teachers believe all students are capable of academic success and commit themselves to facilitating this success. The transformative nature of CRP arises from its commitment to confronting oppression, power differentials, and development of social consciousness. Finally, because CRP supports intellectual liberation, it is deemed an emancipatory pedagogy. Gay (2010) argues that not only is knowledge from diverse ethnic populations made accessible, students are taught to apply this knowledge to their learning experiences, thus helping "students realize that no single version of 'truth' is total and permanent" (p.38).

The foundation of culturally responsive pedagogy (Gay, 2010) in culturally relevant pedagogy (Ladson-Billings, 1994; 1995) is obvious in many respects, while also extending the work of Ladson-Billings (1994) through clearly articulated applications to curriculum and instruction. Due to their similarities, the two are often used interchangeably. Together they provide a rich, evidence-based view of successful teachers of diverse students and an ideal to strive toward in teacher education. Within the field of science education, several scholars have utilized these pedagogies as a means to disrupt prevailing conceptions of science, increase underrepresented students' academic success, and engage learners in science practices that lead to social action within the community.

Literature Review – Educating Culturally Responsive Science Teachers

CRP Science reflects several attributes of culturally relevant and responsive pedagogies in that it (a) contextualizes instruction in students' lives and experiences (Basu & Calabrese Barton, 2007; Calabrese Barton, 1998; Mensah, 2011); (b) engages learners in inquiry (Bianchini & Brenner, 2010; Kelly-Jackson & Jackson, 2011); (c) occurs in respectful and inclusive learning environments where multiple perspectives are acknowledged (Lee, 2004; Elmesky & Tobin, 2005) and language supports are widely implemented (Lee, 2004; Johnson, 2009); (d) uses science as a platform to uncover negative stereotypes and biases (Brown, 2013; Tate et al., 2008; Laughter & Adams, 2012); and (e) frequently establishes genuine, community-based partnerships to support social action projects (Bouillion & Gomez, 2001; Fusco, 2001). CRP Science stands in stark contrast to traditional science instruction, which features teacher-centered transmission of jargon-heavy concepts, reliance on textbooks as the primary source of information, and concepts taught as discrete bits of information (Akkus et al, 2007; De Boer, 1991; Martin, Mullis, Gonzalez, & Chrostowski, 2004). However, traditional science instruction still pervades today's classrooms.

For teachers to simultaneously implement reform-based science according to the *Framework* (NRC, 2012) and to connect instruction to students' lives, they must possess a wealth of knowledge, skills, and dispositions. To be culturally responsive and reform-based, science teachers must command deep content knowledge, topic-specific pedagogical content knowledge, and provide authentic learning experiences rich in scientific practices, disciplinary core ideas, and crosscutting concepts (NRC, 2012). In addition, they must impart care, promote a sense of community in the classroom, use instruction to uncover oppression, and foster students' cultural competence (i.e., supporting them in academic success that does not run counter to, or at the expense of, their identities) (Gay, 2010; Ladson-Billings, 1994; 1995; Powell et al., 2011; Villegas & Lucas, 2002). Compounding the challenges inherent in personifying these practices, many science teachers are already at a disadvantage because they tend to teach in the same traditional ways they were taught as students (Hammerness et al., 2005; Lortie, 1975). Hence, professional development of practicing teachers is necessary to support their growth.

There have been few instances of PD programs designed to prepare CRP Science teachers (e.g., Lee, 2004; Johnson, 2011). Zozakiewicz and Rodriguez (2007) presented the Project Maxima initiative, which was built from sociotransformative constructivist principles (Rodriguez, 1998) and designed to support fourth- through sixth-grade teachers in establishing more inquiry-based, culturally relevant, and gender-inclusive science instruction. The authors modeled CRP Science and invited critique of their practices as a way to assist teachers in establishing culturally relevant classroom environments. Structured reflection times were planned during monthly meetings and summer institutes, providing the participants and authors with opportunities to discuss how modeled activities were multicultural and gender inclusive. Participants were also asked how they might further modify such activities to fit a particular grade level and context. Additionally, the research team made themselves available to teachers as they struggled with implementation, providing both ongoing support and the use of science equipment.

Participants reported that modeling CRP Science was one of the most influential factors affecting their practice. Additionally, teachers viewed ongoing support as a valuable resource as they began teaching in reform-oriented ways and with new instructional materials. The authors noted that, despite Maxima's successes, they still encountered teacher resistance. To challenge entrenched teaching practices and advance CRP Science, Zozakiewicz and Rodriguez (2007) suggest, "making teaching for diversity a central construct in teacher professional development" (p. 422). While this work showcases a much-needed form of PD and begins to articulate connections between program activities and teachers' reported outcomes, absent is rich detail about the process of becoming culturally responsive, gender-inclusive science teachers.

While literature on teacher development abounds (e.g., Clarke & Hollingsworth, 2002; Hammerness et al., 2005), and specifically on teacher development in the context of PD (e.g., Bell & Gilbert, 1994; 1996; Gregoire, 2003), there are few examples of PD literature exploring the process of teachers' growth as CRP Science educators (e.g., Lee, 2004; Johnson, 2011; Zozakiewicz & Rodriguez, 2007). Furthermore, of these isolated instances, missing is explicit attention to the relationship between the teacher change process and accompanying structural supports. Yet, to best design PD programs capable of supporting teachers' growth as culturally responsive science educators, focus on *process* and *structure* is required. There must be an understanding about the conditions under which the process is facilitated. This study will respond to the call by Sleeter (2012) for research on the impact of CRP projects, including how teachers learn to become culturally responsive. In addition, the research will build upon the work of scholars who design PD for CRP Science (e.g., Lee, 2004; Johnson, 2011;

Zozakiewicz & Rodriguez, 2007), to generate a grounded theory of the process of high school science teachers' becoming CRP Science teachers – paying particular attention to PD structures supporting this process.

Context – STARTS Professional Development

The STARTS PD program was designed for use with high school life science teachers working in five ethnically and linguistically diverse public schools throughout a large school district in the Southeastern United States. The overall aim of STARTS was to prepare high school life science teachers working in these diverse schools to best meet their students' academic needs through culturally responsive, inquiry-based science instruction.

The STARTS program was grounded in bodies of research in the following areas: teacher change in PD environments (Bell & Gilbert, 1994; 1996) effective PD design (Capps et al., 2012; Garet et al., 2001; Loucks-Horsley et al., 2010), CRP (Gay, 2010; Ladson-Billings, 1995; Villegas & Lucas, 2002), reform-based science education (NRC, 2000; 2012), and curriculum design and enactment (Park & Coble, 1997; Stolk et al., 2011). The STARTS PD program was based upon the premise that through job-embedded, ongoing PD that is responsive and contains a dual-focus on science content and pedagogy, teachers' knowledge and practices will be transformed specifically, into a more culturally responsive, inquiry-based form. Furthermore, central to the STARTS program design was the argument that teachers of culturally and linguistically diverse students must be aware of the influence of culture on learning (Aikenhead & Jegede, 1999; Emdin, 2011), their beliefs about students and science teaching, the political nature of schooling (Darling-Hammond, 2010; Jackson, 2009), the importance of relationship-building between teachers and students (Hondo et al., 2008; Valenzuela, 2005), and effective subject-specific CRP strategies (Brown, 2013).

Building responsive classroom environments, connecting students' backgrounds with science instruction, and enhancing culturally congruent discourse were among the program foci. To further situate CRP Science within existing classroom practices, supporting teachers' use of several reform-based science practices were also features of the program. These included practices such as asking questions, analyzing and interpreting data, constructing explanations from evidence, and communicating scientific information (NRC, 2012).

The STARTS program occurred through six major activities in a blended learning environment. Teachers engaged in a modified lesson study (Lewis et al., 2006) to initiative a reflective practitioner stance in which they systematically explored the ability of their instruction to impact intended student outcomes. They also completed a series of three *Growing Awareness Inventory* (GAIn) tasks (Brown & Crippen, in review) to critically examine their classroom environment. These included student-student and student-teacher interactions, learning about students' lives both in and out of school, and suggesting relevant instruction from these findings. In preparation for designing their CRP Science units, teachers also completed a Curriculum Topic Study (CTS) (Keeley, 2005). The completed CTS document provided a scaffold for integrating reform-based science teaching (via CTS findings) with CRP Science teaching (via GAIn findings). In order to ensure that the program was continually responsive to teachers' needs (Loucks-Horsley et al., 2010) several Professional Growth (PG) tasks were also designed. The PG tasks centered on areas of professional growth that the teachers expressed a desire in learning more about, such as formative assessment. To address the lack of available CRP Science materials (Lee, 2004; Mensah, 2011), as their capstone project the STARTS teachers designed CRP Science units that were responsive to their students' backgrounds and needs. Teachers participated in ongoing, face-to-face Saturday Collaboration Sessions, which served as the main forum for collective participation. During these sessions, the author modeled CRP Science strategies, teachers brainstormed lesson ideas, discussed readings on CRP Science, and mock-taught select CRP Science lessons.

While participating in STARTS, teachers focused in on their students at two levels. The first level of focus was classroom-specific. Teachers were asked to select one of their class periods to follow throughout the program. It was expected that teachers would connect instructional decisions and insights to interactions and outcomes in this classroom. The second level of focus was student-specific. Within the selected classroom, teachers were asked to choose 4-5 "focus group" students to follow closely. Analyses on and input from these students were used to gauge lesson study effectiveness, to hone in on during the GAIn tasks, and to connect data analysis and resulting suggestions with instruction. The choices were up to the teacher and included choosing students who had "promise," students who were more eager to communicate with the teacher, and students who were disengaged.

For this study, the STARTS PD program was designed to support science teachers through the processes of: (a) developing culturally responsive knowledge and practices, (b) developing reform-based science instructional practices, and (c) designing CRP Science instructional materials aligned with state and national science education standards, district-mandated pacing guides, and End of Course exam content. Similar to Johnson (2011), I refrain from claiming that the STARTS PD in itself “was the sole variable in transforming practice” (p.175), but do contend that STARTS experiences, alongside additional activities, enabled participating teachers to develop culturally responsive knowledge, practices, and instructional materials. Therefore, this paper will describe the temporal shifts in STARTS teachers’ CRP Science knowledge and practices as well as present a conceptual model of their professional growth.

Methods

Setting and Participants

The STARTS PD program took place in five diverse high schools in a large school district in the Southeastern United States. The program was situated within a larger, district-funded STEM reform initiative aiming to increase the rigor and accessibility of K-12 STEM education. The district student body is racially and linguistically diverse, with approximately the same percentage of Black, Hispanic, and White students (Hispanic, Black, and Other Race students are classified as “minority” by the district). One of the five high schools from this study mirrored the district’s racial demographics, three schools enrolled greater than 75% racial minority students, and one school was predominantly White. The three schools serving the largest minority student populations were also receiving Title I funds. Among all five high schools, an average of 65% of the student body had achieved proficiency on the state biology End of Course exam, which is required for graduation. However, only 13% of the entire student body had achieved mastery (a score of 4/5 or 5/5 total points).

Six life science teachers from throughout across the five high schools participated in this study. All participants were female, but represented various races and ethnicities as well as years of teaching experience. The teachers all taught some form of high school life science subject, but ranged in the level (e.g., General, Honors) and focus (e.g., Biology with a concentration on English for Speakers of Other Languages [ESOL Biology]). The author began working with and recruiting the six participating teachers during a separate weeklong content-focused summer PD institute. When asked to explain their desire to participate in the STARTS PD program, teachers' responses ranged from general (enhance their teaching abilities) to specific (develop strategies to incorporate students' cultures into science instruction).

Data Collection

Data were concurrently collected and analyzed in multiple stages (Table 4-2). According to Charmaz (2006), grounded theory data are "detailed, focused, and full. They reveal participants' views feeling, intentions, and actions as well as the contexts and structures of their lives" (p.14). To produce rich and thorough descriptions of teachers' CRP Science conceptions and practices over time, numerous data sources were collected in five stages with ongoing analysis supporting the theoretical sampling of new data sources (in addition to pre-established data sources).

Each teacher was observed six times, once a month during the second through fourth months and on three occasions during CRP Science unit implementation. Each observation was video-recorded, transcribed verbatim, and field notes were produced. The field notes contained a chronological breakdown of individual and collective actions, statements, and discernable feelings as well as summaries describing significant processes that were characteristic of CRP and/or CRP Science. Furthermore, STARTS artifacts, such as teachers' completed GAIn tasks and Reflective Writing Protocol (RWP) responses, were collected as they were completed by participants and subsequently analyzed for potential themes. Because the Saturday Collaboration Sessions served as the main structure for brainstorming new lesson ideas, trying out new CRP Science strategies, and receiving feedback, multiple activities were video-recorded and later transcribed as well. These activities and their accompanying data sources are identified next.

The Saturday Collaboration Sessions demarcated each data collection stage. In between each Saturday Collaboration Session, teachers were engaged in various STARTS activities and their classrooms were observed. At each stage the data were read holistically, open-coded by incident, and preliminary patterns and trends in their CRP Science knowledge and practices were recorded in a reflexive journal (Lincoln & Guba, 1985), which was maintained through the entire study. Journal entries were connected to an ongoing Design Decisions Report (DDR) in which any PD design decisions were revised based on emergent findings. For example, as the program progressed, teachers consistently abstained from establishing partnerships with students' family members. Though connecting science content with families' funds of knowledge had been discussed previously, a PG task specifically devoted to practical ways to connect science with families was designed and implemented during the third stage.

During the first stage of data collection and analysis, teachers completed the preliminary *Beliefs About Reformed Science Teaching and Learning* (BARSTL) questionnaire (Sampson, Enderle, & Grooms, 2013) in order to assess their initial beliefs about how science should be taught and learned. They also engaged in lesson study, participated in the first Saturday Collaboration Session, and had their classroom practices observed for the first time. In the second stage, teacher-completed GAIn 1 tasks, autobiographies, and RWPs were examined. Additionally, the first group interview, second observation, and second Saturday Collaboration Session were held. These three sources were video-recorded and transcribed. In the third stage, STARTS activity artifacts such as the second GAIn task, PG tasks, CTS working document, and RWPs were collected and examined. At this time, a third round of classroom observations was conducted. Teachers also attended the third Saturday Collaboration Session in which they engaged in a second group interview, completed a mock teaching session, and provided feedback on the mock teaching activity. All activities were video-recorded and transcribed. During the fourth stage teachers completed all PG tasks, the third GAIn task, and their CRP Science unit templates. Teachers presented their CRP Science units during the final Saturday Collaboration Session and also participated in a STARTS redesign session in which they provided feedback about the structure and nature of the major activities. Both the CRP Science unit presentations and STARTS redesign session were video-recorded and transcribed verbatim. There was also a final concurrent data collection-analysis stage after the fourth Saturday Session. This allowed additional time for any remaining teachers to finalize their CRP Science units. At this time, additional data collection associated with theoretical sampling was also completed. These were often responses to clarification questions collected via email and phone correspondence.

Data Analysis

To understand high school life science teachers' progression as teachers of CRP Science within the context of the STARTS PD program, I employed multiple techniques to assure the methodological rigor of qualitative research, including numerous data sources, multiple stages of analysis, frequent and repeated observation, prolonged engagement, member checking, and an audit trail (Creswell, 2009; Guba & Lincoln, 1989). Additionally, I maintained a reflexive memo-writing journal (Charmaz, 2006) throughout the program, which included reflective notes after each Saturday Collaboration Session, my preliminary analyses, and suggestions for upcoming STARTS activity content based on teachers' emerging needs.

Grounded theory is an appropriate method for examining interactions between individuals or among persons within specific contexts (Charmaz, 2006; Strauss & Corbin, 1998), particularly when a weak literature base exists. Specific attention is paid to the process, action, and the structure within which these are situated, thereby providing rich data sources later used to construct theory from participants' views (Creswell, 2009; Strauss & Corbin, 1998). Grounded theory analysis techniques include open, axial, and selective coding, with the overall aim to move from concrete to abstract through theory generation. Researchers utilizing grounded theory familiarize themselves with existing theories and concepts to develop sensitivity to potential meanings within the data. However, as Charmaz (2006) warns, "such approaches preclude ideas from emerging as you code events" (p. 48). Thus, theories should be set aside as data are initially explored for categories. To reduce the potential for distorting messages within the data, I also engaged in the process of constantly comparing data sources to each other.

According to Strauss and Corbin (1998), grounded theory analysis begins with open coding, in which "categories are discovered in data and developed in terms of their properties and dimensions" (p.102). First, I organized the data sources in

HyperRESEARCH (qualitative data management software) as they were collected. I examined my reflexive journal entries to identify any potential emerging codes around teachers' progression in CRP Science knowledge and practices. Student grouping and student-teacher interactions were two areas of initial focus, as I had observed changes to this end over time in classroom observations. I also paid special attention to any data passages related to family connections and sociopolitical consciousness-raising, as these were areas that teachers infrequently exhibited in their practices. At the end of the first four stages of data collection and analysis, I conducted a more systematic approach to open coding than the incident-by-incident approach previously employed. I began line-by-line coding the group interview transcripts. Like Charmaz (2000), I broke data into single, sensible units and then labeled the actions and meanings portrayed in each unit. Table 4-1 contains a list of preliminary codes including *perceiving that grouping promotes better work*, *getting better means new activities and practices,* and *building relationships with students*. As I progressed through open coding, potential categories began to emerge. These categories were based on either (1) frequency of related codes, (2) multiple representations/facets of a certain process (i.e., properties of codes, Strauss & Corbin, 1998), or (3) potential categories from my reflexive journal. Examples of early potential categories included*: student grouping, teacher scaffolding, family collaboration,* and *sociopolitical consciousness*. I also kept memos of possible conceptual categories as a way to manage the data as I coded them, which were added to my journal.

I then engaged in axial coding to further develop categories according to their properties and dimensions. The related codes were consolidated in HyperRESEARCH according to their similarity in meaning or relation to the categories (Strauss & Corbin, 1998). To explore progression and not just action in a given time period, I also looked across the codes over time. Therefore, I further grouped the coded passages and their emerging categories according to the time in which they occurred (ex: the first group interview occurred several months prior to the CRP Science unit presentations). This resulted in chunks of open codes associated with a developing category over a timeline. Examples of developing categories during this stage of analysis included: *professional growth* (as process), *awareness* (as a state of being), *connecting science with students* (as an action), *teacher satisfaction* (as a state of being and an outcome), and *toolbox* (as an object supporting teacher change). These categories were compared across the teachers and over time periods.

To further develop the categories, I went back to their associated codes to identify properties (i.e., attributes) and dimensions (i.e., range of properties of a category) (Strauss & Corbin, 1998). At this time, I explored which codes were outliers and which codes were more distantly and closely related to one another, if at all. Codes that no longer appeared relevant to the data were removed.

At this point, I constructed Cartesian planes for each category to visually represent the dimensions along which a category ranged. Figure 4-1 illustrates a Cartesian plane for the developing category, *toolbox*, which contains the properties *new topics* and *new strategies*. At this phase of analysis, the dimensions ranged from favorable to unfavorable conditions for the incorporation of a new strategy or relevant science topic to existing instruction. For example, in the top left quadrant are conditions in which it was favorable for STARTS teachers to apply relevant topics to existing science content in the curricula, such as when the topic was combined with a previously used instructional strategy. In the bottom right quadrant are instances in which the application of a new strategy was unfavorable, including the need to cover content and prepare students for the End of Course exam. By articulating the range along which categories existed, I was better able to discern the conditions (where, when, how, and why) associated with a category (Strauss & Corbin, 1998). Additionally, I engaged in theoretical sampling (Charmaz, 2006) for emerging categories that still had ambiguous dimensions (e.g., *repositioning students*). To develop these dimensions further, I sought pertinent data from participating teachers, largely through phone and email correspondences. As I developed richer understandings of the categories, I revised their labels as needed (ex: *connecting science with students* was merged into *instructional change*) and wrote detailed memos describing their properties, all of which were supported with evidence passages. Because the codes were now consolidated according to source (and, therefore, relative time), I looked for relationships, additional properties/dimensions of a code, and where they could be further consolidated.

Once salient categories were identified, I utilized selective coding to integrate and refine them further. Many of these categories and their associated properties/dimensions were repetitive among data sources, including those obtained through theoretical sampling, thus indicating that theoretical saturation had been attained. This resulted in six themes associated with high school life science teachers' progression as CRP Science teachers, which are listed in Table 4-1. I wrote statements that articulated the observed relationships between themes. Finally, I created a narrative reflecting the temporal progressions of these themes and their supporting relational statements. In the narrative, I looked closely for shifts in teachers' CRP Science knowledge and practices, paying special attention to describe these shifts according to their defining properties. The resulting narrative further allowed me to articulate dimensions of the categories.

Becoming a CRP Science Teacher

In my examination of the process high school life science teachers undergo as they become CRP Science teachers within the context of the STARTS PD program, six themes emerged from the data: views of students, CRP Science conceptions, utilizing a toolbox, community building, repositioning students, and instructional changes. These themes are presented as a conceptual model (Figure 4-2). To explore potential relationships between process and supporting structures, my discussion of the data includes teachers' shifts in CRP Science conceptions and practices over distinct time periods according to major STARTS program activities. I begin with an overview of the findings, which are highlighted in the time-ordered matrix (Miles & Huberman, 1994) to illustrate the process of becoming a CRP Science teacher (Table 4-3).

For the six high school life science teachers participating in the STARTS PD program, becoming a CRP Science teacher involved a process of moving from awareness to action. STARTS teachers developed an awareness of CRP Science knowledge, their students, and a toolbox (i.e., a cache of responsive instructional strategies and relevant science topics). As their awareness deepened and expanded, teachers translated their awareness to action through specific instructional changes, repositioning students, and community building. For STARTS teachers, there was a specific instructional pace associated with becoming a CRP Science teacher. As teachers became more student-centered and culturally responsive they made adjustments to their practice that temporarily slowed their normal instructional pace. Teachers elicited students’ prior knowledge, continually gauged student understanding through formative assessment techniques, implemented new instructional strategies that were responsive to student needs, engaged students in multiple science practices, and dove deeper into relevant science topics in an attempt to make them more relatable to students’ lives. Though these adjustments temporarily impacted the amount of material STARTS teachers covered, they observed greater student engagement and deeper learning.

This slower pace was also a result of getting to know their students more deeply, which accompanied changing views of students over time. The views that teachers held of their students progressed from general and assumption-laden at the beginning of the program to specific and connected to students’ lives both in and out of school. As they learned about their students and engaged in STARTS program activities, teachers’ CRP Science conceptions expanded from initially narrow and focused on race to considering power relations and seeing culture as an asset, and, ultimately, to the translation of knowledge about students to classroom practices intended to empower their students.

For this group of teachers, there was also repositioning associated with becoming a CRP Science teacher. As STARTS teachers’ views of students became more informed by what they were learning about their students, they began to reposition students and shift authority in the classroom by utilizing novel instructional strategies from their toolbox. This repositioning had three components, student, teacher, and instructional. Students took on new roles in the classroom and were repositioned as experts and leaders, whereas at the beginning of the STARTS PD program they had a more passive role. The teacher component involved a shifting of authority over time. The relationships between STARTS teachers and their students became more fluid (Ladson-Billings, 1994), which led to new teacher roles. Teachers first spoke of students as capable, then began to articulate a connection between themselves as caring educators and forging meaningful student-teacher relationships. Finally, they decreased students' dependence on them, giving students more control over their assignment choices and classroom interactions.

The instructional component that accompanied student repositioning pertained to the increased use of cooperative learning structures and involving students in creating products together. Furthermore, students' roles in the learning process shifted as well; they were treated as constructors of knowledge as opposed to receivers. For instance, students' self-reflection on their performance and understanding during assignments became characteristic of STARTS teachers' classrooms.

The STARTS teachers emphasized community building within their classrooms. Community building is the action through which they empowered and repositioned students by changing their instruction (e.g., cooperative learning activities) and enacting care. Their attempts to build respectful and equitable learning environments with students were fueled by more than increasing achievement; it was done to "give voice to those who've been silenced in the science classroom" (Zane, Observation 3 debrief). Over time, their purposes for building classroom communities grew. Community building became a way to foster "emotionally safe" spaces (Zane, Group interview 2), student-student interaction, and academic conversations.

The student repositioning and community building associated with becoming a CRP Science teacher yielded instructional changes, where emphasis on content during planning was decreased and instead emphasis on students became a top priority. Collaborative learning became a prominent feature of the STARTS teachers' classrooms over time. Such instructional changes accompanied STARTS teachers who took time to learn about students' lives in and out of school through the lesson study and GAIn tasks. They were also exposed to and asked to utilize a toolbox of responsive instructional strategies and relevant science topics through the Saturday Collaboration Sessions and PG tasks, and purposefully connected these findings to instruction through the CRP Science unit template. As a consequence of changing their instruction, repositioning students, and community building, STARTS teachers observed their students engaging more meaningfully in academic conversation, performing better on classroom assignments, and becoming more autonomous.

Time 1 – Beginning Conceptions

CRP Science Knowledge

> Where I am at [high school], it's very homogenous it's mostly White kids…I didn't even think I could be in here [STARTS program]. Now I see that you could bring in language or culture or food or something like that. (Kate, Saturday Collaboration Session 1)

The initial CRP Science conceptions of teachers were simplistic, often focused on race, and ignored power relations. Kate conveys this in the quote above, describing CRP Science in a way that Sleeter (2012) refers to as cultural celebration. According to Sleeter (2012) viewing CRP as a cultural celebration disconnects culture from academic learning and is a common tendency among teachers who have not critically examined their expectations of underrepresented students. When teachers engage in cultural celebration they view learning about culture as an end to itself, thereby overlooking students' backgrounds as resources to be utilized for learning. Occasionally, the teachers' conceptions of CRP Science centered on facilitating academic learning, but this came through as including "students' likes and dislikes" in instruction (Natalie, RWP 1). Furthermore, CRP Science was viewed by some of the teachers as potentially offensive. They saw it as lumping students into forced categories (based on ethnicity) that they might not necessarily associate with. Natalie speaks of this when discussing potential issues while designing instruction based on students' backgrounds, which she asserts, "must be done with tact and caution without looking too stereotypical. Some students may be offended when you are trying to cater the lesson to their ethnic likings, when you may come across insulting" (RWP 1).

When they talked about being culturally responsive teachers, the STARTS teachers spoke of caring for and being respectful of their students. They described care as having nurturing feelings for students, attending to their emotional needs, and providing them with "a lot of hands-on activities" (Claudia, Lesson study document). Much like the account Bondy, Ross, Hambacher, and Acosta (2013) provide of Dianna, a White first year teacher working with African American students, STARTS teachers spoke of their "own caring actions but not about [their] connectedness to the students and their families" (p. 442). Although there was no direct evidence to support that connections between the teachers and students' families were being forged, the teachers did articulate that in order to care for and be respectful of students, they needed to learn more about students' personal lives. When teachers described their students, these comments were largely assumption-based, referring to previous experiences with other students as their basis for characterizing the students they were currently educating. When teachers rely on assumptions and previous experiences to characterize their students, particularly with diverse students, they run the risk of holding stereotypical and deficit-based views (Ladson-Billings, 1995; Tutwiler, 2007), which negatively impacts the rigor of the learning experiences they provide (Howard, 2010). Though there was no evidence that STARTS teachers openly provided less challenging learning experiences for their diverse students, their instruction was also not reflective of CRP Science.

Accompanying Instructional Practices

> I tend to introduce the material, have students interact with the material in some way and then test them on it. (Christina Joy, RWP 2)

In the first months of the STARTS program, science instruction was primarily teacher-directed and consistent with their reported beliefs about the ways that science should be taught and learned. For example, Zane and Claudia both communicated beliefs about teaching and learning science that were incongruent with CRP Science and reform-based science teaching. They both disagreed that "students should do most of the talking in science classrooms" and "a good science curriculum should focus on the history and nature of science and how science affects people and societies" (BARSTL questionnaire). For Christina Joy, attending to students' questions were seen as counterproductive to covering content. "I have gone off topic for a short bit to answer something relevant a student has brought up" (RWP 1), suggesting that at this time students' inquiries was viewed as a distraction to achieving set lesson objectives. According to Ladson-Billings (1994), the comment made by Christina Joy is representative of an assimilationist and static conception of knowledge in that it "passed in one direction, from teacher to student" (p.81). A classroom environment like this constrains opportunities to elicit and build on students' prior knowledge, thereby reducing deep learning (Bransford, Brown, & Cocking, 2000).

Teachers spoke of translating their knowledge of CRP Science into practice via differentiated instruction, though no elaboration was given as to how this is accomplished nor was it witnessed in classroom observations. Furthermore, some of the teachers expressed tension with differentiating instruction, as it was perceived to produce insufficient instructional rigor. Lorelei articulated this sentiment when she said, "The teacher [should] not adapt the lesson to fit the needs of the students [because the] students' ability level should be challenged" (GAIn 1).

During lesson study, teachers were introduced to exploring the impact of their teaching on student outcomes in a systematic manner. By measuring student outcomes in relation to lesson objectives that were designed for them, the teachers began to examine how well their practices facilitated intended outcomes. They reported that this was the first time they had formally examined their actual versus intended practices. As a result, though their practices were still primarily traditional, teachers did begin to involve students more actively in the learning process than they reported doing in the past. Mainly, this occurred by bringing students up to the front of the classroom to answer questions and conducting lab activities. In isolated instances, student exploration preceded a lecture, providing students with opportunities to learn from experience. When students were engaged in a lab activity, the activities often required that they follow rigid procedures.

For example, during my first observation of Claudia's ESOL Biology class, her students engaged in a lab activity intended to familiarize them with measuring volumes, massing items, and determining densities. Claudia's class contained a group of sixteen 10th grade students whose primary language was Spanish. After asking a series of review questions on the properties of matter in both Spanish and English, Claudia informed her students that they should get their lab notebooks and copy the pre-written hypothesis from the board. The students were then arranged in groups of four and Claudia walked them through each step in a mechanical fashion. In my field notes I recorded:

> Though this lab lets students practice basic lab skills, during the actual part of the lab it appeared to be little more than that. At the end of the class, [Claudia] dedicated time to pull the main concepts out (density, volume, mass) and revisit the hypothesis (one whole-class hypothesis), but this was only done with certain students and she did all the explaining, rather than having students think through the concepts. So, in a sense, while students were *acting* like scientists would, they were not really engaging in any investigation. (Observation 1, 9/13)

Time 2 – Growing in Awareness and Community Building

CRP Science Knowledge

> It's being self-aware, that's the biggest thing so far with this, with STARTS, I'm just aware of myself a lot more. (Lorelei, Group interview 1)

As teachers began their first GAIn task, the ways in which they described CRP Science was in contrast to their beginning conceptions. As they engaged with course readings and critically examined aspects of their classroom practice in the GAIn, the teachers began to build a rationale for enacting CRP Science that was tied to their own professional satisfaction. When describing other teachers' practices, Christina Joy noted,

> It's amazing to me because people are all so, "you're students; here's what it does, here's a cell" with no relevance. The kids are like, "How is this relevant to me?" Sifting through all of our readings I'm like we need to make that relevant; we need to make them see why that's important. . . It's so much more fun for them [the students] and us [the teachers] when we can make them, "Oh. . .," like the light bulb goes off. (Group interview 1)

Much like the ideas expressed by Christina Joy, other STARTS teachers articulated a desire to engage students in science with relevance. However, missing from their comments was a rationale for *why* such approaches are effective beyond the fact that "it's so much more fun for them." Viewing CRP Science from this perspective reduces the transformative nature of the pedagogy, as it overlooks the development of "social consciousness, intellectual critique, and political and personal efficacy in students so that they can combat prejudices, racism, and other forms of oppression and exploitation" (Gay, 2010, p. 37). However, there was evidence of emerging critical awareness in STARTS teachers.

As STARTS teachers engaged in the first GAIn task, they read literature on CRP Science and critical works on classroom environment and schooling. They examined their own classroom environment (both physical and student-student/student-teacher interactions), and suggested strategies for creating (or maintaining) a culturally relevant classroom environment tied to what they observed as well as the CRP Science literature. They then created an action plan for enacting their suggested strategies. This task supported teachers' developing critical consciousness. As the teachers discussed readings about the political nature of schooling, they began to take a critical perspective. They started to translate their critical perspectives to action by building classroom communities, which they felt eased stress and decreased student resistance.

When writing in her completed GAIn 1 task about the positive impact of a culturally responsive classroom, Kate shared,

> Students' stress levels are reduced due to a loss of a need for 'resistance' if the classroom is a welcoming place to 'different' students. The creation of an environment where students help each other in a community-like way has been shown to increase achievement as well as skills to engage in social action. (GAIn 1)

In this quote, Kate articulated that resistance could result from a classroom environment that is unwelcoming to "different" students, which leads to stress. Creating a community reduces student stress and also increases achievement. Zane also articulated what she previously felt about the classroom,

> To me the classroom was not a natural environment; I perceive it not being natural for students, and when I read one of the papers it say {sic}, "It's like jail", and with these kids they are questioning the system but they voice it in a different way and that makes me more confident about the way I manage my classroom; not to let them do whatever they want to do, but try to make it more natural, you know, a community. (Group interview 1).

Among the teachers, emphasis was now placed on creating a classroom community. Similar to Ladson-Billings' (1994) "community of learners" (p.55), community building in the classroom was seen by STARTS teachers as a way to impart care and promote student learning. Discussions of CRP Science no longer centered just on an awareness of students' ethnicities and care, but how backgrounds are seen as assets. This was accompanied by changing conceptions of self and others (Ladson-Billings, 1994), where teachers view themselves and others as cultural beings. As Zane explains:

> I used to have a practice distancing myself from students saying, "I'm Black, I'm Haitian, I'm Caucasian, I'm female, I'm male" . . . I said "You sure? You are a student; I don't know if you're male, you're female – I don't care, you're a student." By doing that I thought it was a good thing, but it also ignored other factors that I take into consideration because to

> not know you as Spanish and considering you only as a student I'm missing out on some useful thing that you bringing to the classroom, and now [I'm of] the same position – 'you are a student, same considerations,' but I have to pay attention to what you can bring to the classroom and make it different – what your contribution can be so we can build a community together. (Group interview 1)

Zane's comment reflects her growing awareness of herself and others as having cultural identities, which influences learning. According to Villegas and Lucas (2002), this passage highlights her expanding sociocultural consciousness, or "awareness that one's worldview is not universal but is profoundly shaped by one's life experiences, as mediated by a variety of factors, chief among them race/ethnicity, social class, and gender" (p.27). Sociocultural consciousness is one of the fundamental orientations for culturally responsive teaching. As they described their roles as educators, STARTS teachers spoke of repositioning their emphasis on instruction to include the students in meaningful ways, as opposed to focusing solely on their needs. Christina Joy stated, "[I'm] trying to really engage them and making it a process more about them instead of about me and the subject matter" (Group interview 1). Though this comment highlights a major shift for Christina Joy from the first time period where she viewed students' input as distracting, she later shared that she struggled with accomplishing this goal.

Accompanying Instructional Practices

> That's what I complained about in my GAIn is how they [students] don't talk to each other and they don't try and blah, blah, blah, and I was like, "Oh! *That's* why; *this* is why," and I'd go back to the things that I already know and like I'm able to actually put them to use in a meaningful way instead of just kind of throwing together. . . these typical inquiry procedures that I already know in my head, but now it actually makes sense and it's for a reason. Like you [pointing to another teacher] were saying at the very beginning, I'm doing things on purpose. (Kate, Group interview 1)

The teachers began to speculate on ways to bring culturally responsive practices into the classroom as well as a rationale for these instructional decisions. Overall, teachers viewed CRP Science structures like collaboration as a way to “promote interaction between students” (Lorelei, GAIn 1), in which students were expected to be responsible for one another’s learning and to teach one another (Ladson-Billings, 1994). As the teachers learned new instructional strategies during the second Saturday Collaboration Session they began to add to their toolbox. Variations of cooperative learning abound in their classrooms, where “students lead discussion groups and reteach concepts” for “validation and respect” (Zane, GAIn 1), small group discussions that could “showcase the group’s knowledge of the topic” (Natalie, GAIn 1), and group-based active learning experiences to “reinforce [science] concepts” (Claudia, GAIn 1). This emphasis on collaboration was reflected in the second round of classroom observations, though students were largely grouped for lab activities and with no specific roles beyond completing the task at hand.

For example, when I visited Christina Joy’s anatomy and physiology classroom for the second time, I observed students working in pairs to distinguish tissue types according to size, shape, function and other features. The environment in Christina Joy’s classroom was consistently lively and task-oriented. In a class of 28, the majority of her students were either Black or Hispanic. During the station activity, Christina Joy continually circulated among student pairs to clarify procedures and ask comprehension questions. Students were often asked to elucidate their rationale for making specific statements, and Christina Joy insisted they produce “scientific reasons” that included the correct usage of terminology. As a facilitator to her students, it was common to hear

Christina Joy make comments such as, “your rationale needs to be scientific. . . *please* make it scientific. . . Instead of saying it looks like the picture, you could say. . .”. Christina Joy often praised them “did you see that?” (motioning to another student) “That was so kind. You got caught doing a good thing; that was lovely. Help out your peers, alright” (10/15/13). Students each had a guiding worksheet, but no specific roles for participation. Their final products were individual lab write-ups in their science journals. While students were engaged with one another, they were individually accountable for their performance. For the first time, the teachers also spoke of slowing down their current pace of instruction and using formative assessment to gauge student learning. Claudia in particular used multiple formative assessment techniques to gauge her students’ conceptual understanding and English proficiency.

STARTS teachers talked very generally about contextualizing instruction in students’ lives, but there was limited discussion about this actually happening through relevant science topics. Zane reported, “I will maybe look at my students and pull out what cultural element they can bring to the classroom and bring those strategies together” (Group interview 1). Furthermore, during this time period some teachers set goals for integrating students’ backgrounds with classroom elements that were never actualized. Zane planned to devote a section of her classroom to a “News Center” displaying “what I [students] learned from relevant biology,” a “Culture Center” on “elements of my culture relevant in biology” and a “Language Center” containing “Scientific terms in my language relevant to biology” (GAIn 1). During the next Saturday Collaboration Session (which was held in Zane’s classroom), I asked her why she had not yet created the display stations. She told me there hadn’t been enough time and she still planned to create the centers. At the conclusion of the STARTS PD program I had not seen the centers.

However, the teachers did begin to design instruction that was responsive to the needs they were learning about their students. In the quote at the beginning of this section, Kate shares a deeper understanding of the reason behind why certain instructional approaches range in their effectiveness. By exploring students' classroom interactions during the GAIn task, Kate began to notice that her male students dominated group conversations, leaving females silent. Before noticing this through one of the GAIn prompts, Kate assumed that her female students were just not participating. However, as the above passage illustrates, Kate now had a deeper understanding of why this was the case, which ultimately impacted her instruction.

Several teachers began to speculate on the connection between their practices and student outcomes. Claudia echoes this sentiment, "We're making those connections of things that perhaps we did it before but we didn't know *why*, you know, connections that I used to do but maybe I'd go back and do it again but I would do it a different way now" (Group interview 1). During this time period, the teachers also made connections between their previously articulated professional goals, perceived issues in the classroom, and potential instructional strategies to address these.

STARTS teachers also became more aware of their own practices. As Lorelei relates, "I've noticed I do labs first now. . . then I'll go back to the notes and talk about, you know, the important vocabulary terms after we've done the lab so they can make that connection with the lab" (Group interview 1). For Lorelei, this represented a significant shift in her teaching practices and beliefs about being a good science teacher from that which she reported in the initial science teaching and learning questionnaire. Lorelei struggled with students' dependency on her, describing her actions during lab time as a "chicken running around with my head cut off." This was consistent with what I observed when first visiting her classroom. During a lab investigation of carbon and macromolecules, I noted that Lorelei "repeatedly brought [students] all materials, helped [students] through procedures, and several [students] were hesitant to proceed without her affirming them, pausing and looking at her until she confirmed the next step" (Observation 1 field notes, 9/11/13). Lorelei saw this aspect of her teaching as a chronic problem and it became an area of professional growth that she selected at the beginning of the STARTS program. However, by the second observation, Lorelei had already involved students in more extensive discourse, this time around the concept of mitosis, than the methods I had witnessed in the past.

The views that STARTS teachers held about their students became based on actual experiences with their students as opposed to previous experiences with other students. However, at this time, most of their discussions of students as individuals were based on information they learned about how students acted *inside* of class time, with little mention of knowing about students' lives outside of school. Yet, the additional GAIn tasks they would soon participate in required a deeper level of understanding about students' lives outside of school.

Time 3 – Moving from Awareness to Action: Becoming Responsive, Experiencing Tensions

CRP Science Knowledge

> CRP are ways of knowing that guide a community, and is not exclusive to one's culture, ethnicity, language or social class. (Lorelei, RWP Change)

The teachers' definitions of CRP Science expanded beyond racial lines, seeing it more as a way of knowing, a stance (Gay, 2010). Lorelei's quote above echoes this sentiment. Students became viewed as members of a community, and CRP Science was viewed as a way to guide the functioning of this community. For the first time, care was now directly connected to its influence on classroom interactions. Teachers began to articulate their importance in maintaining a community of learners. When the teachers conveyed care, it now also included actively seeking out ways to connect better with their students:

> I teach a very diverse group of "regular" learners. I use quotations, because they are far from regular. They are simply not placed in an honors classroom. I felt it would be to my benefit to read how to connect with my "hip hop" learners. (Natalie, GAIn 2)

For STARTS teachers, care was shown through creating respectful, emotionally safe learning environments for their students. The ways in which teachers and students constructed a sense of community in their classrooms was articulated as well: "You're helping the whole community, and one thing that I promote is what I call emotional safety. They have to feel emotionally safe to be able to speak, to share, to go to the board, to interact" (Zane, Group interview 2). Creating a sense of community was seen as a way to foster academic conversation as well, as Christina Joy explains: "A teacher that makes students feel part of a bigger picture and make science relatable to them would foster academic discourse among students" (Christina Joy, GAIn 2).

Through the GAIn tasks, STARTS teachers were prompted to learn about various elements of their students' lives and instructional needs. To foster culturally congruent discourse, the GAIn 2 task prompted teachers to read about student-teacher interactions in CRP Science classrooms, and to critically examine their questioning and communication patterns and resulting student participation. The task also provided instructional strategies that increased students' academic communication (from the literature and from what they observed), and helped create a plan to enact these strategies. The teachers spoke even more specifically about their students, knowing more about them as individuals and planning on ways to connect their lives outside of school to science content. At this time, most comments about students were still based largely on classroom interactions and behavior; yet, purposeful connections between this information and practice were also being made.

> From the first day of school, I noticed how this class is dominated by boys, not only in numbers, but also in the amount of talking in the classroom. There are three girls in this class that speak up, but that number is small since there are so many more boys in the class to "cancel out" the female voice…After watching this video, I can see that every group's "speaker" is a male. I know that while in their small groups, however (from listening as I teach), all but two girls in this class offer suggestions and thoughts to the group (peers). (Kate, GAIn 2)

In this passage, Kate cues into student interactions in specific ways, but still makes inferences based on what she's seen and heard in class. Yet, to integrate responsive strategies with relevant science topics, teachers must learn about the lives and needs of their students outside of school as well (Villegas & Lucas, 2002).

Accompanying Instructional Practices

> After writing and reviewing Gain 2, I want to utilize question and answers in a less invasive way. Instead of teacher questions, students raise hands and teacher calls on student, I would like to employ other alternatives so students do not feel so on the spot and nervous. For example, I can give review or preview questions and have students turn and talk to discuss the answers and then have one member of the group share out. (Christina Joy, GAIn 2)

Because the GAIn tasks required teachers to speculate on ties between what they were learning about students and their classrooms, connections to practice were repeatedly made. As the teachers learned more about CRP Science and their students, the repositioning of students continued and grew in new ways. They began to discuss and implement potential strategies that increasingly positioned students as "intellectual leaders" (Ladson-Billings, 1994, p.117) in their classrooms. Teachers repositioned students as experts.

For example, during my third observation of her biology class, I witnessed first-hand what Zane had previously termed "emotionally safe" spaces. Zane's class had 20 students, who were all either Black (mainly Haitian-American) or Hispanic. Several had recently exited ESOL programs and, during the previous observation debrief, Zane referred to her students as having "lost their voice" (Observation 2, 10/13). During this introductory lesson on genetics, Zane acted more as a conductor than a director, allowing students to drive much of the explanations and discourse. Zane projected multiple-choice items on the whiteboard and had students come up, one at a time, to talk through their choice and connect their rationale to what they'd previously learned. Sensing that this process was slightly uncomfortable for some students, Zane assured students, "I am not giving this task to you to distract you; I am giving this to you to show you how important it is to succeed. We are not alone, we will do this together."

The first student to volunteer was from Zane's focus group. He came to the board, read the question aloud and paused to think through his rationale. Students waited patiently as he explained which choices were incorrect, based on what he remembered. When he selected the incorrect answer ("I cross out A because the advantage of asexual production, which leaves B"), Zane did not judge him and instead redirected to other students. Together, they arrived at the correct answer and justification. In my field notes I wrote,

> [Zane] leads another student through this thought-processing session. But, she still *lets the students drive the process*. . . When another focus group student volunteered, he makes light of his struggles, but all of the students are facing forward, attentive, raising their hands to help him and are so encouraging. This is part of the safe environment that [Zane] has helped them create over time. (Observation 3, 11/13, italics in original)

In this instance, Zane conducted a lesson that empowered students by acknowledging the institutional influence upon them and the imperative to succeed on the End of Course exam. Through this, Zane makes explicit to her students the rules of the culture of power (in this case the standardized test they must pass to graduate), which makes acquiring power easier (Delpit, 1995). The leadership roles that were repeatedly witnessed in teachers' classrooms positively impacted student behavior. Claudia speaks to this,

> My focus group has grown so much. I'm very proud of them. They have improved in different ways. For example one of them likes to be a leader; that's that one – [he] share[s] ideas and opinions, he's a good team worker, rather than talking and disrupting the class and himself like before. The more he's learning the better leader he's becoming to share ideas and to help the others. (Group interview 2)

To provide STARTS teachers with additional instructional strategies for their toolbox, teachers completed PG tasks in which they read practitioner articles on *making student thinking visible* and *effective collaboration*, identified salient strategies, and speculated on ways to implement these strategies. Largely, shifts in teaching were not yet around changing lesson content to include aspects of their students' lives as part of the "official" curriculum (Ladson-Billings, 1994, p.117). Instead they were about changing instructional strategies in ways the teachers reported were more student-centered and empowering. Ideas for collaborative learning became more ordered, with specific student roles, in an attempt to create equitable and rigorous learning experiences. Cooperative learning structures were viewed as essential to enacting reform-based and CRP Science. Natalie states, “I still have the same perspective [about CRP Science], however, I would add the use of group work as a strong mechanism for inquiry-based learning” (RWP Change). Even as the teachers began to learn more about their students’ lives outside of school and added new instructional tools to their toolbox, they shared struggles about not knowing relevant topics to apply to their science instruction. Christina Joy describes this struggle: “This is a hard topic to make relatable to students. . . I can think of a variety of teaching strategies that would be effective for this chapter – but making it more relatable to students has me stumped” (GAIn 2).

As the teachers continued to reposition students and include cooperative-learning activities more frequently, there were noticeable differences in their instruction. For example, in the third lesson I observed, Kate had her anatomy and physiology students work in groups to complete a muscle stations lab. She and Christina Joy had co-designed this lesson, but Kate modified it to make it more responsive to her students’ needs, as she had been actively working to increase communication by female students. During the lesson, Kate required students to practice cooperative learning strategies (students had roles as understanding checker, summarizer, idea generator, etc.) to increase the effectiveness of their groups. In my field notes I noted that she monitored their interactions very carefully (“You have plenty of ideas, but you have really nothing else, so make sure that you are also cooperating in *these* ways (pointing to the list of interactions)”), provided specific feedback and asked clarifying questions about process and content. The students worked in groups of 3-4 and rotated through exploratory stations where they identified the parts of a muscle cell, located muscle fibers on a model, and engaged in muscle fatigue activities (e.g., weight-lifting, wall sitting, and pincer gripping), every ten minutes. The lesson kept students actively engaged. In the words of one female student, “that was really fun and our group was really competitive.” Ironically, the activities permitted competition while also promoting group accountability (Observation 3 field notes, 11/13).

In preparation for designing their CRP Science instructional units, STARTS teachers first completed a Curriculum Topic Study on the unit topic. After completing the CTS, teachers began to place an emphasis on uncovering misconceptions commonly held by students. They articulated their importance to effective instruction. Natalie explained, “I was able to see and read about DNA, its many misconceptions and tackle these with my students. So we went and talked about that because that was one of the misconceptions I found in the [curriculum topic] study,” (Group interview 2).

The teachers also began to talk about the importance of teaching the bigger picture of a concept/big idea in addition to spending time on the smallest details and facts, which led to very specific changes in their practice that were later evident in their implementation of the CRP Science units. However, utilizing these strategies also came at the expense of time. Christina Joy described the tension between the amount of time it takes to cover content and engage students in active learning,

> From the [CRP Science] units I created this year, I am over four weeks behind last year and am now trying to play catch up. . . In the future I have to make these lessons significantly shorter to be able to get through my required material. (Clarification Questions)

Time 4 – Enacting the CRP Science Units

CRP Science Conceptions

> In my mind I thought a good teacher or an effective teaching practice would be for me to just always be there for them; whatever they needed from me then I was there. And then that meant that I was running around my classroom like a chicken with my head cut off and it was just too much. So I came to realize I really need to put more on them because they can do it. I believe in them, I know that they're capable; I just needed to believe in myself that I could let go, too. (Lorelei, Presentation)

As STARTS teachers neared their capstone project, designing and enacting the CRP Science units, they frequently spoke of how important their role as a teacher was in facilitating relationships, student learning, and maintaining a classroom community. The central role of curriculum materials was downplayed, because teachers saw themselves as key factors in student learning whereas this had not been previously emphasized. Natalie expressed this point,

> The most valuable lesson that I've learned from all this is that the more I get to know them the better they do. . . they do better because I have a personal connection with them. I know my students more on a personal level as opposed to just biology work now. (Presentation)

Care became well-articulated, multidimensional, and connected to practice, primarily through continued community building. Community building moved beyond creating emotionally safe classroom spaces to students relying on one another to complete a task, constructing a final product together, and presenting their expert knowledge to the classroom. Lorelei speaks about this when describing a lesson on pedigree analysis and allele frequencies,

> They really needed to rely on each other, too, because at the end they needed the class data to come up with the frequency and to plot everything out. So that created this sense of community, they all relied on each other really to kind of work it through. Some really got it and some others didn't, but they helped each other out. (Presentation)

In this lesson, students were responsible for arriving at a solution together, thereby successfully completing the task. Collaboration was about more than achievement to Lorelei, though. It was about students assisting one another. Of this, Ladson-Billings, (1994) states, “culturally relevant teachers encouraged a community of learners rather than competitive, individual achievement. By demanding a higher level of academic success for the entire class, individual success did not suffer” (p.480).

Through the GAIn and PG tasks, teachers were prompted to learn about students’ activities outside of school, how students spend their free time, and how they feel about various science topics (Villegas & Lucas, 2002). In the third GAIn task in particular, teachers were asked to sit down with their students, learn specific information about them in relation to science, and then make instructional decisions based on their findings. Through this and other actions (e.g., Christina Joy used social media to connect with her students and showcase their exemplary work), STARTS teachers were “careful to demonstrate a connectedness with each of their students” (Ladson-Billings, 1994, p.66).

Accompanying Instructional Practices

> I’m just so proud of the fact that I have it [the CRP Science unit]. With CRP, instead of just thinking about the content, which I would normally do when planning, I was forced to bring in my students into what I was thinking about. (Kate, Group interview 2)

STARTS teachers designed CRP Science units around the following topics: DNA structure and function, protein synthesis, the cell cycle, and the musculoskeletal system. When they spoke of their CRP Science units, the teachers placed a strong and sustained emphasis on students. Kate’s quote above captures this emphasis, as she shifted her instructional design focus from the notion of teaching *content* to teaching *students.* By the time they were creating and implementing their CRP Science units, the teachers' conceptions of CRP Science were action-oriented. Student engagement increased, as did student choice in assignments. Because the teachers were implementing novel instructional materials, the slower pace became even more evident during this time period, not only for scaffolding new instructional strategies but also for diving deeper into topics that were relatable to students' lives.

Natalie discusses this element when commenting on the lesson she designed to explore the various forms of mutations. With hopes of making content more relatable to her students, Natalie involved students in a collaborative learning activity where they explored mutation-causing diseases that were common in various ethnic populations (e.g., Tay-Sach's disease, sickle cell anemia):

> So this was a good lesson that I never had done before. Whenever I talked about mutations I just kind of did four or five Powerpoint slides on the types of mutations and just moved on and never really made it personal to them, and because I made it personal they did better on the tests. (Presentation)

To design their CRP Science units, teachers utilized several tools from their toolbox. Kate applied an instructional strategy she learned from one of the PG tasks during a sarcomere contraction activity. During the lesson, Kate involved students in monitoring their forms of group communication through a worksheet she designed. She then used the worksheet to have students reflect on which types of interactions they were likely to have engaged in and which they needed to improve upon to increase the depth of their communications in the future. The teachers also expanded their assessments to include multiple ways to demonstrate proficiency. Claudia shares,

> I planned for them to express their learning, either by drawing or in their presentation. . . For example my students who spoke less English, they did the best chart. My students with the middle English [proficiency], they

> were the ones who made the better connections of their understanding among everyone. (Presentation)

Providing students with multiple ways to demonstrate proficiency stands in stark contrast to my previous observations of Claudia, where she relied heavily on textbook-based worksheets as the primary way to evaluate her students. By expanding her assessment approaches, Claudia repositioned students as learners who are “capable of academic success, given the appropriate learning environment and instructional support” (Powell, 2011, p. 90).

What resulted among STARTS teachers’ classrooms as the CRP Science units were enacted was not only a noticeable difference in student-to-student communication, but also shifting interactions between teacher and student, which further repositioned students in their roles as learners. Lorelei articulated this change,

> They didn’t even need me, and the labs are so. . . they run just so smooth. I kind of get to sit back and listen to their conversations and I’m like, ‘Yes! They get it.’ I walk around and I talk to them, I get to know them more. It [the conversation] can be something that’s kind of related, and then you kind of branch off a little bit, and then we bring it back. (Presentation)

Elements of the STARTS teachers’ classrooms were not only congruous with CRP Science, but also reflective of learner-centered environments. Bransford, Brown, and Cocking (2000) note that, “the term ‘learner-centered’. . . refer[s] to environments that pay careful attention to the knowledge, skills, attitudes, and beliefs that learners bring to the educational setting. . . includ[ing] teaching practices that have been called ‘culturally responsive’, ‘culturally appropriate’, ‘culturally compatible’, and ‘culturally relevant’” (pp. 133-4).

Reflecting on their unit design, STARTS teachers shared both successes and challenges. While their characterization of CRP Science expanded, some teachers still struggled with narrow conceptions of how to enact CRP Science instruction. Christina Joy reports,

> The fact of the matter is even though we're doing culturally responsive instruction, at some point the kids have to have notes or material or something. I'm going to have to teach something. It's not all, "Ok, get in a group; get in a group." (Presentation)

At one level, Christina Joy's comment reflects a transmission view of learning and a trivialized view of CRP Science, in which the paradigm is reduced to steps to follow as opposed to pedagogy for empowering diverse students (Sleeter, 2012). However, a closer examination of her words reveals a serious challenge for teachers trying to enact a responsive pedagogy in a restrictive, evaluation-driven environment. Lorelei elucidates the institutional influence teachers perceived as a continual challenge to teaching CRP Science:

> The district provides a suggested pacing guide at the start of the school year. Although the pace is a suggestion, the biology course contains an End of Course exam as well as a district-provided semester exam. These two assessments cover content aligned with the district pace. Meaning, if you do not follow the pacing chart, the students will be tested on material you never taught. (Clarification Questions)

Though multiple teachers articulated that students were learning more science through a culturally responsive approach, this occurrence holds specific implications for supporting teachers as they experience the backlash associated with enacting innovative pedagogies (Sleeter, 2012).

Discussion

As a research and development program, the STARTS PD program was designed to prepare CRP Science teachers capable of designing and implementing culturally responsive, reform-based science instructional materials. The research question I sought to answer was, "*for high school life science teachers participating in* *an explicit PD program on CRP Science, what defines the process of becoming culturally responsive educators?*" My analysis led to the development of a conceptual model representing the process of becoming a CRP Science teacher within this context, thereby responding to the call made by Patchen and Cox-Petersen (2008) to "encourage science educators to pursue additional research to determine what teachers are actually doing in classrooms to enact CRP and to document the strategies most effective in making the shifts to CRP" (p. 1010). Through this model, six themes characteristic of the process were elucidated: CRP Science conceptions, views of students, repositioning students, utilizing a toolbox, community building, and instructional changes.

Much like Gay's (2010) view of CRP as empowering, and Ladson-Billings' (1994) description of culturally relevant teachers' conceptions of self and others, STARTS teachers believed that all of the students they worked with were capable of success. They validated students' identities through instruction, decreased students' reliance on them, and, over time, came to treat teaching as "pulling knowledge out" of students rather than depositing information (p.34). Over the course of the STARTS program, teachers exemplified the multidimensional nature of CRP (Gay, 2010) as their relationships with students became more fluid and equitable. Great care was taken to build a classroom community, and students were treated as members of this community (Ladson-Billings, 1994). Collaborative learning became a regular element of the teachers' repertoire, though it was occasionally seen at the expense of time.

As STARTS teachers grew professionally they enacted several elements of CRP Science. Though they began to develop sociocultural consciousness and view knowledge critically, there was only one instance of engaging students in the critical exploration of science topics. Yet, Morrison, Robbins, and Rose (2008) argued that sociopolitical/critical consciousness is the cornerstone of CRP: “It is through critical consciousness that students are empowered with the tools to transform their lives and ultimately the conduct of our society” (p.443). Though studies of CRP in general education are limited in examples of sociopolitical consciousness (Morrison et al., 2008), the field of CRP Science is rich with opportunities to include issues important to the community (e.g., Bouillion & Gomez, 2001; Fusco, 2001; Mensah, 2011) and confront negative stereotypes, biases, and forms of oppression (e.g., Calabrese Barton, 1998; Laughter & Adams, 2012). However, with the exception of isolated studies (e.g., Mensah, 2011; Laughter & Adams, 2012), opportunities for students to examine science from a critical perspective were designed by science education researchers, not teachers. Therefore, additional research is required not only to develop sociopolitical/critical consciousness in science teachers, but also how to support science teachers’ design of critical culturally relevant instructional materials.

Additionally, research is required on designing PD programs that support responsive teaching in a restrictive environment because CRP Science teachers are fighting an uphill battle. Sleeter (2012) identifies the political backlash associated with culturally responsive teaching, arguing that schools with underachieving students are more often pressured to conform to standardization rather than responsiveness. Citing an expansive literature base, Sleeter (2012) asserts that teachers are given “less time to research and develop curriculum that students can relate to, non-tested curriculum disappears under pressure to raise test scores, and teachers are increasingly patrolled to make sure they are teaching the required curriculum, at the required pace” (p.577). The NRC (2012) advocates reducing the amount of science content covered in curricula to core ideas in four disciplinary areas (life sciences; earth and space sciences; physical sciences; and engineering, technology, and applications of science) in an effort to support sustained engagement and deeper learning. However, opportunities to include culturally responsive instruction around these core ideas must also be acknowledged at the policy level in order for reform of this magnitude to be actualized.

Table 4-1. Becoming CRP Science teachers.

Selective codes	Axial codes	Open codes
Views of Students	Awareness Sociopolitical elements	Perceiving the classroom environment as not natural, Being forced to think of students and not just content
CRP Science Conceptions	Awareness Teacher satisfaction Teacher progression	Acknowledging importance of relevance in instruction, Being culturally responsive means engaging activities Being culturally responsive is rare
Toolbox	Topic vs strategy Family connections	Getting better means new activities and practices, Identifying new techniques, It's natural to build from preexisting lessons
Community Building	Creating safe spaces Care	Care is required for students to trust, Care is responsible for positive St-T relationships
Repositioning Students	Student grouping Student outcomes	Believing in her students, Perceiving that grouping promotes better work
Instructional Changes	Professional growth Connecting science with students Assessment	Seeing old way of questioning as invasive, Gaining deeper understanding of *why* to make instructional strategies

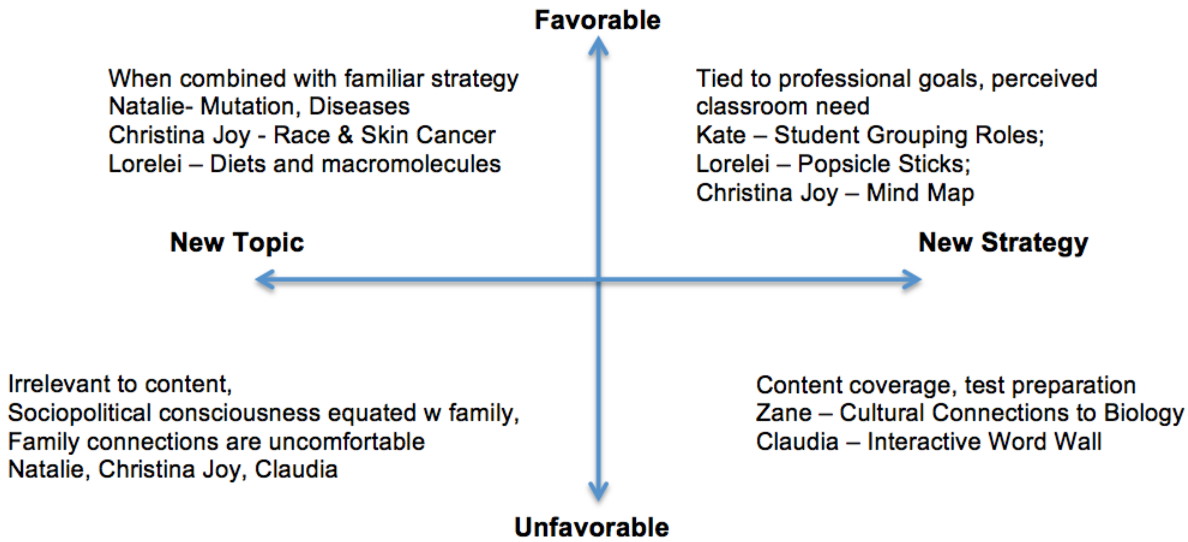


Figure 4-1. Cartesian plane diagram illustrating dimensions of the category, *Toolbox*, which contains new strategies and new topics.

Table 4-2. Data collection/analysis stages during the STARTS research and development project.

Data sources	Project timeline / Data collection stage: Stage 1		Stage 2	Stage 3	Stage 4			Stage 5	
	Aug '13	Sep '13	Oct '13	Nov '13	Dec '13	Jan '14	Feb '14	Mar '14,	April '14
BARSTL questionnaire	X								
Classroom observations*		X	X	X	X	X			
Group interviews			X	X					
Reflective Writing Prompts	X	X	X	X	X	X			
Lesson study documents		X							
Autobiography			X						
GAIn tasks			X	X	X				
CTS document				X					
PG tasks				X	X				
CRP Science units					X	X			
Saturday Collaboration Session artifacts		X	X	X		X			
Clarification Questions (email, phone correspondence)							X	X	X

Note: *The Dec '13 and Jan '14 classroom observation dates depended upon when teachers implemented their CRP Science units. Field notes accompany each classroom observation. Design Decisions Report was maintained throughout.

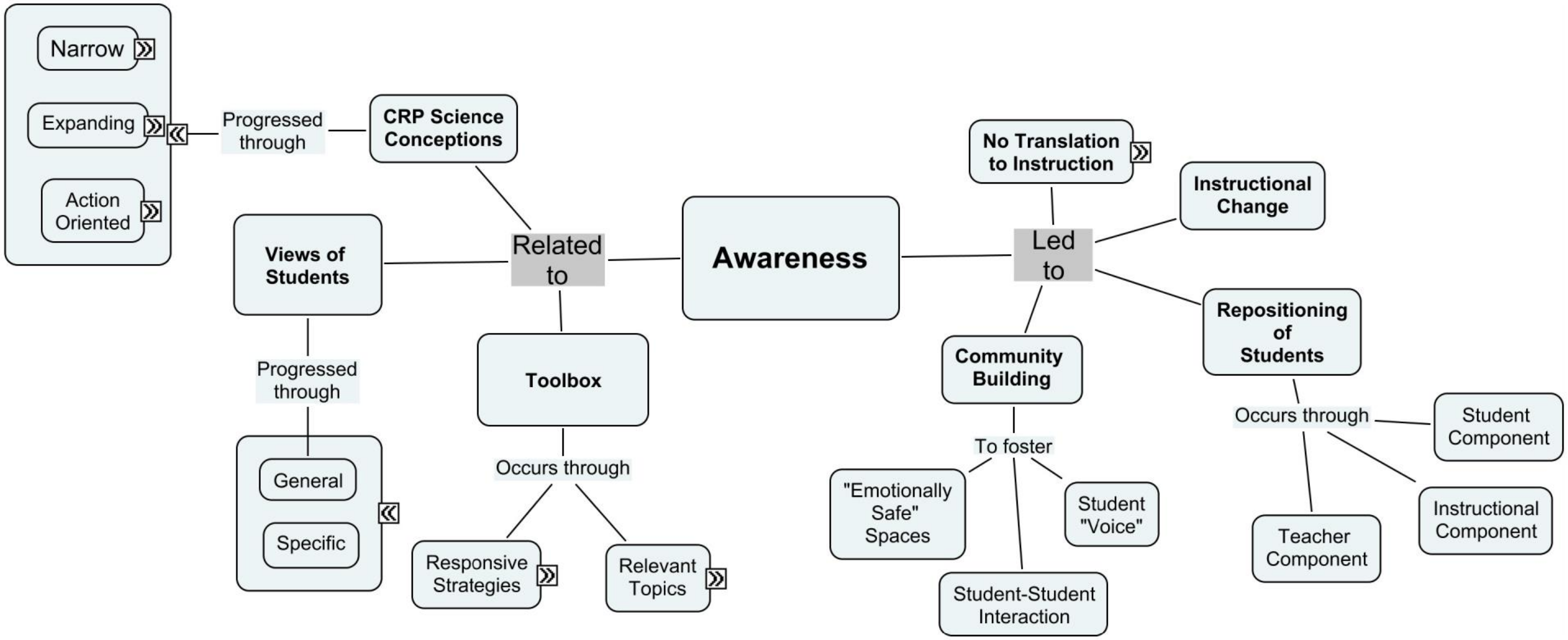


Figure 4-2. Conceptual model of the process of becoming a CRP Science teacher.

Table 4-3. Time-ordered matrix: Teachers' progressions as CRP Science teachers.

	Time 1: 8/1/13-9/15/13	Time 2: 9/16/13-10/15/13	Time 3: 10/16/13-11/30/13	Time 4: 12/1/13 – 1/31/14
PD Activities	CRP Science readings, Lesson Study, Observation 1, Saturday Collaboration Session 1	GAIn 1, Autobiography, Begin CTS Group Interview 1, Observation 2, Saturday Collaboration Session 2	GAIn 2, Professional Growth tasks, Complete CTS, Begin CRP Science unit design, Group Interview 2, Observation 3, Saturday Collaboration Session 3	GAIn 3, Professional Growth tasks, Complete and enact CRP Science unit, Observations 4-6, Saturday Collaboration Session 4
CRP Science Conceptions	Focused on race, Missing critical perspective, Students' likes and dislikes, Care is about liking students	Critical perspective on schooling, Forming a community, Background as asset, Compare current practices to CRP	A way of knowing and being, Care is multi-faceted and about connecting with students,	Teacher's role is important, Relationship building, Care connected to practice
Views of Students	Based on assumptions and previous experiences with other students	Based on classroom interactions, Examining the impact of instruction on students	Students are capable individuals, Making connections between students and instruction	Based on conversations with students, Learning about their lives outside of school, Connected to instruction
Repositioning Students	N/A	Increasing active role	Students as leaders, experts Student communication is primary discourse in classroom	Teachers let go of control, Decreased reliance on teacher, Students construct product together
Community Building	N/A	Reduces student stress, Promotes interaction, Conveys care	Emotionally safe spaces, Mechanism for academic success	Students depend on each other, Students construct product together
Toolbox	Relevant topics are potentially offensive	Concept mapping as a way to elicit understanding	Cooperative learning roles, Challenge finding relevant topics, Uncovering student misconceptions	Applying relevant topics to responsive instructional strategies, Questioning scaffolds
Instructional Changes	Teacher-directed, Some active learning experiences, but follow rigid procedures	Begin student-centered stance, Cooperative learning for lab activities, Formative assessment	Cooperative learning as mechanism for reform-based science teaching, Empowering students, Student reflection	Multiple ways to demonstrate proficiency, Continued practices from Times 2 and 3

CHAPTER 5
DESIGNING FOR CULTURALLY RESPONSIVE SCIENCE EDUCATION THROUGH PROFESSIONAL DEVELOPMENT

Introduction

It is hard to deny the important role teachers play in facilitating science education reform. According to the National Research Council [NRC] (2012), “ultimately, the interactions between teachers and students in individual classrooms are the determining factor in whether students learn science successfully” (p. 255). For diverse individuals who are often underrepresented in the science, technology, engineering, and mathematics (STEM) disciplines, academic success in science is increased when teachers integrate their cultural and linguistic backgrounds with academically rigorous instruction (Banks et al., 2005; Lee & Luykx, 2007). Calls for science education reform that attends simultaneously to diverse students’ needs and academic rigor are not new (Lee & Fradd, 1998); yet they often remain unanswered (Mensah, 2011; Zozakiewicz & Rodriguez, 2007).

Embedded within the literature exploring such culturally responsive pedagogies in science education (hereafter referred to as CRP Science) is the professional development (PD) of CRP Science teachers who are capable of effectively educating diverse students. Although some scholars have begun to examine PD programs with this aim (Lee, 2004; Lee et al., 2004; Johnson, 2011; Zozakiewicz & Rodriguez, 2007), none have done so from a design-based perspective with the intent to produce usable knowledge about how to best construct such experiences. Yet, Cohen and Hill (2002) have asserted that “what teachers actually learn in professional development experiences has the greatest impact on their beliefs and practices, and eventually, on student learning outcomes” (cited in Lee & Buxton, 2010, p. 125). Given the necessity to ensure academic excellence for diverse students through CRP Science and the great potential of PD to support science teachers' development as culturally responsive educators, design-based approaches are crucial. This study employed typological analysis (Hatch, 2002) and matrix analysis (Averill, 2002; Miles & Huberman, 1994) to address the research question, *what features of the STARTS design framework can be associated with supporting changes in culturally responsive knowledge and practices of high school life science teachers?* In this paper I report on the critical characteristics of the STARTS (*Science Teachers Are Responsive To Students*) PD program for developing CRP Science teachers that designed and enacted innovative instructional materials. To generate usable knowledge about preparing CRP Science teachers through PD, I also present the revised STARTS design framework and an accompanying set of design principles.

Theoretical Framework

Central to this study is the exploration of the influence of STARTS PD experiences on teachers' growing knowledge and practices. Therefore, design-based research (DBR) serves as an appropriate framework guiding this study. DBR is used for constructing effective learning environments via theoretically grounded educational interventions and is suited for examining learning processes in environments that are designed and systematically altered by the researcher (Barab, 2006, McKenney & Reeves, 2012). Design studies occur in naturalistic settings where context plays a large role in that multiple variables are present and cannot be controlled for (Barab & Squire 2004; Fishman et al., 2004). Thus, a focus of design studies is the exploration of mechanisms undergirding learning through a novel *in situ* educational intervention (Confrey, 2006; Shavelson & Towne, 2002). To accomplish this goal, design researchers engage in iterative cycles of problem analysis, design, implementation, examination, and redesign (Wang & Hannafin, 2005). Though constant comparative analysis is not exclusive to DBR, the purpose for concurrent data collection and analysis in design studies is the revision of an educational tool to better understand and impact the learning progression (Confrey & Lachance, 2000; Joseph, 2004).

DBR intends to provide "experience-near significance and experience-distant relevance" (Barab & Squire, 2004, p.6) through the production of knowledge about learning in a given context and theories that guide future educational tool design (Barab, 2006; Confrey, 2006; Songer, 2006). Studying the progression of an educational tool from design to implementation provides a sense of how these tools are appropriated in action as well as connections between tool and context (Squire et al., 2003). To establish the local impact and general relevance Barab and Squire (2004) refer to, design studies aim to produce usable knowledge about a given educational tool while also advancing theory. Therefore, specific outcomes of DBR should include the generation of theory and the explication of an innovative product through design frameworks (Edelson, 2002; McKenney & Reeves, 2012). These outcomes enable work from design studies to be adopted by others and adapted to new contexts, further lending themselves to the pragmatic nature of DBR.

However, the quality of such products should be well-established through specific criteria. Design researchers are responsible for demonstrating methodological rigor in both the internal processes of research and the designed intervention's potential impact on teaching and learning, particularly because of their active involvement in development and research (Barab & Squire, 2004). It is common for design researchers to serve as curriculum designers (Joseph, 2004; Songer, 2006), professional developers (Raval, McKenney, & Pieters, 2010), teachers (Confrey & Lachance, 2000), and participant observers (Hjalmarson & Diefes-Dux, 2008; Squire et al., 2003). To establish trustworthiness and reliability, educational design researchers collect numerous forms of data (Brown & Edelson, 2003; Hjalmarson & Diefes-Dux, 2008) and provide a variety of evidence about the research process (Joseph, 2004), as well as the intervention's potential impact on practice (Confrey & Lachance, 2000; Songer, 2006).

Design studies are ultimately intended as a practical endeavor producing usable knowledge about solutions to educational dilemmas experienced by teachers and learners (Kelly, 2004) through the production of design frameworks and theory (Edelson, 2002). After reporting findings to the guiding question for this study, I will present a revised design framework and set of design principles. Local theory generated on teachers' progression as CRP Science teachers in this setting (Chapter 4) is reported elsewhere. First, I begin with a review of the related literature from which the STARTS PD program was built.

Review of Related Literature

The literature on effective methods of PD is vast. Over time, scholars have identified multiple hallmarks of high-quality PD programs. Though far from an exhaustive list, these hallmarks include: job-embedded tasks that connect to teachers' daily practices (Borko, 2004; Croft et al., 2010), the collective participation of teachers from similar grade levels and subject areas (Garet et al., 2001), the modeling of innovative strategies and best practices (Loucks-Horsley et al., 2010), active learning experiences (Desimone, 2009; Garet et al., 2001), dual focus on content and pedagogy (Garet et al., 2001; Loucks-Horsley et al., 2010), and ongoing support (Desimone, 2009). Effective PD programs utilizing core features such as these have positively impacted the knowledge and practices of science teachers as well as student performance (e.g., Crippen et al., 2010; Luft, 2001; Parke & Coble, 1997).

Because reform-based science teaching (i.e., engaging students in the practices of science [NRC, 2012] and inquiry [NRC, 2000]) is an element of CRP Science, PD experiences that support science teachers' use of inquiry are also needed. In an exhaustive review of the literature on inquiry-based PD, Capps, Crawford, and Constas (2012) identified multiple experiences that were effective in supporting reform-based science teaching. According to the authors, supportive PD experiences are in accord with state and national standards, require teachers to develop innovative lessons, engage teachers in reflection and inquiry-based learning activities, include content knowledge learning opportunities, and discuss transference of program objectives to classroom practices. Such experiences actively engage teachers in the practices they advocate. In order to prepare a teaching workforce capable of engaging students in science practices, PD containing these features is needed.

Even highly effective science teachers require additional PD experiences to successfully meet the needs of diverse learners, as they must address the constraints inherent in responsive teaching in restrictive environments (Tate, Clarke, Gallagher, & McLaughlin, 2008). To promote science education that is more inclusive of diverse students, the NRC (2012) recommends instruction that "build(s) on students' interests and backgrounds so as to engage them more meaningfully and support them in sustained learning" (p.283). A goal of this magnitude requires specific strategies for preparing teachers who can provide accessible science. Because teachers who enact

CRP Science require unique knowledge and practices, additional PD supports must be designed and provided for this purpose. Of the few studies of PD for CRP Science teachers, researchers have involved teachers in: learning about inquiry and cooperative learning strategies, conducting home visits, completing a conversational Spanish course (Johnson, 2011); reflexive approaches to collaboration, community building, modeling multicultural science instruction, and content-focused summer institutes (Zozakiewicz & Rodriguez, 2007). They have determined the focus of PD sessions by conducting inquiry-based investigations, sharing best practices, examining student learning, discussing their personal experiences as newcomers to the United States, and reading theories on learning (Lee, 2004). Among the sources, science educators asked teachers to construct classroom materials that incorporate students' backgrounds. Yet, the supports provided to this end are not well articulated nor are the actual products. Further, the focus of each study was either on teachers' perceptions of the value of the program or changes in their practices over time. Absent from these studies is the relationship between structural elements and the resulting professional growth of teachers. Though PD elements are identified to various degrees, the rationale for and the particular ordering of the experiences is implicit. Yet, to best design effective PD, these relationships must be elucidated.

Supporting teachers' development as CRP Science teachers and designers of culturally responsive instructional materials is sorely needed. Existing PD studies that support science teachers as instructional designers pertain solely to promoting inquiry-based instruction (Stolk et al., 2011) or alignment to state and national standards (Jackson & Ash, 2012). Through the design, enactment, and evaluation of the STARTS

PD program, this study acknowledges the importance of empowering teachers as designers of CRP Science instructional materials, thereby building capacity for sustainable change and addressing a lack of culturally responsive materials (Lee, 2004; NRC, 2012). Through this approach, the study directly addresses Mensah's (2011) assertion that the "content specific application of culturally relevant teaching [CRT] seems to be the missing link in the research on CRT and teacher education" (p.297). As an educational intervention, the STARTS PD program was designed based on the literature on effective PD for supporting reform-based CRP Science practices. In the following section, the program is detailed according to its theoretical grounding, objectives, and activities.

The STARTS PD Program

The STARTS PD program was designed to prepare culturally responsive, reform-based high school life science teachers who create and implement novel CRP Science instructional materials. To accomplish these goals, the program was grounded in multiple bodies of research including: effective PD methods for CRP Science (Johnson, 2011; Zozakiewicz & Rodriguez, 2007), inquiry-based science instruction (Capps et al., 2012; Loucks-Horsley et al., 2010), and online teacher PD (Dede, 2006); teacher change via PD experiences (Bell & Gilbert, 1994; 1996); and providing support to teachers as instructional designers (Parke & Coble, 1997; Stolk et al., 2011) Table 5-1 provides a comprehensive list of the theoretical grounding for the STARTS activities..

The STARTS program was job-embedded, thereby providing participating teachers with multiple opportunities to enact and reflect on CRP Science in their daily practices (Coggshall, Rasmussen, Colton, Milton, & Jacques, 2012; Desimone, 2009). As teachers learned reform-based, CRP Science knowledge and practices their professional growth was supported in a blended environment. Ongoing support occurred face-to-face during monthly Saturday Collaboration Sessions as well as in online environments (Dede, 2006; Loucks-Horsley et al., 2010). During STARTS, teachers engaged in six major activities, all of which I facilitated. Each activity will be detailed according to its ability to facilitate the STARTS PD program goals. A timeline of the STARTS PD program is presented in Figure 5-1.

Lesson Study

Learning how to teach requires practice and study. As teachers design, enact, and subsequently analyze lessons their teaching will likely improve. However, this is dependent upon several factors, including careful observation of effective elements and critical reflection on strategies needing improvement. Lesson study fosters teacher growth through collaboration in professional learning communities where developing knowledge for teaching is a major focus (Shimizu, 2002). Originating in Japan as an innovative PD approach (Isoda, 2010), a major focus of lesson study is the development of research lessons intended to meet specific student learning goals. As a result, lesson study features teachers working collaboratively to identify target goals for student learning and construct corresponding high-quality lessons. Professional learning communities engage in a cycle of reflective practice with the aim of constructing, analyzing, and revising a research lesson (Loucks-Horsley et al., 2010). Long-term student learning goals based on a specific theme are identified; lessons aligned with these goals are devised and implemented while team members observe and collect data on student learning; finally, debriefing and revision based on analysis and feedback occurs (Lewis et al., 2006; Mutch-Jones et al., 2012; Shimizu, 2002).

Lesson study was the first major activity teachers engaged in during the STARTS program. The lesson study cycle was intended to help teachers understand their students' learning needs, reflect on the impact of their practice on student outcomes, and identify areas for professional growth that may not have been previously articulated. During this modified lesson study cycle, teachers worked in pairs to first identify one class period apiece to focus on, identified target student outcomes, and then constructed a science lesson intended to address learning goals specifically for their classes. Because teacher pairs often taught at different schools, each teacher then video-recorded the lesson, focusing closely on a group of 3-4 students who were of special interest to the teacher. Teachers then observed one another's recordings and provided feedback through the use of a structured feedback guide that was managed in the STARTS online course system. To complete the lesson study cycle, teachers then met face-to-face during the second Saturday Collaboration Session, debriefed the entire process, and brainstormed ideas for lesson redesign based on findings.

Growing Awareness Inventory (GAIn) Tasks

To promote CRP Science and student responsiveness, teachers completed the *Growing Awareness Inventory* (GAIn) tasks (Brown & Crippen, in review). The GAIn tasks are a series of three reflective practice protocols that provide STARTS teachers with structured support as they learn to identify and meaningfully incorporate students' cultural and linguistic backgrounds into reform-based science instruction. The GAIn has been designed to develop CRP Science teachers as they complete specific tasks. Each of these tasks are student-centered and aligned with key tenets of culturally responsive pedagogy, such as affirming students' backgrounds, sociocultural awareness, and building a community of learners (Gay, 2010; Ladson-Billings, 1995; Villegas & Lucas, 2002).

The GAIn tasks were intended to transition teachers from exploring their practice from a classroom-centered perspective to connecting instruction to beyond-the-classroom factors (i.e., students' home lives). For example, the first GAIn task focused on information teachers learned about their students' needs during class time. In the final GAIn task, this focus moved to learning about students' needs outside of the classroom and school. The GAIn tasks were designed to help STARTS teachers critically examine the implicit messages conveyed by their classroom environments, relationships between teacher and students, students' preferred communication patterns, and to speculate on ways to incorporate CRP Science intro classroom instruction. The GAIn tasks also served as the primary structure for integrating information that was learned about students into the capstone project, the CRP Science unit.

Through the GAIn tasks, STARTS teachers were expected to gain experience connecting students' backgrounds and interests to reform-based instructional strategies and assessment practices that build on these strengths. Though the GAIn does not represent an exhaustive picture of CRP Science, it provides a starting point for teachers to more deeply understand students' cultural backgrounds and connect this knowledge to instruction in meaningful ways, which is uncharacteristic of traditional science classrooms (Martin, Mullis, Gonzalez, & Chrostowski, 2004).

Curriculum Topic Study

The Curriculum Topic Study (CTS) process is systematic and in-depth, utilizing a set of resources and strategies designed to bridge research and practice in ways that improve science teaching and learning (Keeley, 2005). The teacher identifies a science topic (e.g., cells; rocks and minerals) and a CTS guide then identifies readings that support teachers' development of knowledge on the topic (e.g., *Benchmarks for Science Literacy*, American Association for the Advancement of Science [AAAS], 1993; *Science for all Americans*, AAAS, 1990).

CTS provides structure and guidance for teachers to explore core science ideas and the progression of crosscutting concepts. This better prepares them to engage students in authentic inquiry experiences and science practices. Furthermore, CTS provides teachers with resources to learn about research on student learning. Educational materials such as the CTS enable teachers to learn about and participate in the practices of science. Such scaffolds are necessary, given that many science teachers have never been involved in authentic inquiry throughout their formal schooling experiences (Barnes & Barnes, 2005). During the STARTS program, teachers collaboratively conducted a CTS for the specific science topic featured in their innovative culturally responsive science unit.

STARTS teachers worked in teams to conduct a CTS as a way to foster reform-based science teaching by deepening their knowledge of the science content to be featured in their CRP Science unit, examining research on student learning and suggested instructional strategies for their topic, exploring the progression of crosscutting concepts for this topic, elucidating relevant state and national science education standards, and providing a structured way to support the design of their CRP Science units. The resulting document became the foundation for the reform-based science portion of teachers' CRP Science units and was later integrated with GAIn findings, which formed the culturally responsive portion of the unit. Adamson, Santau, and Lee (2013) argue that "to effectively teach science, teachers must not only master science content, but also be familiar with how students learn science" (p. 556). By engaging in a Curriculum Topic Study, teachers can accomplish both of these goals.

Professional Growth Tasks

Professional Growth (PG) tasks arose out of the need for PD programs to continually be responsive to teachers' needs and connect to their daily practices. The PG tasks began about halfway through the STARTS program as a result of emergent findings, including new professional goals articulated by teachers as well as trends from classroom observations. The teachers selected three topics on which they wanted to learn more (e.g., *making student thinking visible, student grouping/effective collaboration*, and *connecting families & science*). To further assist STARTS teachers in achieving their professional goals, the PG tasks prompted teachers to identify key features of effective CRP Science and reform-based science practices (from the literature, through video recordings of STARTS teachers exemplifying a practice, or by analyzing sample lesson plans), and then considering how to modify and apply these practices for their classroom contexts.

Certain PG tasks were designed to increase teachers' use of discourse-fostering and assessment strategies in the classroom, as these became areas of professional growth identified by teachers. For example, in the *Making Student Thinking Visible* PG task, teachers were asked to consider how questioning techniques could be used as a way to elucidate students' understandings of science concepts during whole-class discussion. They then watched a video clip of a STARTS teacher executing these strategies with her biology students, speculated on ways to increase the use of similar questions in their classroom, and made an action plan for this.

Saturday Collaboration Sessions

The collective participation of teachers from similar subject areas, schools, and/or grade levels is fundamental to fostering professional growth. Through collective participation, teachers meaningfully collaborated with one another in professional learning communities (PLCs). According to Cochran-Smith and Lytle (1999), PLCs provide a learning environment in which teachers work together to “identify discrepancies between theories and practices, challenge common routines, draw on the work of others for generative frameworks, and attempt to make visible much of that which is taken for granted about teaching and learning” (p.293).

In the PD literature, researchers often participated in PLCs to probe further about teachers’ changing practices and beliefs (Zozakiewicz & Rodriguez, 2007), address specific issues voiced by teachers (Bell & Gilbert, 1994) introduce and model new activities (Lee, 2004; Luft, 2001), and discuss instruction progression and student learning (Davis & Varma, 2008). The collective participation of teachers in PLCs occurred across grade level, within and among schools in a particular district (Garet et al., 2001). In addition to voicing concerns and brainstorming innovative approaches to science instruction, teachers used PLCs as a space to align their teaching philosophies with current research (Parke & Coble, 1997), analyze problem-based inquiry lessons (Crippen, 2012; Parke & Coble, 1997), and share best practices (Crippen et al., 2010, Lee, 2004).

During the STARTS PD program teachers met in a PLC for all the purposes cited above. The Saturday Collaboration Sessions became the primary forum for collective participation. Teachers met monthly in these face-to-face, all day Saturday Collaboration Sessions where they brainstormed lesson ideas, completed major tasks, voiced concerns, and designed innovative instruction. The Saturday Collaboration Sessions were also a time for me as lead researcher, and, eventually, STARTS teachers, to model reform-based, CRP Science instructional strategies.

CRP Science Units

As the capstone project of STARTS, the CRP Science units were intended to bridge together science content and students' interests and learning needs, thereby creating meaningful and challenging science instruction that is truly student-centered. Teachers were assisted through the process of creating their culturally responsive science units in multiple ways. First, as part of each major activity (lesson study, CTS, GAIn and PG tasks), teachers were provided with a series of scaffolds leading them to reflect on salient elements of each task and their current practices, speculate on ways to connect what was learned into instruction, and then implement trial lessons utilizing their suggested connections. Second, teachers worked collaboratively in both face-to-face and online environments to brainstorm potential connections and instructional strategies. Finally, teachers voiced their interest in learning more about specific topics (e.g., effective collaboration in the science classroom, making student thinking visible). These topics were included in the STARTS program, with specific tasks designed to support teachers in learning about research-based strategies, critically observing their colleagues practicing these strategies, then speculating on potential connections to their CRP Science unit.

Methods

For this study I examined the ability of STARTS PD features (i.e., major activities) to support teachers' progression as CRP Science educators, thereby aiming to produce usable knowledge about the program. The study utilized typological analysis (Hatch, 2002) and matrix analysis (Averill, 2002; Miles & Huberman, 1994) to address the research question, *what features of the STARTS design framework can be associated with supporting the changes in culturally responsive knowledge and practices of high school life science teachers?* Participating teachers and the larger research setting, as well as data collection and analysis methods, will be detailed in the following sections before findings are presented.

Participants & Setting

Six high school life science teachers from throughout a large, culturally and linguistically diverse school district in the Southeastern United States participated in this study. All teachers were female, but they represented multiple ethnic backgrounds. Their years of professional experience ranged from two to 24 years. Five of the six teachers received traditional training in education. One teacher was alternatively certified. While participating in the STARTS PD program, teachers selected one class period to follow throughout the program. Teachers were expected to apply what they learned during STARTS to science instruction for this class period. Within this particular class, teachers were then asked to select four-to-five "focus group" students and closely monitor their progress. The focus group students were chosen by teachers for a variety of reasons, ranging from those who were disengaged to students that teachers wanted to learn more about. The subject area taught in the focus class, as well as the racial makeup of students for these classes, is presented along with demographic details about the six participants in Table 5-2.

These six teachers represented five of the more than 20 high schools in the district; demographic details of the five schools are also found in Table 5-2. The biology End of Course exam is a high-stakes assessment required for graduation. To pass the exam, students must demonstrate proficiency and earn at least three out of five possible points. A score of four or five indicates mastery. Because of this high stakes standardized exam, there are additional constraints and added stresses placed on both students and their teachers. Therefore, teachers from the life science disciplines were chosen because of the desire to enact and examine PD experiences in the presence of such contextual factors.

Data Collection & Instruments

Multiple data sources were collected to determine the ability of STARTS PD framework features to support teachers' professional growth. As the STARTS teachers completed each activity, I engaged in a process of concurrent data collection and preliminary analysis (Strauss & Corbin, 1998) for all activity artifacts (see Table 5-1), looking specifically for evidence of CRP Science and/or reform-based knowledge and practices as well as any explicit connections between the STARTS activities and teachers' professional growth. To aid the collection of rich data, I also created a Reflective Writing Prompt (RWP) for every STARTS activity. While the RWPs had practical value in that they structured PG tasks and teachers' reflections, from a research standpoint they enabled me to seek answers to questions that arose during preliminary analysis. To document all design decisions and revisions, I kept an ongoing reflexive journal (Lincoln & Guba, 1985). The journal was maintained throughout all stages of the STARTS research and development program and contained, “a database with records of each decision, whether motivated by literature review, field research, or the demands of practice” (Joseph, 2004, p.241) in addition to preliminary analysis thoughts. As a result, this journal also served as an audit trail.

Additionally, I conducted two semi-structured group interviews at the second (10/13) and third (11/13) Saturday Collaboration Sessions. Interview questions centered on teachers’ experiences with the STARTS tasks, their beliefs about CRP Science, what they were learning about students in their focus classroom, and the process of designing CRP Science instructional materials. These interviews were audio-recorded and transcribed. Teachers also participated in a mock teaching feedback session (third Saturday Collaboration Session, 11/13) and STARTS redesign session (fourth Saturday Collaboration Session, 1/14) in which they were asked to provide feedback on the effectiveness of specific STARTS activities as well as suggestions for structural redesign of the program. At the fourth Saturday Collaboration Session (1/14), each teacher also presented their CRP Science units. Each of these sessions and activities were video-recorded and transcribed.

I also observed teachers’ classroom practices six times during the STARTS PD program, once a month during the second through fourth months and three times during the enactment of their CRP Science units. One teacher did not complete her CRP Science unit. Thus, five teachers were observed as they enacted their CRP Science units. Each observation was video-recorded, transcribed, and copious field notes were recorded. To assist the examination of CRP Science and reform-based practices, I used the Culturally Responsive Instruction Observation Protocol (CRIOP) developed by the

Collaborative Center for Literacy Development (CCLD) (Malo-Juvera, Powell, & Cantrell, 2013; Powell et al., 2011) and the Reformed Teacher Observation Protocol (RTOP) developed by the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) project (Piburn & Sawada, 2000).

The CRIOP contains 25 indicators across seven pillars: Classroom Relationships, Family Collaboration, Assessment Practices, Curriculum/Planned Learning Experiences, Pedagogy/Instructional Practices, Discourse/Instructional Conversation, and Sociopolitical Consciousness. The Classroom Relationships pillar was designed to capture elements of the classroom environment, such as respectful learning atmosphere, high teacher expectations, and productive student collaboration. Family Collaboration measures the extent to which the teacher reaches out to family and establishes partnerships. The Assessment Practices pillar represents teachers' use of formative assessment practices and student self-assessment. Curriculum/Planned Learning Experiences focus on the degree to which the curriculum utilizes students' prior knowledge, experiences, and diverse perspectives. Inquiry-based practices, teacher scaffolding, and developing academic vocabularies are all contained within the Pedagogy/Instructional Practices pillar. The inclusion of culturally congruent discourse and instructional strategies that promote academic conversation are encapsulated in the Discourse/Instructional Conversation pillar. Finally, Sociopolitical Consciousness pertains to the ways in which the curriculum includes opportunities for students to explore issues important to the local context and confront stereotypes and bias. Performance on each indicator ranges on a scale from 1 (not at all) to 4 (to a great extent). Each pillar is scored holistically; therefore, the total possible points for each pillar ranges depending upon the number of indicators contained within each pillar.

The RTOP consists of 25 items divided among three major subsets: (1) Lesson Design and Implementation; (2) Content; and (3) Classroom Culture. The subset of Lesson Design and Implementation items were created to capture reform-based, constructivist lessons. For example, the degrees to which instruction recognizes students' prior knowledge and utilizes student-generated ideas are measured. The second category, Content, measures science and/or mathematics content as well as the process of inquiry. This is further broken down into two subscales, one focused on capturing propositional knowledge (e.g., fundamental concepts are explored) and the other focused on procedural knowledge (e.g., student reflection). The Classroom Culture items subset measures how often students are encouraged to actively participate and communicate their ideas, as opposed to teacher-directed instruction. This category is divided into two subscales, communicative interactions (e.g., high proportion of student conversation) and student-teacher relationships (e.g., teacher as a resource person). Performance on each item ranges on a scale from 0 (never occurred) to 4 (very descriptive). The maximum points for each subscale is 20 points (5 items each subscale). The total possible points equals 100. However, high school science teachers typically average a score of 42, which is the lowest score among all comparison groups (middle school, community college, and university students) (Piburn & Sawada, 2000).

I first trained on the RTOP through the online training videos as well as by participating in a full-day training session with a graduate student. Additionally, I trained on and helped revise the original CRIOP at the CCLD during the summer of 2012. During the face-to-face training session with the graduate student, we observed and evaluated two videos of science and mathematics classrooms that were unrelated to the project according to the RTOP and CRIOP. We discussed our scores and came to consensus for items from both observation protocols. Additionally, during the first Saturday Session, the STARTS teachers observed and evaluated the same two videos with the RTOP and CRIOP. We then discussed their results and came to group consensus. After each observation I also engaged in member checking by providing teachers with field notes and RTOP and CRIOP scores.

Data Analysis

The data were analyzed in multiple stages using qualitative analysis approaches, including methods for typological analysis (Hatch, 2002) and matrix analysis (Averill, 2002; Miles & Huberman, 1994). Miles and Huberman (1994) suggest that an effects matrix is appropriate for determining “what changes a particular program or treatment brought about in its target population” (p.137). Before identifying features of the STARTS PD framework that influenced teachers’ professional growth, I first sought to determine any trends and patterns in teachers’ shifting CRP Science and reform-based knowledge and practices over time. To do this, I employed typological analysis methods (Hatch, 2002) to examine the classroom observations, field notes, and teachers’ completed STARTS artifacts.

The first step in typological analysis is to read through the data and divide sections by predetermined categories/typologies. The typologies I was interested in were the various elements of CRP Science and reform-based science teaching, which were identified and operationalized according to the CRIOP and RTOP, respectively.

First, I coded all classroom observations according to the CRIOP and RTOP scales. These were recorded as evidence of either CRP Science or reform-based science classroom *practices*. In addition to direct observation of practices, I was also interested in teachers' CRP Science and reform-based science teaching *knowledge*. Therefore, I also coded various teacher artifacts according to the CRIOP pillars and RTOP subscales. These data sources included teachers' completed GAIn and PG tasks, lesson study documents, CTS documents, and RWPs.

The next step in the analysis was to compile the main ideas associated with each typology in a summary sheet for all six teachers. The summary sheets were organized in HyperRESEARCH (qualitative data management software program) and contained information for each teacher's CRP Science and reform-based knowledge and practices according to the typologies. I isolated the codes by each teacher, and wrote a descriptive summary of their reform-based and CRP Science knowledge and practices, which condensed the large data set.

Following the construction of summary sheets, the next step in typological analysis was to discern any emerging patterns, relationships, or trends (Hatch, 2002). Because I was ultimately interested in understanding how their culturally responsive and reform-based science teaching knowledge and practices developed over time in the STARTS program, I isolated the coded instances per teacher across a timeline, demarcated by the various STARTS activities. I then broke the summaries for each participant into four categories: CRP Science *knowledge*, CRP Science *practices*, reform-based science teaching *knowledge*, and reform-based science teaching *practices*. I repeated this step, now looking for connections and patterns across the teachers. Through this, I could then examine patterns in developing knowledge and practices over time, such as similarities, differences, and correspondences among the categories. My goal for engaging in these steps was to determine to what degree teachers' practices were reflective of CRP Science and reform-based science teaching over time. Through this process, I developed an empirical basis for exploring which STARTS PD features were capable of supporting shifts in teachers' CRP Science and reform-based knowledge and practices.

I also conducted a grounded theory analysis of the data sources in order to understand STARTS teachers' progression as CRP Science teachers in this context, as reported in Chapter 4. Through open, axial, and selective coding, I identified six themes associated with teachers' professional growth: CRP Science conceptions, views of students, community building, repositioning students, utilizing a toolbox, and instructional changes. Findings from this study are mentioned here, as the progression themes are relevant to the next phase of analysis.

Once there was an empirical foundation for exploring the ways in which STARTS activities supported teachers' development as reform-based, CRP Science educators, I employed methods for matrix analysis (Averill, 2002; Miles & Huberman, 1994) and constant comparative analysis (Strauss & Corbin, 1998) in an attempt to identify relationships between STARTS activities and teacher outcomes, which were represented by the six progression themes identified through the grounded theory analysis. Miles and Huberman (1994) state that a matrix involves "the crossing of two or more main dimensions or variables. . . to see how they interact" (p. 239). The resulting matrix provides a visual display of the relationship between structural elements (in this case, the STARTS PD activities) and changes in practice.

To better isolate relationships between STARTS activities and outcomes, the six themes of teachers' progression as CRP Science teachers were expanded to seven outcomes, with *instructional changes* becoming *new topics* and *new strategies*. I then examined the data and isolated instances in which a teacher made a direct connection between one of the outcomes and a specific STARTS activity. For example, in the passage below, Lorelei refers to an article she read for a PG task on collaborative learning as the source of new instructional strategies she utilized:

> The student grouping article was the one I learned the most from and utilized these strategies in the classroom. I also plan on continuing the use of the strategies detailed. . . I will continue to use the strategies discussed in the student grouping article and plan on early implementation next year. (Lorelei, RWP Evaluation)

If no direct connection was reported, it did not necessarily mean that the particular activity did not assist in multiple dimensions of professional growth. Rather, it indicated that there was no direct reporting of the connection in data sources. Across the data sources I identified 171 such direct connections. Because "one event often leads to another, and then to another. . . making the relationships among events very difficult to sort out" (Strauss & Corbin, 1998, p. 184), I constructed a matrix containing cells populated with the format *STARTS Activity -> Teacher Outcome* (Table 5-3). This activity-outcome matrix enabled me to discern the degree to which the various STARTS activities accounted for each outcome, and thereby locate the phenomena of professional growth in context (Strauss & Corbin, 1998).

In the matrix, the STARTS activity is one dimension and the specific outcome is another. For example, one column might contain information for *Lesson Study -> Views* *of Students*. The corresponding cell contains the total number of isolated evidence passages for a direction connection between the STARTS Activity, lesson study, and the outcome theme, community building. In the instance of *Lesson Study -> Views of Students,* the total number of isolated evidence passages is one. The total of all connections identified between any STARTS activity and a given outcome were then summed for that outcome. For example, there were 38 instances of a direct connection among all six STARTS activities and the outcome *Views of Students*. To represent the degree to which a given activity was associated with a particular outcome, I then divided the actual instances of a connection between *Activity -> Outcome* by the total instances and represented this as a percentage. In the *Lesson Study -> Views of Students* example, there were six instances of a direct connection between the lesson study (activity) and views of students (outcome). Thus, lesson study was associated with changing views of students in 16% of all instances.

Through the matrix I could now begin to visualize the relationship between structure (STARTS activity) and process (teachers' progression) (Strauss & Corbin, 1998). According to Averill (2002), "[t]he visual impact of a matrix display can draw the reader's attention to overall trends or points of emphasis across categories as he or she reads the supporting explanation" (p. 858). Thus, to further assist in visually representing this relationship, I constructed one figure for each activity containing the seven teacher outcomes and their associated connections to that particular activity. These figures are presented alongside their associated activities.

I employed numerous mechanisms to enhance the trustworthiness of findings. To establish credibility, I engaged in repeated observation and peer debriefing after each classroom observation. I also conducted member-checking when appropriate (teachers reviewed my field notes and CRIOP and RTOP scores after each observation, confirming and/or revising if needed). To establish confirmability of findings, I achieved triangulation by constant comparison across multiple data sources (e.g., classroom observation transcripts, field notes, group interview transcripts, STARTS activity artifacts completed by each teacher) and created an audit trail through my reflexive journal which contained raw data passages, summaries of theoretical and analytical notes, and methodological notes such as design decisions.

Findings

Before presenting findings of the ways in which STARTS PD program elements supported the professional growth of teachers, I begin with results from teachers' classroom observations during the program to highlight their shifting reform-based and CRP Science practices. Then, I briefly describe six themes that characterize STARTS teachers' professional growth as CRP Science teachers within the context of this PD program.

Figures 5-2 and 5-3 represent the mean CRIOP and RTOP scores, respectively, across STARTS teachers for their classroom observations. There are four data columns for each observation protocol. The Sept. '13 (n=6), Oct. '13 (n=6), and Nov. '13 (n=6) columns represent the first three classroom observations. The fourth column (CRP Sci Avg) for each observation protocol represents the average scores across the three observations of the CRP Science unit for each teacher. One teacher did not complete her CRP Science unit. Thus, the CRP Science Avg column contains the averaged scores for 15 observations, three observations for each of the five teachers as they enacted their CRP Science units. Teachers taught their CRP Science units over consecutive days (ranging from 5-7 school days) in either December 2013 or January 2014. Teachers' CRIOP and RTOP scores for the entire CRP Science unit were averaged to clearly discern shifts in practice over time. Because the final three observations for each teacher (CRP Sci Avg) occurred consecutively and within the unit itself they were considered as the same time period. The x-axis lists the CRIOP pillars (Figure 5-2) and RTOP subscales (Figure 5-3). On the y-axis, the range (1-4 for CRIOP; 0-20 for RTOP) is aligned to possible total scores of the frequency of these practices. Because each RTOP subscale contains 5 items, there is a possible 20 points for each subscale.

The Translation of CRP Science to Classroom Practice

CRP Science practices

During the STARTS PD program, teachers exhibited consistent growth in several CRP Science practices (Figure 5-2). The consistent increase in the Classroom Relationships pillar is reflective of teachers' growing emphasis on community building within their classrooms over time. Across teachers, care was increasingly demonstrated as they engaged students in cooperative learning activities in attempts to produce equitable and respectful learning environments. Although throughout the STARTS program teachers consistently conveyed high expectations, students became increasingly viewed as capable, which was reflected in the shifting authority of the teachers noted during observations. These authority shifts became more representative of culturally responsive classrooms over time, in which students were engaged as a community of learners, collaboration was the norm, and there were equitable student-teacher relationships (Ladson-Billings, 1994). Direct instruction occurred less frequently over time, and instead students took on more active roles during class time. For example, in Christina Joy and Kate's classrooms students were asked to work in small groups to construct concept maps of the musculoskeletal system and then present their product to the class, providing a supporting rationale for the connections they made across concepts.

These instructional changes also had a positive impact on teachers' use of formative assessment to gauge student learning in addition to students' academic conversations. Increasing formative assessment and discourse-encouraging practices are optimistic findings and stand in contrast to depictions of CRP Science in the literature. In my review of the CRP Science literature, it was difficult to identify instances where the emphasis in science instruction was on fostering science-based academic registers through the use of discourse associated with science (i.e., describing and applying science terms), with the exception of isolated studies (e.g., Laughter & Adams, 2012). In other words, many studies acknowledged the importance of preparing diverse students for thinking and acting scientifically, but very few made explicit the connection between promoting the development of academic registers (Gee, 2008) and the ability to engage in scientific discourse (i.e., "talk" science) (Laughter & Adams, 2012; Lee, 2004). Yet, scientific literacy requires the use of specialized discourse and practices that must be developed in students, as literacy involves both doing and talking science (Lemke, 1990). STARTS teachers often developed students' science literacy through culturally congruent teaching practices that affirmed students' linguistic backgrounds by involving them in academic conversation using language reflective of communication in their homes. For several teachers, such as Claudia, Natalie, and Zane, this also meant that students were asked to use their native languages during instruction. As a result, students were often asked to hold academic conversations with one another in their own words before they were asked to translate it to “science language” (Christina Joy, Observation 3 transcript).

Two areas of CRP Science that were not representative of STARTS teachers’ instruction during classroom observations were family collaborations and the treatment of science topics in a critical manner. These critical reviews of science were intended to produce sociopolitical consciousness in students. The two observed instances of science as a platform for sociopolitical and critical awareness came from Christina Joy (Nov ‘13) and Zane (Nov ‘13). During a lesson on the integumentary system, Christina Joy prompted her students to explore skin cancer rates according to race in an attempt to increase awareness of a serious topic, “especially since [the curriculum] mostly talk[s] about skin cancer in relation to light-skinned people – not too relevant to my kids” (email correspondence, 3/14). In a lesson on biotechnology, Zane used whole-class discussion time as an opportunity to confront negative stereotypes:

Zane	This is also very useful. . . a crime is committed, DNA samples are found at the crime scene. Now what they have to do is to find a potential suspect and they match the DNA found at the crime scene, the DNA of the potential suspect. And we know that’s important because. . . now people are in jail for a crime they didn’t commit, right, just because they are a Black man riding a bicycle. (Pretending to be a police officer), ‘Who raped you?’ (Pretending to be a victim), ‘A Black man on a bicycle’.
Sts	Exactly!
Zane	And that’s just not right.

During this lesson, Zane’s comments were not intended to downplay the seriousness of a violent crime like sexual assault. Rather, she was pointing out to her students that advances in biotechnology (i.e., DNA testing) enable law enforcement officials to make more accurate arrests as opposed to relying on racial profiling. This was especially relevant to both Zane - a Haitian-American woman with sons - and her students, who were from African American, Caribbean American, or Hispanic backgrounds.

Despite these two examples of using science to increase students' awareness of issues important to their families and community as well as uncover bias, STARTS teachers at large refrained from including such topics in their curricula. Moreover, family partnerships were absent. Collaborations with family are a way for teachers to honor the important influence family has on students' actions and learning (Seitz, 2011) in addition to moving beyond deficit-based conceptions of families from diverse racial/ethnic backgrounds (Gonzalez et al., 2005). Yet, the only instances of STARTS teachers reaching out to partner with students' family members or using family expertise to support instruction were reported to have occurred in the past. When asked to explain ways in which they currently reached out to parents, STARTS teachers' comments revealed that they viewed sociopolitical issues and family connections as relevant topics to which science content can be applied. For example, when Claudia described instances in which she reached out to students' family members at a school where she taught previously, these were done to bring in scientists who could present information on science topics discussed in class, such as the classification of kingdoms in biology.

One of Claudia's students had a parent who was a professor of microbiology who visited class one day. Reflecting on the experience, she shared,

> He came with a whole lab set up for the students and gave a wonderful speech about organisms that cause diseases. . . he brought different kind of worms. . . [and] . . . slides of microscopes showing a test of a child with severe parasites. (RWP, Connecting Families & Science)

To Claudia, family collaborations were worth establishing if they added depth to science topics already being covered in the curriculum. Additionally, on the occasions where sociopolitical topics were successfully applied to science content, it was facilitated through an instructional strategy that had either been previously learned during the program and used multiple times or was an existing strategy from their toolbox of resources for CRP Science.

The STARTS teachers also reported that they felt uncomfortable reaching out to family, saw this as impractical given the number of students they taught, and were unsure of how to begin establishing a partnership. Though the lack of family partnerships is a concerning trend, it is consistent with several studies of CRP Science that do not identify family connections. While the notion of *community-based science* was prominent within the literature (e.g., Bouillion and Gomez, 2001; Fusco, 2001), it was rare to identify examples of teachers reaching out to family in non-traditional ways or using family expertise to guide classroom instruction and student learning (e.g., Kelly-Jackson & Jackson, 2011; Tobin, 2000).

Reform-based science teaching practices

According to Johnson (2011), multiple elements of CRP Science are "complimentary to components of effective science instruction outlined in the *National Science Education Standards*" (p. 172). The position taken by Johnson in this comment was reflected in the similarities noted among certain aspects of the CRIOP and RTOP scores of STARTS teachers. Just as teachers' CRIOP scores for the Discourse/Instructional Conversation pillar increased over time, so did their RTOP scores for the Communicative Interactions subscale (Figure 5-3). These two categories contain multiple similarities, such as their emphases on active student engagement through academic conversations and communicating information through a variety of media. Over time, STARTS teachers' classrooms became environments where student engagement was evident. Students worked collaboratively and relied on each other to learn science content and construct products that were often presented to the class. They were involved in developing and using models to explain science phenomena, analyzing and interpreting data, and obtaining, evaluating, and communicating scientific information in small group and whole-class settings.

For example, during one of her CRP Science unit lessons, Claudia engaged her ESOL biology students in the construction of various visual representations of DNA structure and function. Students worked in small groups of either four or five to complete the tasks. In one group students were asked to illustrate nucleotide bonding (single, double, or triple bonds), while in another group students created a chart depicting the process of transcription (converting DNA to mRNA). In a third group students were responsible for drawing the structure of a nucleotide; a fourth group focused on translation (converting mRNA to protein). Though the task for each group required a different level of difficulty (which Claudia determined based on their English proficiency), Claudia never communicated this to students. Rather, she helped them feel as though each poster was indeed an equally important contribution. Students then presented their products to the class, explaining the processes depicted in their models in Spanish and English. In my field notes I reported:

> The students appear to be very proud of their work and capable of describing their poster in detail. . . they are completely engaged, not just in their presentation but also in watching others and asking questions. . . [Claudia] asks students to describe what they liked most about this activity. While it seems that she may be aiming for content, the students replied (in Spanish) that they liked working together, representing information through drawing, and presenting alongside others…While this lesson seemed at times to focus on recall-type information, this was quite a powerful lesson in that it allowed the students to work together to take control of their learning, demonstrate their knowledge in a variety of ways,

> and communicate their conceptual understanding to others in Spanish and English. (CRP Science observation, 1/ 2014)

As they participated in the STARTS PD program, teachers' RTOP scores improved in every subscale with the exception of Student-Teacher Relationships. This subscale was consistent across time among the teachers and pertained to how patient teachers were with their students, how much they valued student participation, and how well they acted as a "listener" in the classroom. Throughout the STARTS PD program, teachers consistently held high expectations for their students and were respectful of them during class time. They made an effort to balance their questioning so that numerous students were called on during whole-class discussions. When conducting a lab investigation, they regularly visited with each student group to check comprehension and pose clarifying questions. However, their views on students as capable individuals increased over time such that they began to relinquish control and progressively moved toward less direct instruction.

The influence of the CRP Science unit on STARTS teachers' reform-based science teaching can also be seen. Overall, the teachers designed for and implemented more reform-based science teaching during the CRP Science unit than had been previously observed. Due to the CTS and GAIn influences on the unit, teachers' lessons were more focused on core science ideas and promoted strong conceptual understanding. They also respected, solicited, and built on students' prior knowledge.

Though STARTS teachers did improve in procedural knowledge during the enactment of their CRP Science units, their subscale scores were consistent for every other time period and also the lowest scores across all the subscales. Considering that this subscale was designed to capture the process of inquiry, this is a concerning trend indeed, but is also consistent with the literature on teachers' use of inquiry in science classrooms (Capps, Crawford, & Constas, 2012). I infrequently observed teachers engaging students in the process of constructing their own hypotheses and devising a means for testing them. While it was more common to see students articulating hypotheses before a lab investigation, this usually accompanied a tightly scripted lab where the end goal was acceptance or rejection of the hypothesis. Furthermore, there was only one instance of students critically assessing lab procedures. Additionally, while student reflection on their understanding became a more prominent element of instruction over time, it was rare to observe students' ideas being challenged and critiqued.

Though STARTS teachers spoke of wanting to challenge students' ideas, data revealed that there was a discrepancy between their goals of ideal science (in this case, challenging students' ideas) and their beliefs about how much students' ideas should be critiqued. Natalie is a unique example of this disparity. In her GAIn 2 task she wrote of wanting students who normally do not participate to feel comfortable and provided this as a reason for accepting their answers without any critical evaluation. However, by the time she implemented her CRP Science unit, there was evidence that Natalie did indeed challenge her students' positions on science concepts. While presenting an overview of a lesson on mitosis from her CRP Science unit during the final Saturday Collaboration Session, Natalie shares, "When they were done, they'd raise their hands. . . I'd challenge them; even if it was correct I'd challenge them. . . and I'm like 'I'm not telling you you're wrong. I'm just making sure that you understand'" (Presentation). In this activity students worked in groups at stations to learn about the different stages of mitosis, which were presented out of order. Students had to interpret the information they were presented with, deduce the correct order, and provide a justification for their choices based on the available data. Natalie challenged each group's final product, which led to students feeling uncertain. However, while observing this lesson, I witnessed Natalie use structured questioning techniques that moved the groups from feeling uncomfortable to being more certain of their final products, all the while providing evidence to support their decisions.

STARTS teachers' growth around the Lesson Design subscale was inconsistent. This subset pertains to several student-centered practices. Though students were increasingly engaged as members of a learning community and their prior knowledge elicited, the focus and direction of the lesson was rarely determined by ideas originating with the students themselves. When asked to explain these trends, the teachers spoke at length of the institutional influence they experienced, specifically citing the need to prepare their students for the End of Course exam as a reason for not letting students "take the wheel" when it came to lesson ideas (Claudia, Clarification Questions). The impact of high-stakes testing, such as the End of Course exam, on curriculum narrowing is both concerning and well documented. There is a strong positive correlation between standardized assessments and teacher-directed, passive transmission of discrete facts to students (Au, 2009), which threatens the presence of reform-based and CRP Science practices.

Teachers' Progression as CRP Science Educators.

Teachers' culturally responsive, reform-based science practices reported here are a result of their professional growth as CRP Science teachers. There are six themes that described how the STARTS teachers came to epitomize the practices reflected in the CRIOP and RTOP graphs. They include: CRP Science conceptions, views of students, student repositioning, community building, utilizing a toolbox, and instructional changes. While this progression has been detailed elsewhere (Chapter 4), I present an overview of each theme in preparation for elucidating the STARTS framework elements capable of supporting this professional growth. The CRP Science conceptions theme pertains to STARTS teachers' expanding knowledge of CRP Science, which progressed from being simplistic and tied to race at the beginning of the program to being multidimensional and connected to teachers' practices when STARTS concluded. Teachers' views of students changed over time as well. Whereas at the beginning of STARTS their views of students were assumption-laden and occasionally deficit-based, teachers began to learn about their students in very purposeful ways through the lesson study, GAIn tasks, and Professional Growth tasks. As teachers engaged in these program activities, they viewed their students as capable and proceeded to connect instruction to students' lives both in and out of school. In time, students became more active in their classrooms and were repositioned as leaders, whereas in the first months of the STARTS PD program this was not evident.

Community building was a mechanism for conveying care, establishing fluid student-teacher relationships, and increasing academic discourse. The toolbox represents a collection of instructional strategies and relevant topics that were a mechanism for implementing CRP Science. Johnson (2011) refers to an "'arsenal'. . . that [teachers] can leverage to make their instruction more innovative and responsive to diverse student needs" (p. 183). The STARTS teachers described this as their "toolbox" (Christina Joy, Presentation; Kate, RWP Evaluation) and drew heavily from it when designing their CRP Science units. As teachers' knowledge of CRP Science increased, they also became more aware of their own teaching practices, which caused them to reassess their instructional approaches. Thus, STARTS teachers' shifting knowledge of CRP Science accompanied instructional changes that were less teacher-directed and more reflective of culturally responsive, reform-based science practices.

Elucidating the Relationship between Structure and Process

Findings of teachers' reported connections between the major STARTS program activities and six progression themes encompassing their professional growth are reported in this section, thereby elucidating the relationship between structural program elements and the process of becoming a CRP Science teacher.

Lesson Study

Figure 5-4 illustrates teachers' reported connections between the lesson study and their outcomes as CRP Science teachers. Overall, the lesson study was reported to increase STARTS teachers' knowledge of their students, their teaching practices, and to a smaller extent, conceptions of CRP Science. Additionally, there was evidence that the lesson study experience was accountable for the addition of new instructional strategies and relevant topics to teachers' toolboxes. However, when compared with other program activities, lesson study was not largely responsible for supporting the CRP Science knowledge and practices of participating teachers.

When STARTS teachers spoke of the in-depth process of lesson study, its benefits and challenges, they primarily perceived it as a way to begin exploring their teaching in a systematic manner. Zane explains, "I liked that it was the first thing that we did because it was kind of an introduction to exploring our teaching" (Redesign Session). The lesson study fostered the critical exploration of STARTS teachers' practices, the intended and actual outcomes on students, which ultimately led teachers to refine their professional goals so they were more responsive to students than when initially identified. Christina Joy describes such changes,

> Now that I have done a lesson study, I have identified that I would like to grow in terms of reflection for myself and my students, so this is actually my professional goal for this year – student reflection. . . rarely do I go back and have them reflect on what they have learned and what they might still have questions about. (RWP 2)

In addition to serving as a vehicle for exploring their practices, STARTS teachers also became more conscious of their students through lesson study, both academically and socially. However, because of the nature of lesson study as a tool for identifying and selecting student learning goals, STARTS teachers' comments about students' behaviors tended to focus on areas for improvement, such as strengthening their abilities to work cooperatively. Though their comments about students were still general at this time in the program, the lesson study served as a structured introduction to begin purposefully connecting instruction with specific student needs as well as expanding teachers' desired lesson outcomes beyond academic performance to include student qualities that influence their motivation. For example, after sensing a disparity between student interactions outside and inside of class time, Natalie and Lorelei became mainly concerned with supporting their students' abilities to work effectively in groups where everyone's ideas could be expressed. This focus on developing collaborative and respectful environments is a component of both CRP Science and reform-based science teaching, in which students interact with one another in meaningful ways, thereby creating a classroom community.

When discussing their experiences with lesson study, STARTS teachers shared concerns about the timing of the task. These concerns centered around two issues: not yet knowing students well enough, and their practices being in transition at the beginning of the school year. A second, and perhaps more concerning set of issues focused on the structure of the lesson study experience. Listening further to STARTS teachers speak of their challenges with the lesson study task at the following Saturday Collaboration Session, it became evident that additional structuring was required to make this experience more beneficial to their professional growth. The suggestions shared by STARTS teachers highlighted a need for better scaffolding of the observation and analysis phase in particular.

For the teachers, the overall effectiveness of the lesson study was hampered by asking them to set out on a project of this magnitude primarily on their own. Kate shares her thoughts to this end,

> Another issue that came up with the lesson study activity was analyzing one another's video recordings of teaching the lessons. There were some snags with technology and mailing videos, but I think the honest issue was that it was our first time doing an activity completely on our own time. (RWP 2)

Despite the challenges faced by STARTS teachers as they participated in the lesson study, data revealed that it was fairly beneficial to their developing knowledge of reform-based, CRP Science teaching as it provided them with a new level of awareness of their practices as well as a deeper consideration of their students when planning instruction.

GAIn

The GAIn tasks were strongly associated with several outcomes related to becoming CRP Science teachers, including STARTS teachers' awareness of CRP Science, their teaching practices, views of students, and adding to their toolbox through new relevant science topics and responsive instructional strategies (Figure 5-5). As

STARTS teachers talked about the influence of the GAIn on their professional growth, they reported that the prompts contained within the GAIn tasks helped organize their thoughts and facilitated reflection on translation to practice. They spoke of critically analyzing their practice and applying learned strategies to their instruction for specific purposes. Kate explains,

> The GAIn activities made it possible for me to make a connection between the strategies that I had learned about (jigsaw, concept maps, equal student questioning) and my actual teaching practices, meaning, I could now identify issues [in the classroom] through the GAIn, give myself solutions to those issues, and put those solutions into practice. (RWP Evaluation)

Kate’s transition from awareness to practice was clear over time. When first selecting her focus group students, Kate chose a group of four females whom she identified as not speaking up in class. As she learned more about these students through the GAIn tasks, Kate discovered that they were often spoken over during group activities. Kate struggled to devise strategies for overcoming this obstacle at first, but over the course of STARTS she learned and implemented cooperative learning strategies that increased their participation. However, when completing the third GAIn task, Kate learned that her four female students identified as being “bad at science” and said they were disinterested in science as a subject. As a result, Kate employed additional strategies that were introduced in STARTS and also began to incorporate relevant science topics into instruction as a way to engage her students. Kate reported success with her four female students, noting that they not only became more confident and frequently communicated during science processes, but also became more self-reliant over time.

The GAIn readings were intended to serve as exemplars of effective CRP Science and a springboard for reflection on practice and subsequent action. Christina Joy's comment supports these intentions:

> Reading from articles about here is what a culturally responsive [classroom] looks like, here's what it doesn't look like, and saying to myself, "ok, are there any elements over here I kind of want to shift?" So I would have never read articles on that prior to this or analyzed any of this to that extent. (Group interview 1)

In this passage, Christina Joy describes how a GAIn reading pertaining to classroom environment enabled her to envision what a culturally responsive classroom might look like, contrast her own classroom environment and practices to the example, and then speculate on potential changes as a result. Hence, the GAIn assignments also had a profound influence on teachers' shifting conceptions of CRP Science.

Christina Joy's comment highlights another primary purpose of the GAIn tasks, to introduce STARTS teachers to effective science practices. Their expanding awareness of CRP Science and their teaching practices prompted STARTS teachers to consider new instructional approaches. Sometimes these changes were related to events witnessed inside the classroom, while at others they were directly connected to what STARTS teachers learned about their students outside of the classroom. Often, this was through the building of a classroom community, where students felt respected and comfortable. As a result, typical students' roles were often repositioned to include more ownership and opportunities for acting as teacher and leader. The STARTS teachers also utilized instructional strategies learned during the program that they felt helped them enact CRP Science, such as questioning scaffolds that elicited students' prior knowledge, and connected these conceptions to science content. When they spoke of associated student outcomes, they were positive. “The Tissue and Integumentary system were a huge success with utilizing what I had learned through the GAIn” (Christina Joy, RWP Evaluation).

Although not intentionally designed for this purpose, the GAIn also served as a structure that helped STARTS teachers add to their toolbox, whether it was implementing a novel strategy in response to an issue they observed in the classroom or identifying a science topic that was relevant to what they learned about students’ lives outside of class. Among the teachers, the GAIn tasks were regarded as a major contributor to creating connections between science instruction and culturally relevant topics.

When identifying shortcomings of the GAIn tasks, the STARTS teachers pointed to a need for more specific questions to ask students as they began to consider ways to connect instruction with students’ lives. For the third GAIn assignment, STARTS teachers were asked to speculate on ways to connect students’ backgrounds to instruction by first administering a survey to all students about their interest in science and then holding a conversation with each of their focus group students. The information learned was then supposed to be directly applied to a new lesson that featured a relevant science topic and a responsive instructional strategy. Of the list of potential student questions provided in the third GAIn task, Natalie explained:

> Many of the students responded to ‘texting and hanging out with friends’ when I asked what their hobbies are. I wish I would have asked them what ‘hanging out’ consists of. I would have liked to know more specifics about their lives outside of school. For instance, what is their family background or have they always lived in that house? I feel those types of questions would allow them to explain their stories better to me. (RWP Evaluation)

While the concern voiced by Natalie is important to address, as the task would have been more beneficial to her if more structured questions were provided, it is important to note that the GAIn was designed as a structured way to begin considering how to link what teachers know about students to relevant instruction. It was not intended to be the only instance of learning about students or a substitute for learning about students beyond these assignments.

CTS

Several STARTS teachers admitted that completing a Curriculum Topic Study was the most complex activity of all their STARTS experiences. In fact, teachers reported that the process was frustrating and the overall value of CTS was not clear until they had completed the activity. After completing the CTS, their perspectives shifted dramatically. When STARTS teachers spoke about their experiences with CTS, it was largely around identifying new strategies for teaching familiar concepts that were more aligned to reform-based science practices (Figure 5-6). They talked of coming away with a better understanding of how to recognize and teach the “bigger issue,” which they contrasted with their existing practices. Thus, the CTS experience also functioned as a way for teachers to continue gaining awareness of their instructional practices. Natalie stated, “In the readings, there’s DNA in the cells and cells are made up of molecules. A lot of kids don’t make that connection and even myself, I never made that connection before until today, so seeing the bigger issue” (Group interview 1). Teaching the core ideas of a science discipline, as opposed to disconnected facts, enables teachers to organize instruction around the knowledge structure of the discipline and promote deeper exploration of essential concepts (Keeley, 2005; NRC, 2012).

For the first time, STARTS teachers commented on the importance of uncovering students' misconceptions, citing the CTS as a cache of resources for this information. As they recognized a disconnect between several of their practices and those espoused in the CTS resources, STARTS teachers began to reconsider effective science instruction: "before I teach a lesson now I'm going to look up. . . what are the misconceptions before we start. . . and then compare them to what I think my misconceptions are for students" (Christina Joy, Group interview 1). By eliciting and challenging students' misconceptions, teachers are better positioned to support conceptual change (Bransford, Brown, & Cocking, 2000). Furthermore, this shift also highlights the increasing student-centeredness that was characteristic of STARTS teachers' practices over time. After completing the CTS, STARTS teachers had a solid foundation for their CRP Science unit and a new approach to reform-based science teaching, now emphasizing deeper conceptual learning through teaching connections to big ideas and attending to common misconceptions. To a smaller extent, the CTS experience also provided new science topics that teachers applied to their CRP Science unit design, such as mutations commonly found in individuals of a certain ethnicity, as well as the connection between DNA, geographic location, and resulting skin pigmentation.

Though STARTS teachers viewed CTS as supporting their reform-based science practices, there were mixed opinions about the overall benefit of completing the CTS in preparation for the CRP Science Unit. These opinions were quite polarized and ranged from complete support of the process to feelings of minimal professional gain. This dichotomy was based on the amount of available resources for a specific topic. For example, Claudia, Lorelei, Natalie, and Zane (who all completed their CTS on DNA structure and function) expressed positive outcomes and greater confidence in their teaching practices after completing the CTS. Conversely, Kate and Christina Joy (who partnered to complete their CTS on topics related to the musculoskeletal system) expressed less benefit. Christina Joy stated, “While I got a lot out of the concept mapping and looking at the bigger picture utilizing the [CTS] references, I otherwise did not gain much from this activity” (RWP Evaluation). It appears that the primary limitations of CTS were in the depth and breadth of available content by subject area. Despite the limitations expressed, the CTS activity provided teachers with a more rounded view of reform-based science teaching and prepared them for designing innovative instructional materials.

Professional Growth Tasks

As STARTS teachers moved between awareness and action, they spoke of wanting a “toolbox” (Christina Joy, Presentation) of instructional strategies, and relevant science topics to facilitate their enactment of CRP Science. The PG tasks provided STARTS teachers with plentiful examples of instructional practices that promoted collaborative learning, formative assessment, and more meaningful teacher-student interactions (Figure 5-7). Because CRP Science is deeply contextualized, with the introduction of each strategy STARTS teachers were repeatedly asked to consider how CRP Science instruction might look when enacted based on their students’ and classroom needs (which they had already been following closely through other activities such as the GAIn tasks and lesson study), thereby reducing the acceptance of a “one-size-fits-all” strategy. The PG tasks gave STARTS teachers instructional tools to continue their quest for community building through collaborative learning and repositioning students as more active in their learning. In fact, the PG tasks were the only time in which a teacher highlighted a direct connection between a STARTS activity and student repositioning:

> And then also I took the opportunity to work with them [her students] on the reading that we [STARTS teachers] had to do on the student grouping, and this was how they collected data on the types of statements they were giving. . . we worked a lot on it; they actually got a little annoyed at how much we talked about working together, but then they did have a few reflective prompts like “how do you feel your group work has changed over this time?” So I was reading those, and everyone improved so much. (Kate, Presentation)

In this passage Kate describes how, through a reading on cooperative learning structures, she strove to promote meaningful and equitable academic conversation among her students. In her attempts to increase student-student interaction, Kate repositioned her students in such a way that their comments, insights, and questions were central to the success of the activity.

The PG tasks also facilitated STARTS teachers’ reflection on their practices and beliefs over time. For example, in the *Making Student Thinking Visible* task, STARTS teachers first read a practitioner article on eliciting students’ understanding through structured questioning techniques. They then watched a video excerpt of Natalie employing the questioning technique with her students. Afterwards, they reflected on salient elements of the technique, considered how to apply the method to their own instruction and made a plan for integrating the technique into their instruction. The STARTS teachers then reflected on the effectiveness of the questioning technique once it was enacted in their classrooms.

The PG tasks also had limitations. Though several teachers felt it was beneficial to see each other’s practices modeled as exemplars in the video recordings provided on the STARTS course site, others found that this had limited impact on their instruction and did not necessarily provide “additional skills or tools” to add to their toolbox (Christina Joy, RWP Evaluation). Additionally, certain readings introduced STARTS teachers to approaches that they were uncomfortable with and felt were impractical. Natalie provides an example, “The literature that we went over suggests home visits as a way to reach students in the community setting and I am uncomfortable going to students’ homes” (RWP Evaluation). In this particular instance, the STARTS teachers and I held a discussion about connecting families and science in ways that they were comfortable with. In this conversation STARTS teachers posed alternative solutions such as meeting family during sporting events or extracurricular activities, communicating through email or phone, and connecting at church.

Saturday Collaboration Sessions

In spite of the ongoing commitment required of teachers to devote an entire Saturday to PD (in addition to their online tasks), they perceived the collaboration sessions as valuable for multiple reasons, though this was not necessarily reflected in the matrix analysis findings (Figure 5-8). Although the benefits of collegiality arising from this PLC were minimally connected to the progression themes, the collective participation that occurred during the sessions “provide[d] a nurturing environment for professional learning” (Loucks-Horsley et al., 2010, p. 94), thereby “increas[ing] teachers’ capacity to grow” (Garet et al., 2001, p. 922). The Saturday Collaboration Sessions became a time to hold professional conversations, complete major tasks, brainstorm instructional ideas with one another, observe one another’s teaching, and receive feedback on their practice, all of which they cited as beneficial to their professional growth. As a time to come together and clarify next steps, the sessions eased feelings of being overwhelmed with the larger STARTS tasks. Claudia voiced,

> Actually it [the lesson study] feels overwhelming but when we get together and when we think about it together it's not that bad, it's just the fact that you *think* that you have to do this huge thing, but it's really not that overwhelming. (Group interview 1, italics indicate emphasis)

The collective participation that occurred during the Saturday Collaboration Sessions enabled STARTS teachers to brainstorm ideas for CRP Science, co-design instruction, and share their best practices. Thus, when connected to specific outcomes, STARTS teachers viewed their time together as opportunities to learn new strategies and, to a lesser degree, relevant science topics. This was also a time when I modeled several CRP Science strategies intended to promote equitable science learning, including structured protocols for conversation (e.g., http://www.nsrfharmony.org). Modeling and strategy-sharing provided teachers with new tools for their toolbox, which they drew heavily from when designing their CRP Science units. As a result, STARTS teachers modified their own instruction in ways that they associated with CRP Science.

Though teachers compared each other's practices and considered new instructional strategies, missing from their discussions was a deeper understanding of *why* the new strategies worked. Rather, the emphasis was simply on accepting that the strategies *did* work. Without a deeper understanding of the intentions behind a strategy or curriculum, Buxton, Lee, and Santau (2008) argue that teachers are "unlikely to modify or enrich their ideas about content or pedagogy" (p. 498). Accepting a practice without critical examination supports findings that the Saturday Collaboration Sessions were not closely associated with teachers becoming more aware of their own practices during this activity, but rather that it was a time to acquire new strategies and topics for the toolbox. However, as teachers implemented the instructional strategies learned during the Saturday Collaboration Sessions, reflected on their outcomes (through GAIn and PG tasks), and revised accordingly (through CRP Science unit), their practices became more responsive to students' and classroom needs.

In addition, the PLC sessions forged a supportive network of colleagues that relied on each other while implementing new instruction, even when the teachers taught different subject areas. Over time, STARTS teachers came to depend on one another so strongly that they engaged in collective participation beyond the structured program experiences.

Lorelei I love the brainstorming that we do within this group, like we work really well together. I love bouncing ideas off [Christina Joy] and being able to do like I did with the timeline [activity], being able to email you [the author] and [Christina Joy] and just kind of ask, "ok, what should I do now?" because I forgot right in the middle of a lesson. . . she sent me an email . . . And then the next class I'm like "*oh, okay*, I got a new system now" and it was perfect.

JCB Did it make a difference for your lesson?

Lorelei A huge difference and even in the way that I presented the information of what I wanted them to do, it was like night and day from my second hour [class period] to. . . by the time my fifth hour [class period] rolled around I'm like "ok, I *got* this." (Group interview 2, italics indicate emphasis)

In this instance, Lorelei recalled her experience implementing a new lesson that she co-designed with Christina Joy. Running into a snag, she emailed Christina Joy and me in between classes. Based on the prompt feedback Lorelei received, she was able to make small, but needed, modifications to her instruction, which she describes as leading to "a new system." STARTS teachers also encouraged one another through the difficulties and challenges associated with designing for and implementing a new form of practice. Zane explains, “[t]he collaboration sessions allowed STARTS science teachers to share their experience in the classroom while implementing the CRP strategies. We learned from each other strengths and struggles” (RWP Evaluation). The bond that formed between teachers became so strong as they participated in the STARTS PD program that they even credited one another for instructional strategies that were originally introduced by me.

However, there were instances when faulty design in STARTS activities threatened the positive impacts of collective participation and the Saturday Collaboration Sessions. For example, in preparation to enact their CRP Science units, STARTS teachers engaged in a mock teaching activity during the third Saturday Session. The activity was designed to assist teachers as they implement novel CRP Science instruction, providing them with a low-risk forum for mock teaching one of their CRP Science unit lessons. The teachers noted several drawbacks to the mock teaching activity. First, they felt as though taking on the roles of “teacher” and “student/observer” decreased authenticity, meaning that it was awkward to teach another teacher who is not an actual student and cannot provide feedback such as a student might. The one-on-one nature of the partnership exacerbated this decreased authenticity. Second, there was a disparity between the perceived value of the mock teaching activity and level of professional experience. Natalie and Kate, the two teachers with the least amount of classroom experience, shared that it was beneficial to receive feedback on the actual mechanics of implementing a lesson they had never taught before. However, for a more experienced teacher like Christina Joy, this was not the case.

Christina Joy explained:

> When I design a lesson I feel like after fourteen years I can figure out where. . . it's going to go wrong or whether [students are] going to be confused or where I can be more specific; it's only from experience. . . you kind of already see what the issues are going to be. (Mock teaching feedback transcript)

When working with a group of teachers with such diverse experiences, it was a challenge to meet the professional needs of everyone at a given time. Though the STARTS PD program was designed to be responsive to teachers, there were times when this goal fell short.

CRP Science Unit

Though the STARTS teachers expressed that designing and enacting the CRP Science unit was beneficial to their students and themselves, they rarely talked about the unit in a way that directly connected to their outcomes (Figure 5-9). This is largely because, as the capstone project, the CRP Science unit was built from all of the previous STARTS activities. They learned about science content through the CTS, connections to students through the GAIn tasks, and responsive instructional strategies during the PG tasks and Saturday Collaboration Sessions. In fact, when they presented an overview of their CRP Science units to one another during the final Saturday Collaboration Session, the teachers asserted that the unit was reform-based because it connected to the CTS and PG tasks, and that it was culturally responsive because it connected to the GAIn tasks. This comment made by Christina Joy highlights the influence of the Saturday Collaboration Session, GAIn tasks, lesson study, and the toolbox in the construction of her CRP Science unit:

> I also added because of my GAIn protocol. . . I added some reflection for the students and on the reflection for this particular lab so many kids said to me. . . "I was so happy we did that before the test" . . . this is probably

> the number one thing that I loved and learned about STARTS, it all came from. . . remember when Julie had us do the sticky notes activity? I just took that and modified it for my students' needs. (Presentation)

The sticky notes activity that Christina Joy referred to in this passage was a concept-mapping activity in which teachers used colored Post-It notes to indicate their revised thinking about concepts as they progressed through the CTS. Christina Joy describes how this particular instructional strategy became a tool in her toolbox that was first modified for her students' needs before being utilized. The needs she alludes to were learned during her GAIn tasks, where she highlighted the need for scaffolding academic conversation. Through the construction of their concept maps, Christina Joy's students were held accountable for articulating relationships among concepts with sufficient detail that they could then present it to the class. Furthermore, during the lesson study, Christina Joy noted that her students required more assistance with self-reflections. Over the course of the STARTS program she then included multiple uses of self-reflection in her anatomy and physiology assignments, including this one.

The teachers also found that engaging in CRP Science lessons led to positive student outcomes, which ultimately increased their satisfaction with the final product. Claudia states, "I really liked this [CRP Science Unit]; it seems that there is more connection now with my students, we know each other better and they work better. . . it impacted my students in a positive way" (RWP Evaluation). Kate and Zane spoke of students' increased communication in science, Lorelei of their decreased reliance on her, and Natalie of students' improved performance on tests. Despite the positive outcomes associated with constructing their CRP Science units, STARTS teachers also experienced challenges. In order to keep all teachers on a similar timeline, STARTS teachers had a two-month window for implementing their CRP Science unit. This was announced to teachers at the beginning of the program so they could anticipate which curriculum units would most likely be modified to be more culturally responsive and plan ahead as needed. As a result, the time of year in which the unit was enacted (late November 2013 to late January 2014) constrained possible topics and led to difficulties because of district-mandated pacing guides. Furthermore, this constrained timeline was cited by Zane as the reason for not completing her CRP Science unit. Though her classroom observations indicated that she applied what had been learned during the CTS, there were no obvious connections to her GAIn findings. When asked why this was the case, Zane reported that she had been so busy preparing students for the first attempt at the End of Course exam that she did not have time to modify the unit further.

Additionally, though STARTS teachers spoke of applying science topics to instruction they felt were relatable to their students, this did not happen as often as discussed. For the teachers who applied relevant topics to the CRP Science unit, this was only after they had either learned a responsive instructional strategy during STARTS and used it multiple times or utilized a preexisting strategy that they were very comfortable with. For the teachers in this study, a relevant science topic was not applied in conjunction with a newly learned responsive instructional strategy. The strategy had to be implemented on multiple occasions before then making science content more relatable to students' lives, which further restricted opportunities for sociopolitical topics and family connections. Related to this concern, STARTS teachers also expressed a desire to extend the STARTS program so that they could make additional units more reflective of CRP Science. Kate expresses this sentiment:

> As we discussed at the end of our last collaborative session, there is often a fall-out where teachers' newly learned practices slowly fade out as we

> stop doing STARTS activities. I would have liked to look over my entire year's curriculum at some point in the program, and brainstorm ideas where student interest and my other GAIn findings could be incorporated. This way, I would at least have some ideas written down where I wouldn't feel totally disconnected from CRP practices later on in the year. (RWP Evaluation)

Concerned that their practices might revert to the more traditional approaches utilized before participating in the program, Kate and others wanted to ward off this situation by requesting additional time to construct CRP Science instructional materials for multiple units. This is a weakness of the STARTS framework design. However, because CRP is so deeply contextualized (Gay, 2010), extending CRP Science to all curriculum units serves only as a partial solution, as students, their needs, and backgrounds will change from year to year.

STARTS PD Framework Redesign

The STARTS PD program was designed to develop culturally responsive, reform-based science teachers who create CRP Science instructional materials. As teachers participated in the STARTS PD program, their knowledge and practices became progressively more reflective of reform-based, CRP Science teachers though there were still struggles. By the time the STARTS program concluded, teachers' classrooms were observed to be a place where teacher-student relationships were more fluid than at program onset, academic communication and collaboration increased, and formative assessment was used more frequently. Amid these successes, challenges to developing teachers who enact all dimensions of CRP Science and reform-based science teaching emerged. Inquiry-based science instruction and critical awareness-building experiences were sporadic. Family connections were absent. Hence, the original STARTS PD framework requires reexamination.

In this section, I first present several implications for redesign of the STARTS PD framework (Table 5-4), and conclude by articulating a set of design principles derived from empirical findings and the literature. Design frameworks are “useful for understanding specific elements or phases of educational design research. . . some offer general characterizations while others describe specific phases of the process” (McKenney & Reeves, 2012, p. 73). The level of detail of the specific phases contained within a design framework varies. Those with lower specification are more readily available for adaptation to new contexts than highly specified models imply (McKenney & Reeves, 2012). Therefore I aim to offer a set of design principles to accompany the revised design framework that are prescriptive in nature but produce usable knowledge for science educators and professional developers interested in expanding the presence of CRP Science through PD.

Collectively, these revisions will lengthen the overall duration of the original STARTS PD program, as they call not only for revision of existing PD experiences but also the inclusion of additional activities, such as service-learning projects and inquiry-based active learning experiences. Because of the manner in which STARTS teachers actually applied CRP Science topics to instruction (only after a strategy was learned and well implemented), the timeline must also shift to include more family-based and sociopolitical awareness-raising topics after several student-centered, constructivist strategies have been learned, implemented, revised, and used again (Johnson, 2011). Furthermore, as Morrison, Robbins, and Rose (2008) have argued, teachers require ample time to design CRP instructional materials. The STARTS teachers also echoed this need. Therefore, the revised framework includes structures for expanding CRP

Science out to multiple units so teachers do not fall into the trap of reverting back to traditional practices (Loughran, 2007).

The elements of the revised framework and additional PD experiences must cohere with what teachers are held accountable for (tightly aligned to pacing guide, standards and EOC exam). As Barab and Luehmann (2003) emphasize:

> Given the time and resource constraints of teachers and the fact that they are held publicly accountable through standardized tests, our efforts must result in the creation of usable and powerful tools to support teachers' needs for efficiency as well as effectiveness in the development of learning opportunities. (p.358)

Therefore, to support high school life science teachers' enactment of CRP Science, the science education community must provide resources that are effective within the constraints inherent to the profession. I begin with implications for increasing CRP Science teachers' use of inquiry-based instruction.

Implications for Inquiry-Based Instruction

Over time, the STARTS teachers engaged students more frequently in the practices of science such as obtaining, analyzing and communicating scientific information, using mathematics and computational thinking, and engaging in evidence-based arguments. However, students had little choice over selecting their assignments, their claims were infrequently challenged, and they very rarely designed their own experiments to test hypotheses and conjectures. Because the STARTS PD program was designed to increase such classroom experiences, these outcomes represent a design flaw.

A key element to effective inquiry-based PD is authentic learning experiences where teachers first engage in inquiry cycles as students before considering how to incorporate these experiences into their classrooms. A unique form of PD that can offer such experiences is the scientist-teacher partnership (STP). Designing PD to include meaningful STP experiences can assist teachers in translating content knowledge to inquiry-based science instruction (Brown, Bokor, Crippen, & Koroly, 2014). STPs with this potential have involved teachers in conducting authentic inquiry investigations alongside scientists (Dresner & Worley, 2006; Jeanpierre, Oberhauser, & Freeman, 2005), being guided through inquiry cycles by scientist experts (Harris Willcuts, 2009), and assisting scientists with their ongoing investigations (Lotter, Harwood, & Bonner, 2006). Furthermore, PD experiences that prompt teachers to bring in lessons and adapt them to be more aligned to inquiry support their construction of reform-based science instructional materials (Lotter et al., 2006).

By including an STP component to the revised STARTS PD framework, teachers would have opportunities to engage in inquiry-based learning alongside experts. As they engage in such active learning experiences, their ability to translate these practices to the classroom would be supported through structured time in which teachers modify preexisting materials to more closely resemble inquiry through the 5E lesson planning framework (Bybee et al., 2006).

Implications for Critical Consciousness

Culturally responsive teachers are critically (i.e., sociopolitically, socioculturally, historically) conscious and view teaching as a political act (Ladson-Billings, 1995). Teachers who are critically conscious recognize that individuals from different backgrounds experience the world much differently from one another, as a result of their experiences that are impacted by race, social class, and other facets of identity (Tatum, 1997; Villegas & Lucas, 2002). They enact the social justice foundations of education by empowering diverse students both in and out of school (Bondy et al., 2013; Gay, 2010).

Adopting a critical perspective must first be accomplished and espoused by teachers before they can begin to act as agents of social, political, and educational change. Though STARTS teachers began to develop a critical perspective of schooling over time and emphasized community building as a way to reduce student resistance (Chapter 4), critical consciousness is one area that was largely absent.

Critical consciousness can be developed as teachers become aware that differences in social location lead to differences in access to power (Gamoran, 2008; Villegas & Lucas, 2002). Zozakiewicz and Rodriguez (2007) assisted the development of a critical, multicultural and gender-inclusive perspective in science teachers by applying sociotransformative constructivist principles (i.e., a merge of multicultural education and social constructivism) (Rodriguez, 1998) to PD experiences. In addition to well-established hallmarks of high-quality PD (e.g., Loucks-Horsley et al., 2010), Zozakiewicz and Rodriguez (2007) "made teaching for diversity a central concept throughout the project" through five additional guiding principles of the Maxima PD project, three of which were the focus of their paper and will be named here: "(a) being responsive and theoretically explicit, (b) providing ongoing and on-site support, [and] (c) facilitating reflexive approaches to collaboration" (p.401). Though the STARTS PD program encapsulated these principles, there were dimensions not present in the original STARTS framework. For example, teachers were not engaged in critically reflecting on the impact of cultural practices in society and their daily lives to the degree that Maxima participants experienced. Furthermore, while STARTS teachers were introduced to nonmainstream perspectives of science, they did not critically examine who defines science as it is presented in the curriculum. These are two areas in which the Maxima PD project offered more opportunities for critical analysis of science education and the education system at large than the STARTS program did. Given that the awareness of multicultural and inquiry-based teaching practices increased for teachers participating in the Maxima project, PD experiences like those offered by Zozakiewicz and Rodriguez are warranted for the professional development of CRP Science teachers. Though science teachers may come to know more about culturally responsive, reform-based science teaching through these PD approaches, teachers still need assistance with applying sociopolitical science topics to curricula.

When treated as relevant topics in which science investigation can be contextualized, as the teachers in this study did, suggestions for increasing the coverage of sociopolitical topics in CRP Science classrooms can be informed by the literature on socioscientific issues (SSI). According to Sadler, Amirshokoohi, Kazempour, and Allspaw (2006), socioscientific issues are, “controversial, socially relevant issues within science curricula. . . [that] bridge science and society” (p.353). Though the emphases on CRP Science topics (sociopolitical awareness, uncovering oppression, using science investigation as a platform for emancipation) and SSI (ethical considerations, moral reasoning, argumentation) are often different, there are several underlying similarities. For example, prominent in both fields are the exploration of bias and issues important to the community, which often leads to social action. Furthermore, the literature on teacher perspectives around SSI mirrors the experiences of teachers in this study in that teachers struggled with engaging students in the discussion of controversial topics (Sadler et al., 2006).

To foster the use of SSI in the classroom, Gray and Bryce (2006) argue for PD experiences that make the knowledge and beliefs held by teachers explicit, while also providing supports to confront and examine these beliefs, since many teachers' beliefs about science are incongruous with nature of science views held by science educators and historians of science. Moreover, because controversial issues are often linked to political, social, and/or economic concerns (e.g., genetic engineering), PD experiences should involve teachers in exploring the tentativeness and uncertainty associated with scientific knowledge, which can be done by introducing multiple perspectives on a given phenomenon (Oulton, Dillon, & Grace, 2004). These can be integrated into active learning PD experiences such as extended inquiry cycles and field experiences, which have been employed in programs aimed at increasing science teachers' use of inquiry (Luft, 2001) and argumentation (Crippen, 2012).

Similar to CRP Science, where teachers empower students by developing their attitudes and values in addition to knowledge (Gay, 2010; Kelly-Jackson & Jackson, 2011), Oulton et al. (2004) assert that teachers engaging students in the exploration of controversial topics should: shed light on the nature of controversial issues, motivate students to recognize that one's stance on a topic is influenced by their worldview, critically reflect on their own stance, help students identify bias and critically evaluate claims of neutrality, promote open-mindedness, and share with students how they arrived at their position on the issue. The model presented by Oulton et al. (2004) can be used to support teachers as they attempt to engage students in controversial topics, thereby increasing structure and potentially reducing apprehension. Through sociotransformative- and SSI-informed approaches to PD, educators can develop a critical stance in science teachers while also supporting their use of controversial topics and the practices of science.

Implications for Family Connections

Instructional strategies that bridge discontinuities between diverse students' cultural and linguistic norms and the norms of the science classroom are referred to as culturally congruent (Lee & Buxton, 2010). Cultural congruence can be accomplished by incorporating students' funds of knowledge into instruction. Moll, Amanti, Neff, and Gonzalez (1992) define funds of knowledge as, "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (p. 133), such as agricultural skills, construction and contracting skills, knowledge of medicine, and religious knowledge. Through the use of students' funds of knowledge and community resources, science teachers can build partnerships with families and make science more relevant to diverse students (Lee & Buxton, 2010). However, learning about and establishing partnerships with students and their families takes time.

Villegas and Lucas (2002) suggest key types of information culturally responsive teachers must know about students to enact culturally congruent instruction, including information about students' lives outside of school, their views on school, the relationships to academic disciplines, and the communities they live in. Villegas and Lucas provide guiding questions for educators interested in doing this legwork. Several of these questions were included in the GAIn 3 task. To learn more about students' lives, scholars also suggest conducting home visits (Gonzalez et al., 2005; Johnson, 2011). However, as was the case with STARTS teachers, some may not feel comfortable with such a practice. Ongoing communication with families can occur through multiple avenues, many of which (e.g., participating in community events, church) were already suggested by STARTS teachers. Yet, they did not engage in these activities.

Designing PD experiences that enable teachers to learn more about students' lives and backgrounds in a manner that is respectful of teachers' initial hesitations and time constraints requires the incorporation of tasks that can be completed at school, at least as they are setting out on an entirely new practice. Such activities include using photo-elicitation methods (Allen, 2007; Clark-Ibáñez, 2004) as a way for students to share information about their lives in relation to a particular phenomenon or core science ideas or cultural memoirs where students share a story of themselves as cultural beings and reflect on the influences that have shaped who they are (Allen, 2007). These two suggestions can assist teachers in learning about students' funds of knowledge from within the school walls.

However, teachers *should* get into the community in order to learn more about their students. Calabrese Barton (2000) accomplished this through engaging her preservice teachers (PSTs) in community service-learning projects, "activities that combine classroom work with social action and service in order to promote development of students' subject matter knowledge, practical skills, social responsibility, and civic values" (p. 801). For the PSTs with whom Calabrese Barton (2000) worked, service-learning experiences prompted a critical awareness where they questioned their beliefs about science content and pedagogy, schooling, and the community. By engaging in service-learning, PSTs formed ideas about students and science beyond the school walls, viewed children as children and not just students to be taught, and gained awareness of their own cultural norms. PD that utilizes a service-learning approach, prompted with reflection and implications for classroom practice, could help teachers craft culturally congruent instruction as well as establish family and community ties. Whether this happens through volunteering at a community event (Villegas & Lucas, 2002), engaging in family science programs (McCollough, 2011), or another outlet depends upon specific contextual needs.

Since the inception of the standards-based reform movement, policies have been implemented to gain control of teachers' actions and routine classroom operations and this has resulted in the intensification of the teaching profession (Apple, 2009). Teachers have been cast as managers expected to produce annual growth in students on high-stakes assessments (Sleeter & Stillman, 2009). They experience decreased time for PD due to increased professional demands (Wei, Darling-Hammond, & Adamson, 2010), and de-skilling through adherence to rigid pacing guides and repeated testing of students (Apple, 2009). Therefore, engaging teachers in service learning must be tied to some form of "academic credit granting component" (Crippen et al., 2010, p. 643) or additional professional accountability standards. Should teachers engage in a service-learning project, it could be woven through another project that honors what teachers are held responsible for every day.

Revised STARTS Design Principles

Mindful of both the strengths and flaws within the STARTS PD program, I present a set of design principles for a revised PD framework with the same goals as the original: to prepare reform-based CRP Science teachers capable of constructing and enacting CRP Science instructional materials. van den Akker (1999) argues that "the major knowledge to be gained from development research is in the form of (both substantive and methodological) ‘design principles’” (p. 9). The author then presents a formula for articulating design principles, which I will use to present my revised design principles. These principles will be constructed from empirical findings and the relevant literature. Though the principles emanating from findings were originally grounded in the literature (see Table 5-1), here such principles will be presented without citations to emphasize their empirical nature. Principles that were derived from the literature but were not applied to the original STARTS framework will be cited accordingly.

To design PD for the purpose of preparing reform-based, CRP Science teachers and designers of CRP Science instructional materials, it is best advised that the PD support teachers’ knowledge of CRP Science and their students through activities that:

- Provide experiences for teachers to critically observe their classrooms, learn more about their students’ lives in and out of school, and identify science topics that are relevant to students;
- Assist teachers in identifying themselves as cultural beings with unique experiences that have shaped who they are today;
- Engage teachers in uncovering the historical, social, and political nature of schooling as well as problematizing and expanding perceptions of science as it is currently taught in school (Gamoran, 2008; Villegas & Lucas, 2002);
- Involve teachers in critically reflecting on the impact of cultural practices in society and their daily lives (Zozakiewicz & Rodriguez, 2007);
- Engage in service-learning projects beyond the school walls (Calabrese Barton, 2000);
- Assign students tasks such as photo-elicitation (Clark-Ibáñez, 2004) or cultural memoir construction (Allen, 2007) around a particular scientific phenomenon.

The teachers should also be supported in developing CRP Science practices through activities that:

- Present teachers with practical examples of CRP Science (through readings and modeling), opportunities to critique these examples, speculate on ways to apply these examples to their classrooms, and reflect on outcomes;

- Engage teachers in the examination of their practice on intended student outcomes and then suggest instructional revisions based on findings;
- Offer structured time for the collective participation of teachers in which they can brainstorm lesson ideas, co-design instruction, and receive critical feedback;
- Allow teachers to first learn about and implement responsive instructional strategies and then consider how to utilize these strategies by applying them to relevant science topics;
- Provide a structured template for integrating information learned about students into science instruction;
- Offer ongoing support and frequent communication between teachers and researchers/professional developers;
- Connect findings from service-learning projects (Calabrese Barton, 2000) or home visits to instructional design (Gonzalez et al., 2005) (either through responsive instructional strategies or relevant science topics);
- Utilize a set of guidelines for engaging students in the exploration of controversial science topics (Oulton et al., 2004).

Teachers' knowledge of reform-based science teaching should be supported through activities that:

- Engage teachers in the systematic study of science curriculum topics;
- Engage teachers in inquiry-based active learning experiences (Jeanpierre, Oberhauser, & Freeman, 2005);
- Provide teachers with readings and experiences that help them understand how students learn science (Crippen et al., 2010);
- Offer opportunities for teachers to increase their science content knowledge (Lee, 2004);
- Make teachers' knowledge and beliefs about science explicit, while also providing supports to confront and examine these beliefs (Gray & Bryce, 2006);
- Explore the tentativeness and uncertainty associated with scientific knowledge (Oulton et al., 2004).

Teachers' reform-based science practices should be supported through activities that:

- Assist teachers in translating content knowledge to reform-based science instruction;
- Offer ongoing support and frequent communication between teachers and researchers/professional developers;
- Engage teachers in inquiry-based active learning experiences (Jeanpierre, Oberhauser, & Freeman, 2005).

Teachers should be supported as designers of reform-based CRP Science instructional materials through activities that:

- Engage teachers in critically analyzing existing sample lesson plans for elements of CRP Science;
- Provide a set of guidelines for integrating information learned about students into science instruction;
- Provide teachers with structured lesson planning templates;
- Offer structured time for the collective participation of teachers in which they can brainstorm lesson ideas, co-design instruction, and receive critical feedback;
- Offer ongoing support and frequent communication between teachers and researchers/professional developers;
- Prompt teachers to bring in lessons and adapt them to be more aligned to inquiry support teachers' construction of reform-based science instructional materials (Lotter et al., 2006);
- Utilize a set of guidelines for engaging students in the exploration of controversial science topics (Oulton et al., 2004) or making instruction gender-inclusive (Zozakiewicz & Rodriguez, 2007).

Final Remarks

The STARTS PD program was designed to support the development of reform-based, CRP Science teachers, thereby seeking to advance the wide-scale implementation of CRP Science. Despite the potential of CRP Science to ameliorate educational inequity, the approach remains marginalized. Loucks-Horsley et al. (2010) assert that if PD efforts are to be actualized, policymakers must embrace the visions of science education advocated within them. Much like the argument posed by Sadler et al. (2006), I propose that if CRP Science is to become a reality in today's classrooms, science educators must promote the inclusion of CRP Science topics in state and national standards and make the case that CRP Science curricula are complementary to and reinforce standards-based science instruction. The findings of this study indicate complementarity between reform-based science teaching and CRP Science.

To increase the sustainability of programs like STARTS and overcome the lack of CRP Science materials, science educators must support teachers in designing deeply contextualized instructional materials like those espoused by CRP scholars. A heuristic could help accomplish this goal, much in the way Norton-Meier, Hand, and Ardasheva (2013) scaffolded teachers' use of argument-based inquiry through the Science Writing Heuristic. However, a necessary first step to constructing a research-grounded heuristic of this magnitude is a better understanding of how teachers engage in the design CRP Science materials. What does this process look like? What are the strengths and weaknesses of engaging teachers in the design of innovative materials such as these? Research around this area is sorely needed as the science education community seeks to best support the development of CRP Science teachers.

Table 5-1. STARTS PD program theoretical grounding.

Goal	Design structure	Theoretical grounding	Data produced
CRP Science	Lesson study	• Improving teaching requires collaboration, examination, and practice (Lewis, 2002; Loucks-Horsley et al., 2010) • Student data inform practice (Lewis, 2002; Shimizu, 2002) • Effective PD* is job-embedded (Borko, 2004; Desimone, 2009)	• Lesson study artifacts • Completed research lesson • Student worksheets • RWP***
CRP Science	GAIn tasks	• CR** teachers are socioculturally aware (Villegas & Lucas, 2002) • CR teachers validate students' backgrounds (Gay, 2010) • CR teachers build communities of learners (Ladson-Billings, 1994) • Reflection is necessary for developing a CR stance (Lucas & Grinberg, 2008; Wiggins et al., 2007)	• Completed GAIn tasks • Student survey results
Reform-based science teaching	Curriculum Topic Study (CTS)	• Expert teachers have strong content and pedagogical knowledge (Keeley, 2005) • Teacher expertise positively impacts student learning (Keeley, 2005) • Effective PD engages teachers in the study of learning theories (Crippen et al., 2010) • Effective PD is job-embedded (Borko, 2004; Desimone, 2009)	• CTS working document • RWP

Table 5-1. Continued

Goal	Design structure	Theoretical grounding	Data produced
CRP Science, Reform-based science teaching	Professional Growth (PG) tasks	• CRP Science is complementary to reform-based science education (Johnson, 2011) • Cooperative learning increases student engagement (Johnson et al., 1994) • Formative assessment strategies reveal conceptual understanding (Sadler, 1989). • Diverse students' academic performance increases with family involvement (Antunez, 2000; Jeynes, 2005) • Reflection is an essential component of learning and improvement (Hammerness et al., 2005)	• RWP for each PG task
CRP Science unit design	CRP Science unit	• Curriculum is central to teaching (Ball & Cohen, 1996) • Paucity of CRP Science curriculum materials (Lee, 2004; Mensah, 2009) • PD can support teachers as designers (Parke & Coble, 1997; Stolk et al., 2011) • Structured lesson planning templates aid teachers' construction of curriculum materials (Jackson & Ash, 2012)	• CRP Science unit template • Student worksheets

Table 5-1. Continued

Goal	Design structure	Theoretical grounding	Data produced
CRP Science, Reform-based science teaching, CRP Science unit design	Saturday Collaboration Sessions	• Effective PD provides active learning experiences (Brown et al., 2014; Crippen, 2012) • Modeling novel instruction facilitates teacher development (Capps et al., 2012; Zozakiewicz & Rodriguez, 2007) • Collective participation positively impacts teacher development (Garet et al., 2001) • Teacher development occurs on personal, social, and professional dimensions (Bell & Gilbert, 1996). • Ongoing support is essential to effective PD (Brown et al., 2014; Capps et al., 2012; Lee, 2004)	• RWP for each session • Group interviews 1 & 2 (+) • Mock teaching feedback session (+) • STARTS Redesign session (+) • CRP Science unit present-ations (+)

Note: *Professional Development, **Culturally Responsive, *** Reflective Writing Prompt, (+) video-recorded and transcribed.

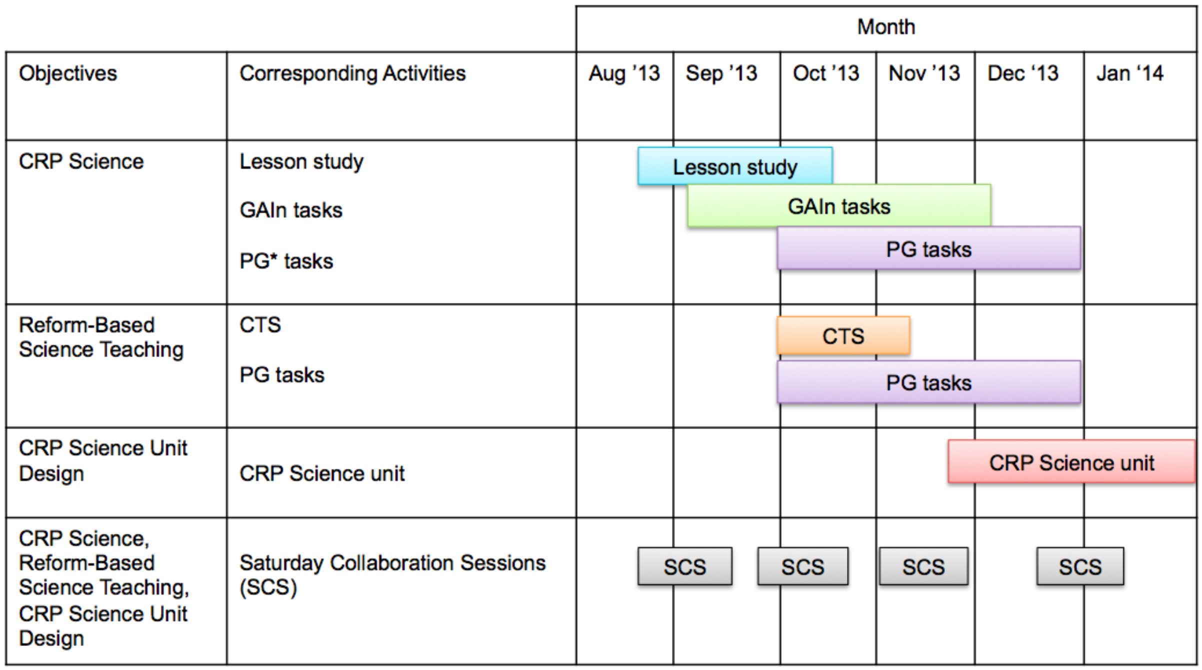


Figure 5-1. STARTS PD program timeline.

Table 5-2. Demographic information for participants and schools.

Teacher	Subject area taught	Focus class student racial makeup	School-wide free and reduced lunch population (%)	School-wide biology End of Course exam proficiency, mastery (%)
Christina Joy	Anatomy & Physiology	Black, Hispanic	64	55, 8
Claudia	ESOL Biology	Hispanic	77	52, 7
Kate	Anatomy & Physiology	Asian, White, Multirace	21	91, 21
Lorelei	Honors Biology	White, Hispanic	34	78, 16
Natalie	General Biology	Black, Hispanic, White	34	78, 16
Zane	General Biology	Black, Hispanic	75	52, 6

Table 5-3. STARTS activity-outcome matrix.

Activity-outcome	CRP Science conceptions	Views of students	Teaching practices	Community building	Student repositioning	New topic	New strategy
Lesson Study	1 (6%)	6 (16%)	11 (20%)	0 (0%)	0 (0%)	1 (8%)	1 (3%)
GAIn	15 (88%)	29 (76%)	31 (55%)	5 (63%)	0 (0%)	6 (50%)	7 (18%)
CTS	1 (6%)	1 (3%)	9 (16%)	0 (0%)	0 (0%)	2 (17%)	12 (31%)
PG tasks*	0 (0%)	0 (0%)	3 (5%)	2 (25%)	1 (100%)	0 (0%)	9 (23%)
CRP Science Unit	0 (0%)	2 (5%)	1 (2%)	1 (13%)	0 (0%)	1 (8%)	0 (0%)
Sat. Collab. Session**	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	2 (17%)	10 (26%)
Total	17 (100%)	38 (100%)	56 (100%)	8 (100%)	1 (100%)	12 (100%)	39 (100%)

Note: *Professional Growth tasks, **Saturday Collaboration Sessions.

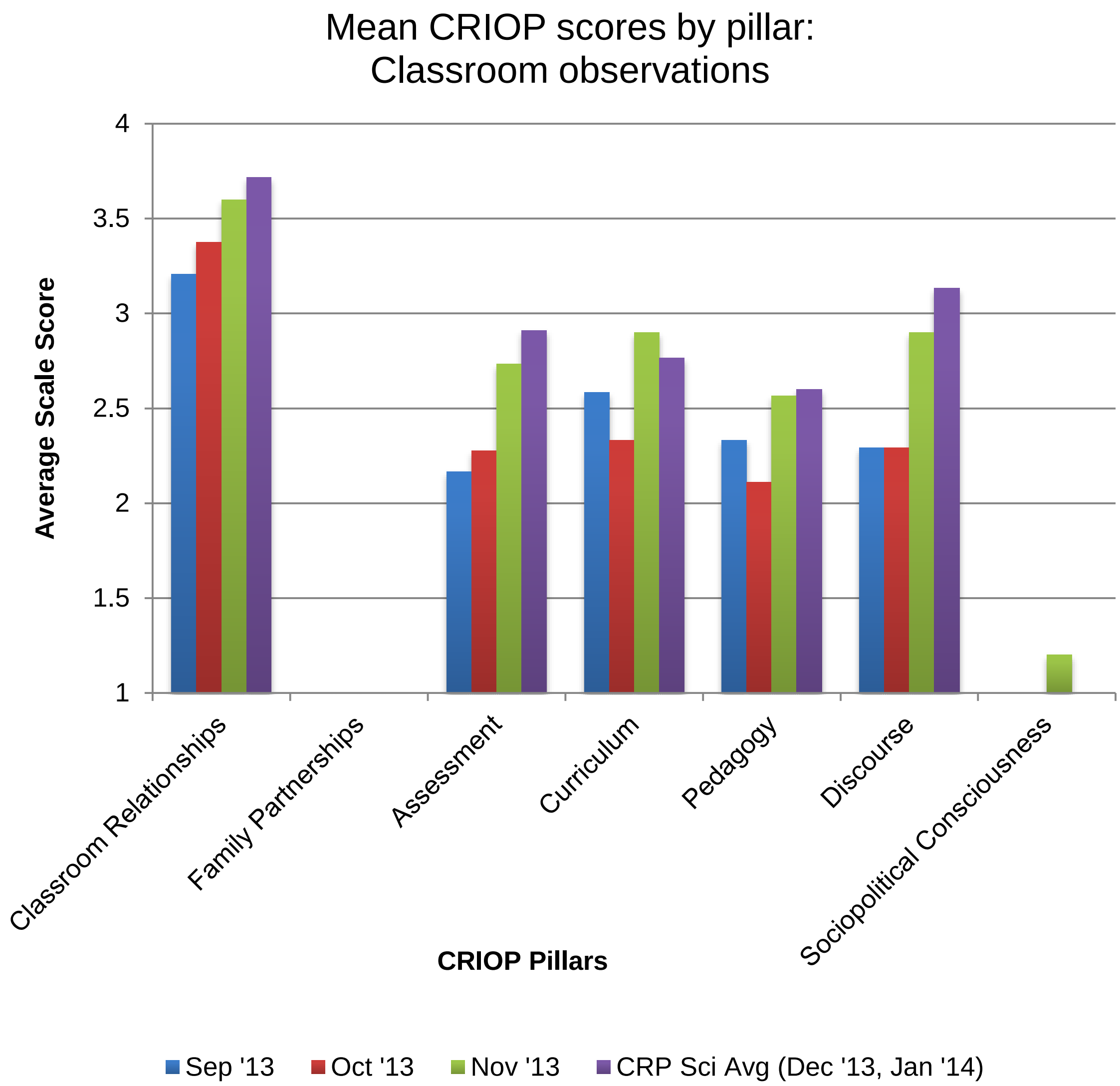


Figure 5-2. Mean CRIOP scores by pillar: Classroom observations.

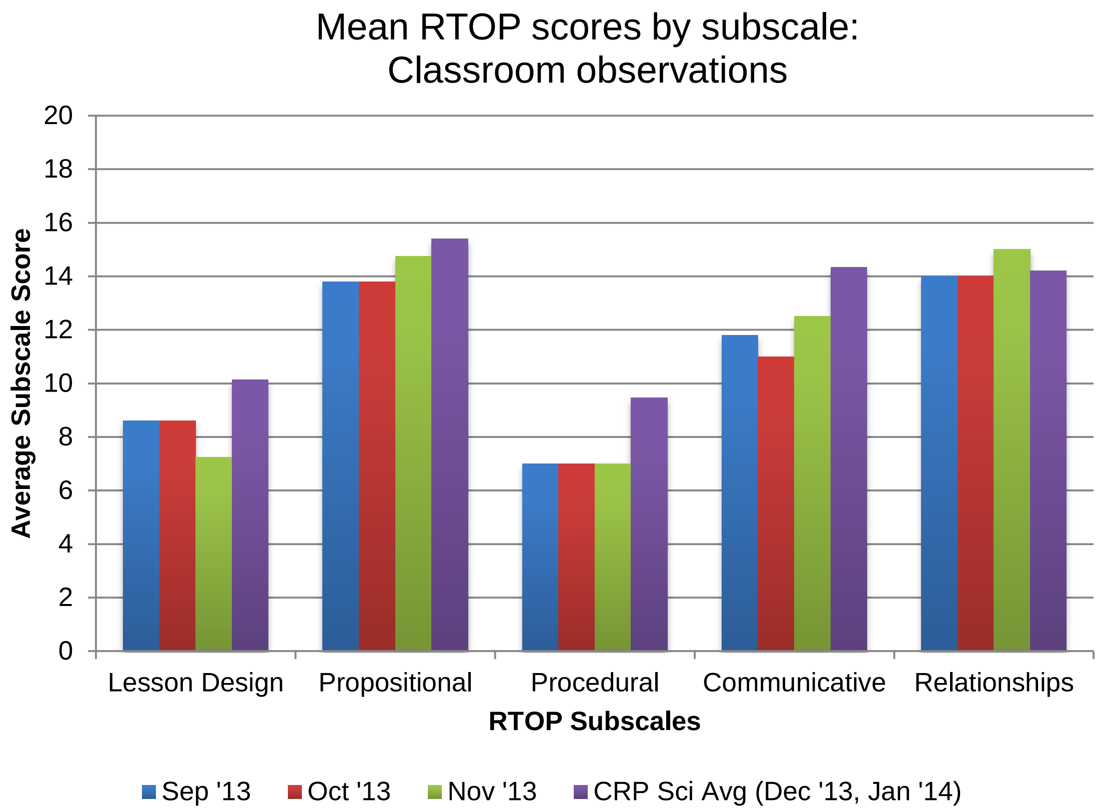


Figure 5-3. Mean RTOP scores by subscale: Classroom observations.

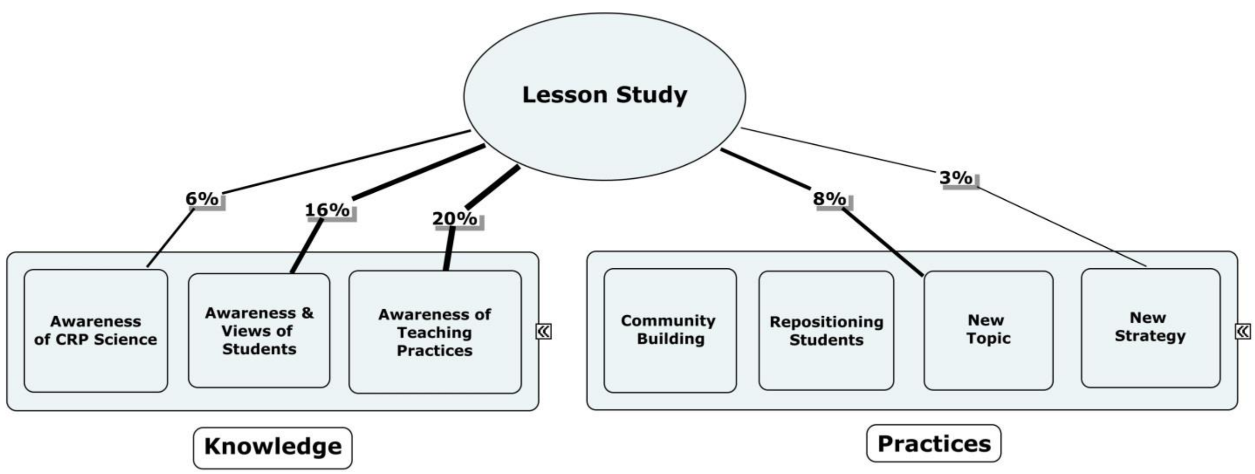


Figure 5-4. Reported connections between lesson study and teacher outcomes.

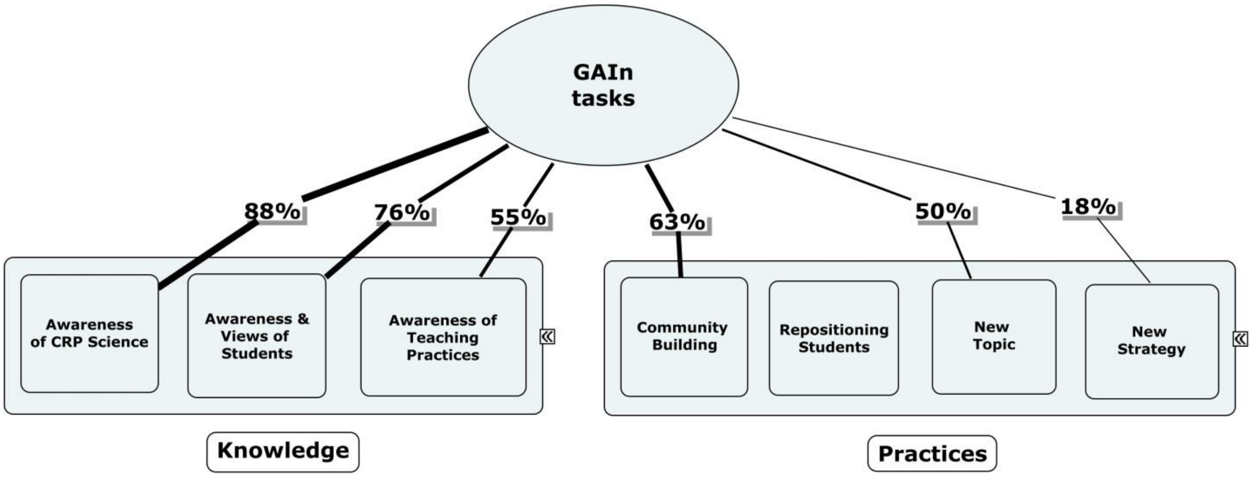


Figure 5-5. Reported connections between GAIn tasks and teacher outcomes.

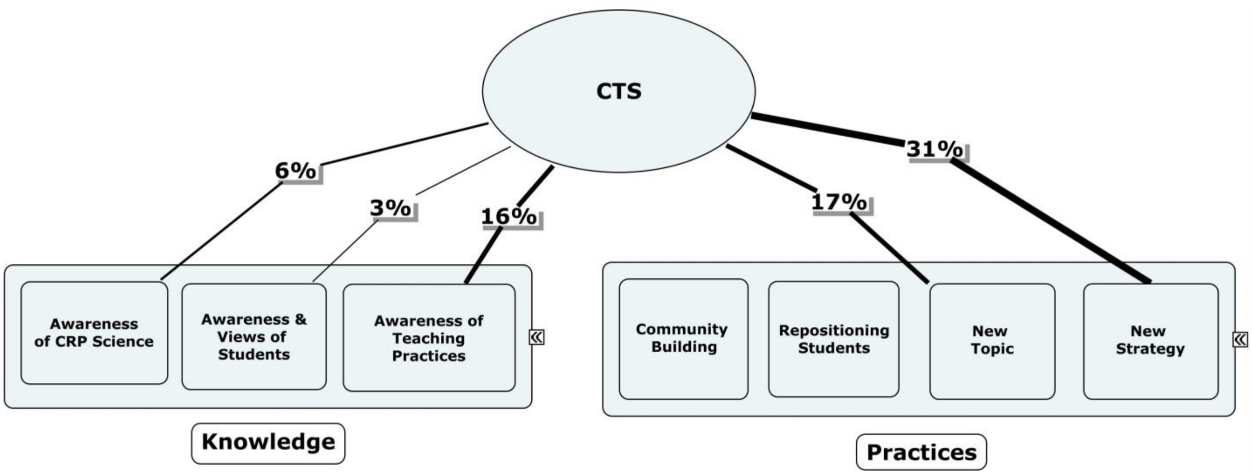


Figure 5-6. Reported connections between Curriculum Topic Study and teacher outcomes.

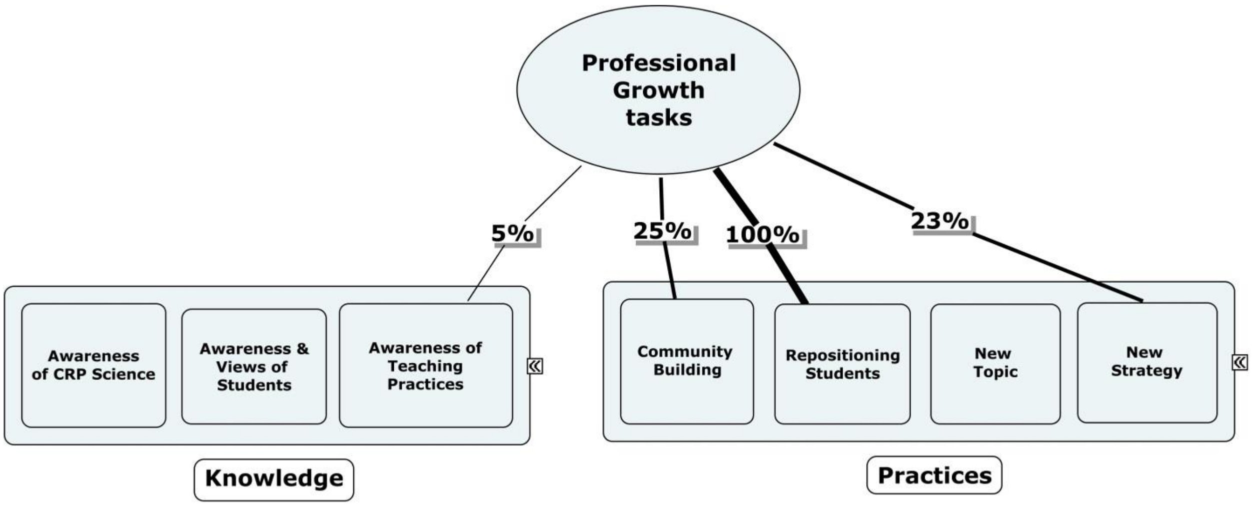


Figure 5-7. Reported connections between Professional Growth tasks and teacher outcomes.

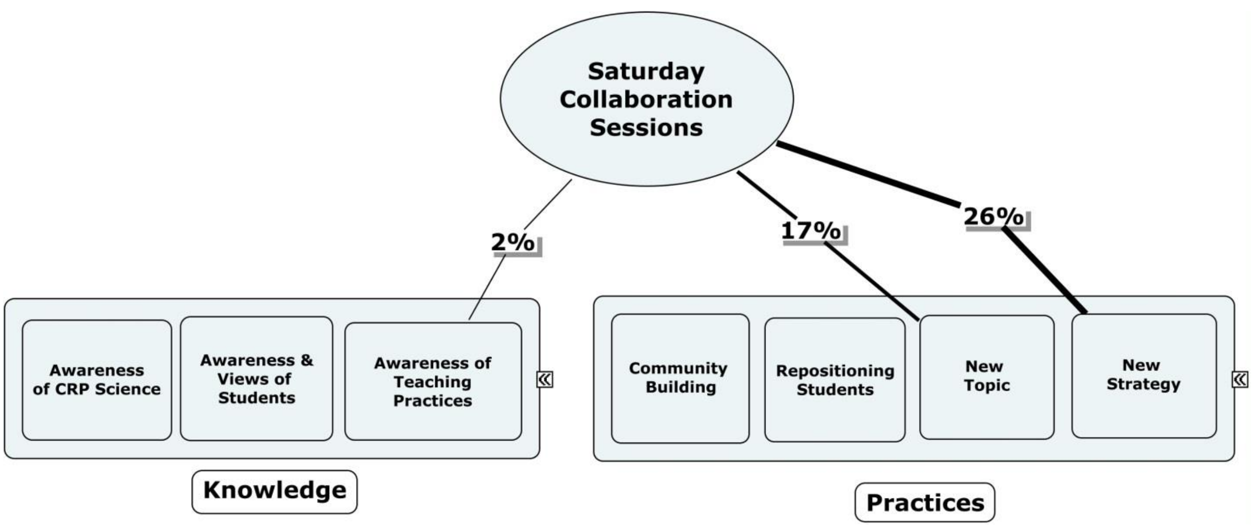


Figure 5-8. Reported connections between Saturday Collaboration Sessions and teacher outcomes.

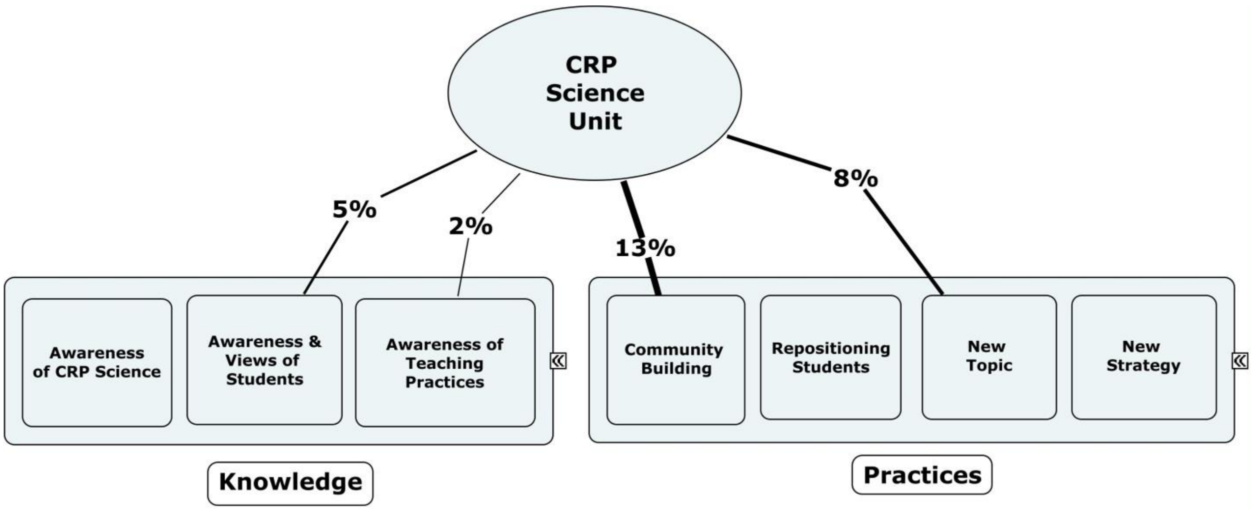


Figure 5-9. Reported connections between CRP Science unit and teacher outcomes.

Table 5-4. Revised STARTS PD design framework.

Goal	Design objectives (Corresponding CRIOP, RTOP items)	Design structure	Observed outcomes	Redesign suggestions (Accompany design principles)
	Reflect on impact of practice on select student outcomes Plan science lesson with culturally responsive and reform-based elements (CRIOP 5.2, 5.4; RTOP 4.6, 4.7, 4.8) Identify CRIOP- and/or RTOP-focused areas for professional growth	Lesson study	(+) Begin exploring practice, (+) Identify professional growth goals, (+) Student awareness (-) Overwhelming as first task, (-) CRP Science narrowly enacted, (-) Restructure the observation & analysis phase	
CRP Science	Develop awareness of messages conveyed by classroom environment, including student-student interactions (CRIOP Pillar I, CRIOP 5.1, 5.4) Develop awareness of relationship between teacher communication/questioning patterns and student participation (CRIOP 6.1, 6.2, 6.3) Speculate on ways to incorporate culturally relevant topics into lesson plans (CRIOP 4.1, 5.1, 5.4 Suggest instructional strategies based on information learned about students (CRIOP 4.1, 5.1, 5.4) Explore examples of CRP Science and compare it to current practice	GAIn	(+) Critically analyze the impact of practice on students, (+) Introduce CRP Science practices, (+) Expand ideas of CRP Science, (+) Add tools to Toolbox, (+) Learn about students' experiences in- and out-of school, (+) Connect instruction to students' experiences, (+) Shifting authority, (+) Increased student communication, (-) Specific questions needed to identify relevant topics	[Inquiry connections – Active learning experiences, STP, modify existing lesson plans] [Family connections – Service-learning component; cultural memoirs; photo-elicitation projects] [Sociopolitical connections – Develop critically reflexive stance; guidelines for supporting teachers' use of controversial topics]
	Explore effective culturally responsive instructional approaches Identify students' families' funds of knowledge Identify approaches for connecting science instruction to these funds of knowledge and make a plan to implement (CRIOP 2.1, 2.3, 4.1)	PG task: *Families & Science*	(+) Add tools to Toolbox, (+) Identify effective science practices, (+) Structure for connecting effective practices to classroom needs (-) Impractical content, (-) Uncomfortable connecting with family	

Table 5-4. Continued

Goal	Design objectives (Corresponding CRIOP, RTOP items)	Design structure	Observed outcomes	Redesign suggestions (Accompany design principles)
Reform-based science teaching	Deepen knowledge of the science topic that CRP Science Unit is designed around (RTOP 4.6, 4.7, 4.8, 4.11) Examine research on student learning and instructional strategies for CRP Science Unit topic (RTOP 3.1, 3.2) Explore the progression of crosscutting concepts for CRP Science Unit topic (RTOP 4.6, 4.7) Identify state and national education standards for CRP Science Unit topic and align the unit to these standards (RTOP 4.6)	CTS	(+) Teach content as "bigger picture", (+) Awareness of teaching practices, Importance of uncovering and addressing student misconceptions, (+) Add tools to Toolbox, (-) Complex, (-) Limited resources for topic, (-) Guiding document redundant at times	
	Apply learned strategies to classroom instruction (RTOP 5.17, 5.19) Make a plan to implement strategies during CRP Science Unit, connecting to GAIn and CTS findings (CRIOP 1.4, 3.1, 3.2, 6.1, 6.3; RTOP 3.2, 5.16, 5.17, 5.19, 5.20)	PG tasks: *Making Student Thinking Visible; Student Grouping*	(+) Add tools to Toolbox, (+) Identify effective science practices, (+) Structure for connecting effective practices to classroom needs, (+) Reposition student roles, (-) Limited benefit to seeing teachers' practices in action	

Table 5-4. Continued

Goal	Design objectives (Corresponding CRIOP, RTOP items)	Design structure	Observed outcomes	Redesign suggestions (Accompany design principles)
CRP Science unit design	Critically analyze sample lesson plans for CRIOP, RTOP connections Design instructional materials (or modify existing materials) to make them more culturally responsive (GAIn connection) and reform-based (CTS connection)	PG tasks	(+) Add tools to Toolbox, (+) Identify effective science practices, (+) Structure for connecting effective practices to classroom needs (-) Limited benefit to seeing Fellows' practices in action, (-) Impractical content	
	Bridge together science content (through CTS) and students' interests and needs (through GAIn), thereby creating meaningful and challenging science instruction that is student-centered	CRP Science unit template	(+) Structure connecting GAIn and CTS, (+) Add tools to Toolbox, (+) Comprehensive instruction, (+) Community building, (+) Responsive to students, (-) Time of year constrained possible topics, (-) Only completed for one unit	
CRP Science, Reform-based science teaching, CRP Science unit design	Design objectives from above were reinforced during the Saturday Collaboration Sessions	Saturday Collaboration Sessions	(+) Collective participation, (+) Supportive network, (+) Observe CRP Science practices, (+) Co-design CRP Science instruction, (+) Model and share instructional strategies, (-) Accepting practices without critical examination, (-) Limited professional benefit from certain activities	

Note: (+) = reported benefits; (-) = reported limitations.

CHAPTER 6
DISCUSSION

Designing for CRP Science

There is an imperative to disrupt the inequalities in science achievement by preparing teachers who can successfully educate diverse students. The chronic achievement gap points to much-needed pedagogical reform. While engaging students in the authentic practices of science is advocated as a way to achieve Science for All (AAAS, 1990; NRC, 2012), many scholars argue that bridging students' backgrounds with canonical science is also necessary when educating diverse students as it reduces incongruences between home and school (Aikenhead & Jegede, 1999; Lee & Buxton, 2010) and increases the authenticity of science learning (Buxton, 2006; Calabrese Barton, 1998). However, teachers are often underprepared for such an endeavor and struggle with enacting culturally responsive pedagogies in science education (CRP Science). Moreover, responsive teaching within restrictive school environments is daunting due to political backlash (Sleeter, 2012) and the scarcity of curriculum resources (Lee, 2004; Mensah, 2009). Thus, not only do science teachers require explicit supports for CRP Science teaching and to construct culturally responsive instructional materials, but such initiatives must also acknowledge the larger contextual influences at play.

Few studies have detailed programs of this magnitude. Such studies have explored teachers' responses to the professional development (PD) and how PD experiences affected classroom practices (Zozakiewicz & Rodriguez, 2007) as well as how teachers' beliefs (Lee, 2004) and practices changed over time (Lee, 2004; Johnson, 2011). Yet, none have done so with the explicit goal of producing usable knowledge through the generation of theory about the progression of teachers as CRP Science educators and the simultaneous identification of a design framework capable of supporting this growth. However, to best develop effective programs and CRP Science teachers, elucidating the relationship between process and structure is necessary. By articulating the process of becoming a CRP Science teacher via PD and identifying supporting mechanisms, this study answered the calls made by Patchen and Cox-Petersen (2008) to "encourage science educators to pursue additional research to determine what teachers are actually doing in classrooms to enact CRP and to document the strategies most effective in making the shifts to CRP" (p. 1010) and the request by Sleeter (2012) for research on the impact of CRP projects, including how teachers learn to become culturally responsive.

This qualitative study employed a design-based research (DBR) framework (Barab & Squire, 2004; Wang & Hannafin, 2005) to detail the STARTS (Science Teachers Are Responsive To Students) PD program as a designed intervention, elucidate associated learning progressions, and identify the mechanisms undergirding these progressions. The inquiry was guided by two research questions. The first research question required an analysis of teachers' progressions as CRP Science educators while participating in the STARTS PD program. The second research question directed an examination of the relationship between STARTS program design elements (i.e., major activities) and teachers' CRP Science knowledge and practices. To best address the research questions and their aims, classroom observations, focus group interviews, and numerous program artifacts were analyzed through multiple methods, including grounded theory analysis (Charmaz, 2006; Strauss & Corbin, 1998), typological analysis (Hatch, 2002), and matrix analysis (Averill, 2002; Miles & Huberman, 1994). Characteristic of DBR, the present study produced usable knowledge through the generation of local theory (McKenney & Reeves, 2012), a design framework (Edelson, 2002), and accompanying design principles (van den Akker, 1999), thereby demonstrating both local impact and general relevance.

In this chapter, an overview of the findings of this study and their connection to the literature is presented first, implications for CRP Science and PD in science education are discussed in relation to the findings, the limitations of this study are elucidated, and, finally, the chapter concludes with a final note on the study.

Connecting Findings to the Literature

Over the course of the STARTS program, participating teachers exemplified the multidimensional nature of CRP to a certain extent. Care was taken to build a classroom community where students were treated as members of this community (Ladson-Billings, 1994). These findings are supportive of research from Patchen and Cox-Petersen (2008) and Johnson (2011) that the relationships between teachers and their students were fluid, interactions were rebalanced, and students' input was valued more over time. In contrast to the two elementary teachers with whom Patchen and Cox-Petersen (2008) worked, STARTS teachers shifted authority in the classroom on both conceptual (i.e., eliciting prior knowledge) and structural levels (i.e., providing opportunities for student-directed study). Further, STARTS teachers epitomized several elements of Sammie, a culturally responsive middle school science teacher depicted by Kelly-Jackson and Jackson (2011). For instance, several teachers displayed student work and encouraging posters around the classroom, expected students to be responsible for one another's learning over time, and fostered this through collaborative learning with specific roles. There were also patterns of CRP Science that STARTS teachers did not embrace. Though there were isolated instances in which STARTS teachers discussed issues of oppression and power within their classrooms, the findings of this study are similar to Patchen and Cox-Petersen (2008) who found that few teachers neither "mentioned power relationships explicitly nor did [they] integrate an analysis or consideration of power relations into their instruction" (p. 1005).

One of the most noteworthy findings of the present study was the ability of teachers to translate CRP Science knowledge to practice through instruction that incorporated relevant science topics with responsive strategies. For example, Christina Joy had students explore skin cancer rates according to race, Kate problematized the pseudoscience of phrenology as a form of oppression enacted by the dominant culture, and Natalie had students become "experts" on a disease of their choice, which she pre-selected according to students' ethnicities. While it is acknowledged that curriculum and instruction are but two of four critical aspects of culturally responsive pedagogy (Gay, 2010), the central role of curriculum materials in enacting educational reform cannot be overlooked (Ball & Cohen, 1996; Lee & Buxton, 2010).

A number of researchers have described challenges to teachers' using students' lives as a starting point for instruction (e.g., Patchen & Cox-Petersen, 2008; Bianchini & Brenner, 2010). While some STARTS teachers alluded to such difficulties, they were largely successful with the task. The findings suggest that teachers benefit from specific PD features when constructing CRP Science materials (Table 6-1), and that they sought these opportunities beyond the experiences provided by the design. Specifically, the STARTS teachers cited the *Growing Awareness Inventory* (GAIn) tasks, Saturday

Collaboration Sessions, and *Curriculum Topic Study* (CTS) as primary activities contributing to their CRP Science instructional decisions.

Another interesting finding was the complementarity between teachers' reform-based and CRP Science practices over time. As teachers' CRP Science practices became more reflective of those that have been previously described in the published literature, their reform-based science practices improved in all areas except Student/Teacher Relationships, which remained consistent throughout the STARTS program. While others have acknowledged the complementary nature of reform-based science teaching and CRP Science vis-à-vis inquiry (e.g., Johnson, 2011), absent from the literature is an explicit examination of the progression of the two side-by-side. The findings of this study indicate a specific and corresponding progression in teachers' reform-based, CRP Science practices.

Over time, STARTS teachers' classrooms became environments where student engagement was evident. Students worked collaboratively and relied on each other to learn science content and construct products that were often presented to their classmates. They developed and used models to explain science phenomena, analyzed and interpreted data, and obtained, evaluated, and communicated scientific information in culturally congruent manners in both small group and whole-class settings. These results are important for advancing the presence of CRP Science through a strategy suggested by Sadler et al. (2006). They indicated that a case must be made that nontraditional pedagogies – such as teaching socioscientific issues (SSI) and CRP Science –reinforce standards-based science education. This is particularly important, as the impact of the standards-based movement and its resulting high-stakes tests, such as the biology End of Course exam, on curriculum narrowing has been well documented (Au, 2009; Darling-Hammond, 2010). Thus, the impetus for teachers to enact CRP Science is threatened when related standards are absent. The results of this study strengthen the argument that CRP Science reinforces standards-based science education.

The effectiveness of particular STARTS framework elements in developing specific aspects of CRP Science teachers' knowledge and practices was another important finding. PD in science education largely focuses on supporting teachers' inquiry-based instruction (Luft, 2001), content knowledge (Lee, 2004), and adaptation of premade curricula (Bell & Gilbert, 1994). Seldom do PD programs address these foci while also developing teachers who are multicultural science educators (Lee & Buxton, 2010; Moore, 2007). Multicultural science education approaches, such as CRP Science, have "a more critical focus on the process of teaching and learning of science" than the science instruction espoused in more traditional PD in science education (Moore, 2007, p. 775). As a result, Moore (2007) explains, "[p]rofessional development along the lines of multicultural science education gives a more critical stance toward teaching science, constructing scientific knowledge, and using this knowledge in ways that empower both students and teachers" (p. 776). Table 6-1 illuminates the salient STARTS features associated with supporting the development of the CRP Science teachers in this study.

Findings indicate that as teachers participated in the STARTS program, their views of students, conceptions of CRP Science, and instructional practices shifted to become more representative of CRP Science. Much like scholars aiming to develop CRP Science teachers (e.g., Lee, 2004; Johnson, 2011; Zozakiewicz & Rodriguez, 2007), the findings of this study point to the need to assist teachers' awareness of several key elements, including science content knowledge, CRP Science and reform-based pedagogical knowledge, knowledge of themselves as cultural beings in relation to the students they serve, and in-depth knowledge of students' experiences and needs. Other researchers have advocated the use of specific experiences to develop culturally responsive teachers (e.g., Ferguson, 2008; Zozakiewicz & Rodriguez, 2007). While not reducing the importance of approaches suggested by other CRP Science scholars, the results of this study indicate that developing CRP Science teachers may be accomplished without such experiences. For example, teachers in this study did not need to engage in dialogic conversation in order to teach for diversity and understanding, as suggested by Zozakiewicz and Rodriguez (2007). Furthermore, STARTS teachers still promoted culturally congruent discourse without enrolling in conversational Spanish classes, as participants from Johnson's (2011) research did. For STARTS participants there were multiple occasions on which Spanish terms were used to facilitate culturally congruent instruction for linguistically diverse learners, even among teachers who were not bilingual. For example, I observed Christina Joy using Spanish cognates to clarify anatomy and physiology terms (e.g., "orbicularis oris, this is the kissing muscle. You know, [puckering lips] beso, [touching mouth] por la boca; that muscle", CRP Science unit field notes, 1/29/14). The results suggest that such experiences may not be required to produce science teachers who embrace reform-based, culturally responsive pedagogies.

In response to "challenges in facilitating teachers' professional development in support of culturally and linguistically diverse students' academic success in science," Buxton, Lee, and Santau (2008) developed a comprehensive 3rd–5th grade curriculum for use with teachers participating in PD that addressed science content, inquiry, English language and literacy supports, and mathematics connections (p. 497). The authors stated that designing their own curriculum materials was a necessity in order to overcome challenges. However, the findings of this study suggest that, with the proper PD supports, teachers are completely capable of constructing such materials. STARTS teachers constructed and implemented materials that addressed common misconceptions, focused on core science ideas, integrated students' experiences and needs, and aligned to state science education standards. Involving teachers in the construction of instructional materials increases teacher ownership (Parke & Coble, 1997), supports changes to practice in a more sustainable manner (Brown et al., 2014), and are an imperative for CRP Science materials in particular, which are in scarce supply (Lee, 2004) and are "never completely beyond context; nor. . . ever totally replicable" (Gay, 2010, p.184).

Findings of the study contribute to the existing literature base on CRP Science and PD in science education. These findings, articulated above, have implications for the design of PD for CRP Science and future research. In the following section those implications are illuminated.

Elaborating on Implications & Identifying Avenues for Future Research

In Chapters 4 and 5, I provided findings-based discussion and implications sections on supporting teachers' CRP Science development through PD. In these chapters I stated that, beyond the supports offered by the STARTS program, science teachers require assistance with adopting critical stances, connecting science with students' families, and designing innovative instructional materials that are reform-based and culturally responsive. To enhance the presence of CRP Science, I argued that, for PD efforts to be actualized, policymakers must embrace the visions of science education advocated within them (Buxton et al., 2008; Loucks-Horsley et al., 2010), as CRP Science ‘‘ultimately clashes with the traditional ways in which education is carried out in our society’’ (Morrison, Robbins, and Rose, 2008, p. 444). Although CRP Science teaching is a challenging endeavor, results of this study indicate that teachers are indeed capable of responsive teaching in restrictive environments.

With design research such as that reported in this study, it is the science educators and professional developers who must evaluate the applicability of the recommendations (i.e., design principles) made. Hence, implications are presented for each community, alongside suggestions for relevant future research. The principal implication for science educators who examine PD for CRP Science is that more research is needed to further understand and articulate which PD experiences facilitate this development in a variety of contexts. There are limited studies to this end (Lee & Buxton, 2010; Moore, 2007). There is also an imperative to explore and identify how to best support teachers in the design of CRP Science instructional materials. Such inquiries are a necessity considering the paucity of current resources and the chronic science achievement gap by race and socioeconomic status.

A second implication for science educators is to continue exploring the development of CRP Science teachers in a variety of contexts – at the preservice and inservice levels. While a growing research base has provided rich descriptions of teachers that embody a CRP stance and enact culturally responsive pedagogies (e.g., Ladson-Billings, 1994; 1995), as well as identify specific orientations that must be developed in CRP teachers (e.g., Villegas & Lucas, 2002), I argue that the science education community in particular should explore what characterizes the professional growth of CRP Science teachers in multiple contexts and under various conditions. How does the local theory generated from this study inform their development? While there is value in the explanatory, descriptive, and predictive power of local theories, because they are derived from findings within domain-specific and limited settings they are still "relatively humble" (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003, p. 9). Through subsequent examinations, local theories are meant to be further refined, validated, and/or refuted (McKenney & Reeves, 2012). Thus, the science education community should continue to explore teachers' professional growth as CRP Science teachers with the additional aim of applying this knowledge to design interventions/learning environments that best support their development. Given the necessity to ensure academic excellence for diverse students through CRP Science and the great influence teachers have on student learning, such investigations are a much-needed next step.

A third suggestion for the science education community is related to the assessment of teachers' CRP Science practices. In this study I used the *Culturally Responsive Instruction Observation Protocol* (CRIOP) (Powell et al., 2012) to assist in determining teachers' CRP Science classroom practices. The constructs depicted in the instrument represent a synthesis of the vast and timely literature on culturally responsive instruction. Operational definitions of specific culturally responsive instruction tenets are provided, making the occasionally nebulous constructs more concrete and directly measurable. However, prior to this dissertation, the instrument has neither been used in high school nor in science classrooms. As a result, there are incongruences between CRP Science and CRP as operationalized through the CRIOP. Inquiry-based science instruction is one component of CRP Science that is treated cursorily in the CRIOP. For example, while inquiry is present it is determined by examining the degree to which, “[s]tudents are encouraged to pose questions and find answers to their questions using a variety of resources” (p. 195). Thus, to examine CRP Science teacher quality and its relation to student outcomes, an instrument reflecting the domain-specific application of CRP should be developed.

The design principles accompanying the revised STARTS framework may guide professional developers aiming to prepare culturally responsive science teachers. However, as mentioned previously, PD initiatives must take into account larger contextual influences. They must cohere with accountability measures for teachers, which means a tight alignment to district-, state-, and national standards as well as demonstrating student achievement. Research must connect student learning to CRP Science (Lee & Luykx, 2007; Sleeter, 2012) and include student artifacts to illuminate key mediators of the learning process. Currently, there is limited research that accomplishes this goal. Compounding the issue, the literature base documenting the effect of culturally responsive pedagogy on student achievement consists primarily of small-scale case studies (Cammarota & Romero, 2009; Ladson-Billings, 1995). Thus, to increase CRP Science on a wide-scale, additional research is required that connects CRP Science to diverse students’ achievement on standardized tests such as the biology End of Course exam (for this group of participating teachers) and national assessments of science achievement.

Additional research may help further refine the design principles proposed in this study, particularly in the areas of supporting a critical and family-connected stance among science teachers and the translation of this stance to instructional materials that are emancipatory and academically rigorous. The fact that participating teachers did not embrace certain crucial elements of CRP Science (i.e., family connections, using science instruction to uncover and problematize oppression and bias), even while participating in an empirically grounded PD program designed to foster this growth, alludes to the complex task of developing a critical and community-connected stance among these science teachers. Other studies acknowledge such challenges for teachers (e.g., Morrison et al., 2008). A closer examination of the reasons for this perpetual issue as well as strategies for addressing the dilemma is warranted. Furthermore, this study was concerned with identifying salient PD features associated with supporting the changing CRP Science knowledge and practices of teachers. While the analysis identified direct connections between teachers' professional development and specific design elements, it is uncertain why these specific features were effective for the professional growth of this group of teachers. The literature upon which the STARTS program was designed provides plausible explanations for the effectiveness of each design element (refer to Table 5-1). For instance, Ross, Bondy, and Kyle (1993) assert that, "the reflective process. . . ensures that [teachers'] decisions will be constantly reevaluated in terms of their actual impact" (p.6). However, an empirical foundation to this end was beyond the scope of the study. Additional research related to identifying and modeling the causal nature of the relationship between these variables is merited.

Future research examining the effectiveness of PD programs for CRP Science should first evaluate the quality of PD experiences and then make suggestions for program redesign based on those findings. Revised programs should be further evaluated for their ability to produce sustainable impact on teachers' practices, as there is a risk of retreat to former pedagogies once the program has ended (Bell & Gilbert, 1994; Loughran, 2007). To promote CRP Science in multiple settings, the program should be scaled up once effectiveness has been determined. However, Lee and Buxton (2010) have noted considerable challenges when attempting to scale up PD for CRP Science initiatives, including a weak conceptual base to draw from when designing PD of this magnitude, accountability policies that reinforce assimilation into mainstream cultures, and confronting contextual constraints. While this dissertation adds to the conceptual base Lee and Buxton (2010) speak of, much work in this area is still needed.

Moreover, while research indicates that diverse students perform better academically when families are involved in their education (Antunez, 2000; Jeynes, 2005) and when taught in emancipating ways (Ladson-Billings, 1995), the teachers in this study reported positive student outcomes without explicit attention to either. As a result, further research is needed to explore the ways in which a *culturally responsive* approach promotes better academic performance for diverse students as opposed to a *responsive* approach.

Limitations of the Study

As with the design of an intervention, the research design also imposes constraints. There are several limitations to this study. They include: (a) time, (b) instruments, and (c) generalizability.

Time

The first limitation pertains to the temporal scope of the data that were collected, particularly classroom observations. Even though I observed each teacher's classroom practices six times during the STARTS program, I was unable to observe the entirety of their practices. Through the collection of numerous additional artifacts (e.g., completed GAIn tasks, lesson study documents, PG tasks, and CTS working document) I attempted to increase methodological rigor by using these data as sources for triangulation. For example, I analyzed these artifacts for teachers' statements of their practices. Doing this also allowed me the opportunity to honor teachers' self-reported practices. These sources were then compared with the repeated classroom observations.

Instruments

A second possible limitation lies with the instruments used to measure teachers' CRP Science and reform-based classroom practices. Though the validity and reliability of both instruments are acceptable, they still pose limitations. The CRIOP (Powell et al., 2012) instrument was originally designed to examine the literacy practices of elementary teachers. Thus, there are limitations to the ways that CRP Science was operationalized. I attempted to mitigate this by also looking for elements of practice that were representative of the synthesis of CRP Science, such as reform-based science teaching practices. However, ultimately the use of the CRIOP constrains the characterization of CRP Science. The RTOP (Piburn & Sawada, 2000) has been widely used to characterize the inquiry-based practices of science classrooms (e.g., Judson & Lawson, 2007; Park, Jang, Chen, & Jung, 2011; Roehrig, Kruse, & Kern, 2007). However, because the instrument also includes mathematics reform-based instruction, teachers' scores do not necessarily translate directly to a measure of their inquiry-based practice. As a result, I chose to acknowledge the influence of both science and mathematics education reform contained within the instrument and referred to instruction as "reform-based." Finally, there were limitations pertaining to assigning scores to each teacher. Though I trained on each protocol, there were still limitations as I was the only rater. Thus, no inter-rater reliability could be determined. In an attempt to reduce bias I engaged in member checking with the teachers after every observation.

Generalizability

A critique of design studies is their limited generalizability (Kelly, 2004), as the research and educational intervention are often highly contextualized. This study was delimited to the six high school life science teachers who participated in the STARTS PD program. Furthermore, the recruitment and selection process limited the breadth of the findings of the study. Though teachers represented a wide range of professional experience, they were selected from a population of *Summer Science Institute* (SSI) participants. As a result, the teachers in this study were highly motivated, volunteering not only in the weeklong residential SSI experience but also in the intensive 7-month STARTS program. Hence, the generalizability of the results is limited beyond the teachers in this study. However, it should be noted that, because no two settings are alike, grounded theory research is not necessarily intended to produce results that can be generalized (Charmaz, 2006).

Conclusion

This study sought to produce usable knowledge by elucidating the process of becoming a CRP Science teacher and instructional designer in the context of the STARTS PD program. Additionally, because of the design-based nature of the study, identifying salient program features capable of supporting teachers' progressions was also essential. Ultimately, this study sought to advance the knowledge base in science education by articulating the relationship between process and structure.

STARTS participating teachers demonstrated evidence of CRP Science teaching over time. Six themes were characteristic among teachers as they developed CRP Science knowledge and practices: their expanding awareness of CRP Science, shifting views of students, community building, student repositioning, acquisition and application of a toolbox of responsive instructional strategies and relevant science topics, and the accompanying instructional changes. Amid this progression, there were crucial elements of CRP Science that teachers did not enact, including family partnerships and using science instruction to uncover and ameliorate oppression.

Several design elements were associated with teachers' professional growth, including critical exploration of and reflection on practice, collective participation, examining critical perspectives on education for diverse students, brainstorming CRP Science lesson ideas, and structured opportunities to learn about students' lives alongside the scaffolded integration of students' backgrounds with reform-based science instruction. These results highlight the need for additional research in several areas, including: facilitating teachers' development as CRP Science educators in a variety of contexts and scale-up of such interventions, exploring and identifying how to best support teachers in the construction of academically rigorous CRP Science instructional materials, developing a discipline-specific instrument for measuring teachers' CRP Science practices, and determining a causal model for the relationships among the variables. Additionally, because the teachers in this study reported positive student learning outcomes when they were taught in ways that did not reflect comprehensive visions of CRP Science, research is also needed to explore the ways in which a *culturally responsive* approach promotes better academic performance for diverse students as opposed to a *responsive* approach. Collectively, these studies chart the path for a new phase of science education reform.

Table 6-1. Features of the STARTS program, their accompanying activities, and associated outcomes of teachers' CRP Science knowledge and practices.

Salient feature	Corresponding STARTS activities	Teacher outcome
Critically exploring/analyzing teaching practices	Lesson study, GAIn tasks, PG tasks	More aware of teaching practices
Reflecting on the impact of practice on intended versus actual student outcomes	Lesson study, GAIn tasks, PG tasks	More aware of teaching practices, Connect instruction to students they serve versus prior emphasis primarily on content
Purposefully connecting instruction with specific student needs	Lesson study, GAIn tasks, CRP Science unit	Design instruction that utilizes responsive strategies
Providing examples of CRP Science and reform-based science instruction	GAIn tasks, PG tasks, CTS, SCS	Deeper understanding of CPR Science and reform-based science teaching
Comparing current practices to CRP Science and reform-based science exemplars	GAIn tasks, PG tasks	More aware of teaching practices, Deeper understanding of CPR Science and reform-based science teaching, Change instruction
Critically analyzing sample lesson plans for the presence of CRP Science and reform-based science instruction	PG tasks	Implement new instructional strategies
Learning about and developing critical perspectives on education for diverse students	GAIn tasks, SCS	Promoted awareness of CRP Science, Fostered need for relevant instruction
Prompting teachers to learn more about their focus class and focus group students' experiences in and out of school	GAIn tasks	Shifted views of students, Community building Design instruction that utilizes responsive strategies and applies relevant science topics,

Table 6-1. Continued

Salient feature	Corresponding STARTS activities	Teacher outcome
Supporting teachers in making connections between students' experiences and science instruction	GAIn tasks, SCS, CRP Science unit	Design instruction that utilizes responsive strategies and applies relevant science topics
Providing resources for teachers as they suggest responsive strategies and relevant topics	GAIn tasks, PG tasks	Utilize toolbox of strategies and topics, Change instruction
Brainstorming lesson ideas, co-designing lessons, and speculating on how to overcome classroom issues	Lesson study, SCS, CRP Science unit	Design instruction that utilizes responsive strategies and applies relevant science topics
Fostering a supportive network of colleagues	SCS	Eases overwhelming feelings, Assistance when implementing novel instruction

Note: PG: Professional Growth, GAIn: Growing Awareness Inventory, CTS: Curriculum Topic Study, SCS: Saturday Collaboration Sessions.

APPENDIX A
CRP SCIENCE CODING

Study Parameters and Categories of Culturally Responsive Science Education.

CRIOP Pillar	Elements	B&B (05)	B&CB (07)	B&B (10)	B&G (01)	CB (98)	E&T (05)	F (01)	KJ&J (11)	M(11)	P&CP (08)	Lee (04)	T.et al. (08)	L&A (12)
		Author(s)												
Teacher (T) or Student (S) focus		**T**	**S**	**T**	**S**	**S**	**S**	**S**	**T**	**T**	**T**	**T**	**S**	**T**
Formal (F) or Informal (IF) learning environment		**F**	**IF**	**F**	**F**	**IF**	**F**	**IF**	**F**	**F**	**F**	**F**	**F**	**F**
Grade range - Elementary (E), Middle (M), High School (H)		**H**	**M**	**M**	**E**	**M**	**H**	**H**	**M**	**E**	**E**	**E**	**M**	**M**
1. Classroom Relation-ships	1. Ethic of care	X				X	X		X		X			X
	2. High expectations	X							X					X
	3. Respectful environment	X	X	X		X	X	X	X			X		X
	4. Student Collaboration			X		X	X	X	X		X	X		X
2. Family Collabor-ation	1. Genuine partnerships with caregivers				X			X						
	2. Family involvement in positive ways							X				X		
	3.Family expertise supports learning				X			X				X	X	
3. Assessment	1. Formative assessment; demonstrate learning in various ways	X	X	X			X	X	X			X	X	X
	2. Self assessment						X							
4. Curriculum/ Planned Learning Experiences	1. Sts' experiences in curriculum		X	X	X	X	X	X		X			X	X
	2. Diverse perspectives in curriculum		X		X	X	X	X		X	X	X		X

5. Pedagogy/ Instruction	1. Students' lives, experiences contextualized.		X		X	X	X	X				X	X	X
	2. Hands-on, meaningful learning tasks	X	X	X	X	X	X	X	X	X	X	X	X	X
	3. Developing academic vocabularies			X								X	X	
	4. Scaffold student learning	X		X					X			X	X	X
	5. Inquiry-based	X		X	X	X	X	X	X	X		X	X	X
	6. Student choice			X		X	X	X			X		X	
6. Discourse/ Instructional Conversation	1. Engagement via discourse			X							X		X	X
	2. Equitable discourse practices		X	X							X	X		X
	3. Promote academic conversation			X					X	X			X	
	4. Develop linguistic competence			X								X	X	
7. Socio-political Conscious-ness	1. Issues important to the community		X		X	X	X	X		X			X	X
	2. Confront negative stereotypes and biases		X		X	X	X	X					X	X

Author Key

Code	Reference
B&B (05)	Barnes, M.B., & Barnes, L.W. (2005). Using inquiry processes to investigate knowledge, skills, and perceptions of diverse learners: An approach to working with prospective and current science teachers. In A. J. Rodriguez & R. S. Kitchen (Eds.), *Preparing mathematics and science teachers for diverse classrooms: Promising strategies for transforming pedagogy* (pp. 61-86). Mahwah, NJ: Lawrence Erlbaum Associates.
B&CB (07)	Basu, S.J., & Calabrese Barton, A. (2007). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching, 44*(3), 466-489. doi: 10.1002/tea.20143
B&B (10)	Bianchini, J.A., & Brenner, M.E. (2010). The role of induction in learning to teach toward equity: A study of beginning science and mathematics teachers. *Science Education, 94*(1), 164-195. doi: 10.1002/sce.20353
B&G (01)	Bouillion, L.M., & Gomez, L.M. (2001). Connecting school and community with science learning: Real world problems and school- community partnerships as contextual scaffolds. *Journal of Research in Science Teaching, 38*(8), 878-898.
CB (98)	Calabrese Barton, A. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching, 35*(4), 379-394.
E&T (05)	Elmesky, R., & Tobin, K. (2005). Expanding our understandings of urban science education by expanding the roles of students as researchers. *Journal of Research in Science Teaching, 42*(7), 807-828.
F (01)	Fusco, D. (2001). Creating relevant science through urban planning and gardening. *Journal of Research in Science Teaching, 38*(8), 860-877.
KJ&J (11)	Kelly-Jackson, C.P., & Jackson, T.O. (2011). Meeting their fullest potential: The beliefs and teaching of a culturally relevant science teacher. *Creative Education, 2*(4), 408-413.
L&A (12)	Laughter, J.C, & Adams, A.D. (2012). Culturally relevant science teaching in middle school. *Urban Education, 47*(6), 1106-1134.
Lee (04)	Lee, O. (2004). Teacher change in beliefs and practices in science and literacy instruction with English language learners. *Journal of Research in Science Teaching, 41*(1), 65-93. doi: 10.1002/tea.10125
M (11)	Mensah, F.M. (2011). A case for culturally relevant teaching in science education and lessons learned for teacher education. *The Journal of Negro Education, 80*(3), 296-309.
P&CP (08)	Patchen, T., & Cox-Petersen, A. (2008). Constructing cultural relevance in science: A case study of two elementary teachers. *Science Education, 92*(6), 994-1014. doi: 10.1002/sce.20282
T et.al. (08)	Tate, E.D., Clark, D.B., Gallagher, J.J., & McLaughlin, D. (2008). Designing science instruction for diverse learners. In Y. Kali, M. C. Linn & J. E. Roseman (Eds.), *Designing coherent science education: implications for curriculum, instruction, and policy* (pp. 65-93). New York, NY: Teachers College.

APPENDIX B
INFORMED CONSENT

Title of Study: Designing for Culturally Responsive Science through Professional Development
Investigator: Julie C. Brown
Contact Phone Number: (352) 870-2517

Purpose of the Study
The purpose of this study is to facilitate and explore changes in science teachers' knowledge, classroom practices, and ability to design instructional materials while participating in a professional development program.

Procedure
If you volunteer to participate in this study, you will be asked to do the following. Additionally, data collection (in the form of audio recordings, video recordings, artifact collection) may arise from, but is not limited to, the following tasks:

- Complete a survey about your teaching and learning needs, as well as your students' learning needs
- Allow video-recorded observations of you classroom practices
- Hold ongoing, informal conversations with your colleagues and the research team
- Reflect on your practice in an electronic journal and during lesson observation debriefing
- Participate in three audio-recorded, semi-structured interviews, each lasting no more than 45 minutes
- Attend a one weeklong summer institute to develop your cutting edge science knowledge and ability to design culturally responsive, inquiry-based instructional materials. Sessions in this institute may be video recorded to better understand the professional development's impact on your teaching.
- Collaborate with science teacher colleagues from your school on a regular basis to brainstorm curriculum ideas and troubleshoot challenges to design. These collaboration sessions may be video recorded to better understand the professional development's impact on your teaching.
- Participate in a blended professional development (PD) course in which you:
    - Engage in Lesson Study
    - Complete a *Curriculum Topic Study*
    - Complete the *Growing Awareness Inventory* (GAIn)
    - Design instructional materials that are culturally responsive and inquiry-based

** Audio recordings of interviews, video recordings of observations, and artifacts from the blended PD course (e.g., Lesson Study electronic worksheets; Curriculum Topic Study electronic worksheets; video recordings of classroom observations) will be collected and analyzed to better understand the impact of this professional development on your teaching.

Risks and Benefits of Participation
There are risks involved in all research studies. However, minimal risk is envisioned for participating in this project. You will not be identified by name in any reports of this research; pseudonyms will be used. The professional development will provide you with multiple opportunities to continue your development as a science teacher and designer of inquiry-based, culturally responsive instructional materials. Additional potential benefits may include stronger teacher-student relationships and development as a teacher leader.

Time Required and Compensation
All participant tasks will occur over the course of the professional development (approximately 7 months). Participating teachers will be compensated for their full participation including, but not limited to, the design of instructional materials and completion of the summer institute and professional development course.

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2013-U-0143
For Use Through 02/18/2014

Confidentiality
All information gathered in this study will be kept confidential to the extent provided by law. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked file cabinet in the Principal Investigator's office. When the study is completed and the data have been analyzed, the information will be shredded and/or electronically erased.

Voluntary Participation
Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw your consent to participate at any time without penalty. You are encouraged to ask questions about this study at any time during the research study.

Contact Information
If you have any questions or concerns about the study, you may contact the Principal Investigator (Julie C. Brown) at brownjc@ufl.edu or (352) 870-2517. You may also contact the Project Supervisor (Dr. Kent J. Crippen) at kcrippen@coe.ufl.edu or (352) 273-4222. For questions regarding your rights as a research participant in this study you may contact the UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; (352) 392-0433.

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

______________________________ __________________
Signature of Participant Date

____
Participant Name (Please Print)

APPENDIX C
EXCERPTS FROM DESIGN DECISIONS REPORT (DDR)

The DDR contained “a database with records of each decision, whether motivated by literature review, field research, or the demands of practice” (Joseph, 2004, p.241).

In preparation for first Saturday Collaboration Session.
They will have four articles of CRP in science to choose from. Their job is to read 2. Then, read over the CRIOP

Did this because I want to make sure that not only do they get to see examples of CRP Science, but also because this is another way to model what CRP Science looks like and also builds confidence in them as they can see that what I am asking them to design is not so far off from what they already do.

Also, this way they have to discern for themselves what CRP in science looks like, versus giving them a prescriptive list like would’ve been the case had I given them Gay (2010) pp.31-8 to read. How can you expect to ever fit into all of those categories??

Teachers not only need to see modeled examples of this (above and Zozakiewicz & Rodriguez, 2007; Lee, 2004) but also need it to practically link to their classrooms (remember what [Claudia and Christina Joy] said about how they hated when PD was so theoretical and did not provide them with anything to be used in the classroom?) “Professional development is effective when it is explicitly connected to teachers’ work with their students (Darling Hammond & McLaughlin, 1995)” (cited in Stepanek et al, 2007, p.11)

With the CRIOP, I want them to know how they will be evaluated. However, I also need to let them know that (1) I don’t expect them to practice every single one of these tasks – it’s not like a checklist that once you finally get there you are then a fantastic teacher. However, I also did this to let them start thinking about where they might want to grow as we progress through STARTS. They will elucidate this in the Reflective Writing Prompt and regularly monitor their progress.

(1) Tate et al. (2008) excerpt (define any acronyms [TELS: Technology Enhanced Learning in Science] and provide a backdrop; this science activity is for grades XXX deals with XXX topics and can be found at XXX)
(2) Suriel (2010) (science activity for grades XXX deals with XXX topics)
(3) Brown (2013) (science activity for grades XXX deals with XXX topics)
(4) Fraser-Abder et al (2010) (science activity for grades XXX deals with XXX topics)

Based on the two CRP in science readings and the CRIOP, describe for me (in the Reflective Writing Prompts):
(1) How they would characterize culturally responsive science instruction
(2) Which of these elements they already practice with confidence and regularity
(3) Which of these elements they would like to practice more often

Then, read over the RTOP (pp….) and jot down any questions they have about this observation protocol (as well as the CRIOP). For the RTOP, include a Reflective Writing Prompt that asks 2-3 above

Already Practicing

CRIOP elements	RTOP elements
For example:	For example:

Would Like to Practice More Often

CRIOP elements	RTOP elements
For example:	For example:

The answers to these prompts will help them as they develop their goals for the Lesson Study (XXX area of practice that they are interested in exploring), which we will talk about on Saturday.

Also include Agenda on the Moodle site and remind them to bring their **Lesson Study** ideas

- Need resources – how will they read about it? (brief 1-2 page in session; discuss with one another)

Need video-cases for the CRIOP, RTOP
Tools for ambitious science teaching, Kay Toliver

In preparation for the first observation:

The compelling argument has to come from what happens in **<u>their classrooms</u>**.

- I am making this statement based not only on the literature (Gregoire, 2003; Loucks-Horsley et al., 2010), but also on the Fellows' quote choices from the Inside Outside Circle we did during the first Saturday Collaboration Session. Nobody picked any of the more emotionally charged quotes that pointed to larger issues within education and the underrepresented students who disproportionately feel the negative impact of these issues.

Instead, their quote selections at this stage tended to revolve around the following themes:

- Learners come in with prior knowledge
- Teachers need support in making changes in their classrooms

So, back to the main point, that the compelling argument at this point seems to stem from what goes on in their classrooms.

Ex: how students *act*
How students *perform*
How their teaching impacts these student outcomes (action, performance, etc.)

So, to make CRP Science compelling, they need to see it make an impact with their students.

- The lesson study is set up to do this to an extent.
- Less emphasis needs to be on having them examine where they match up in the CRIOP/RTOP directly.

I drafted several post-observation debrief questions to make the argument compelling.
During class time, what matters most to you? (Probe with questions until I isolate "what" it is and "why" it is)
At XXX point in the lesson I noticed you did XXX technique (pick out a CRP Science or RTOP technique).

(a) *Tell me about why you decided to do this particular strategy and how it relates to your intended practices (from the CRIOP self-assessment)*
(b) *What impact did this have on student performance?*

CRIOP self-assessment versus actual

Let's look over your self-assessment together. Prior to teaching this lesson, you expected to use XXX CRIOP strategies (and list a few). I saw you do many of these frequently and well (or some other descriptor).
Tell me about which, if any, of these strategies you originally intended to use but feel you did not practice today.
Why do you think this is so, that you did not practice XXX?

In preparation for the CRP Science tasks:
Furthermore, I need to select readings that make the message more compelling by connecting it tightly to their contextual needs.

Valuing Students' Communication Preferences
I chose four readings and am very pleased with these for the following reasons:

(1) They are tailored to the students the Fellows are working with
    a. Example: gifted students ([Kate] and [Lorelei]), urban and hip hop ([Zane], [Natalie], [Christina Joy]), and English Language Learners ([Claudia])
(2) Each one connects directly to science, which is good because they can see CRP contextualized within science, not just on a general, literacy, or elementary level
(3) They are each practical, offering teaching strategies or directions for such strategies

But I need to also design the activity so that it asks them to briefly describe WHY they chose this particular reading (Before You Teach section). That way I can further identify the details of their compelling message (*what* is compelling to them and *why*) as well as design the PD around this, whether it be additional readings in that area or a new assignment twist…

Accompanying the *Professional Growth* tasks:
Side note: I am going to highlight the STARTS Fellows' best practices by making available a video clip on our Moodle site of each part in action. The Fellows have shared with me that they find great value in observing one another's practices, and several PD for science education sources have used observation as a way to initiate teachers' reflection on their practices (Lee, 2004; Luft, 2001) as well as learn best practices from expert teachers (Garet et al., 2001).

So for example, if we are looking at the classroom environment, I might put up pictures of [Christina Joy's] class or a brief video of the students working together, then, possibly tie this to an assignment, such as the GAIn **Before you Teach** section. Or, if we are looking at facilitating academic discourse, I could highlight a section of someone's video where I see this happening and then upload it to the site and ask the Fellows to provide evidence of where they see this happening and provide a rationale for *why* it was effective. This would be engaging and give them a chance to see one another in action.

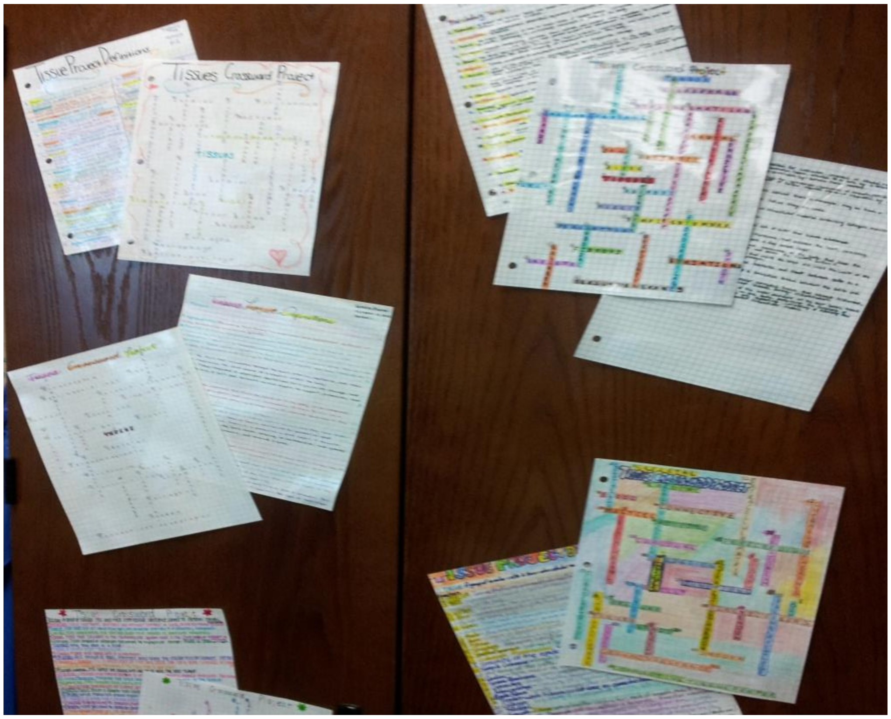
APPENDIX D
RESEARCHER'S FIELD NOTES

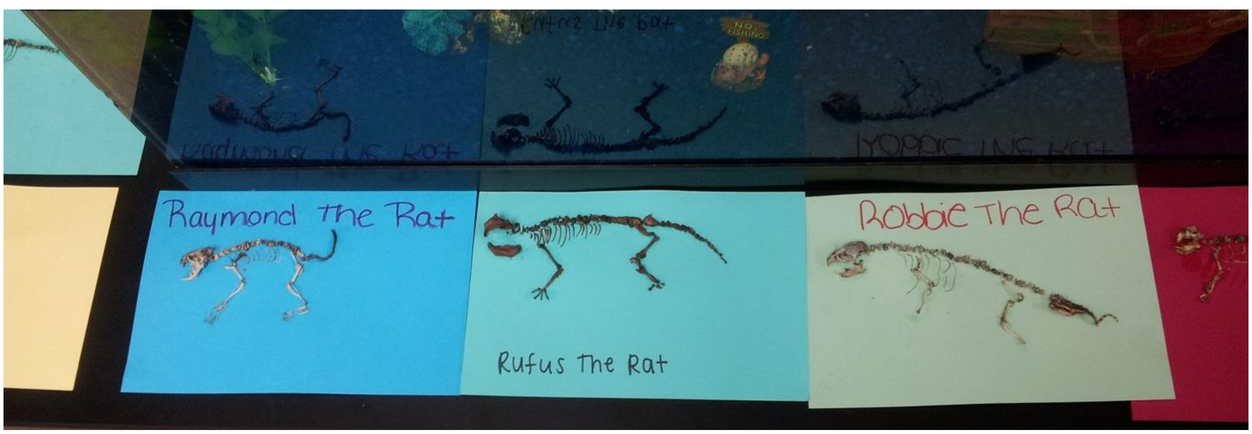
[Christina Joy] – October 15, 2013

Summary

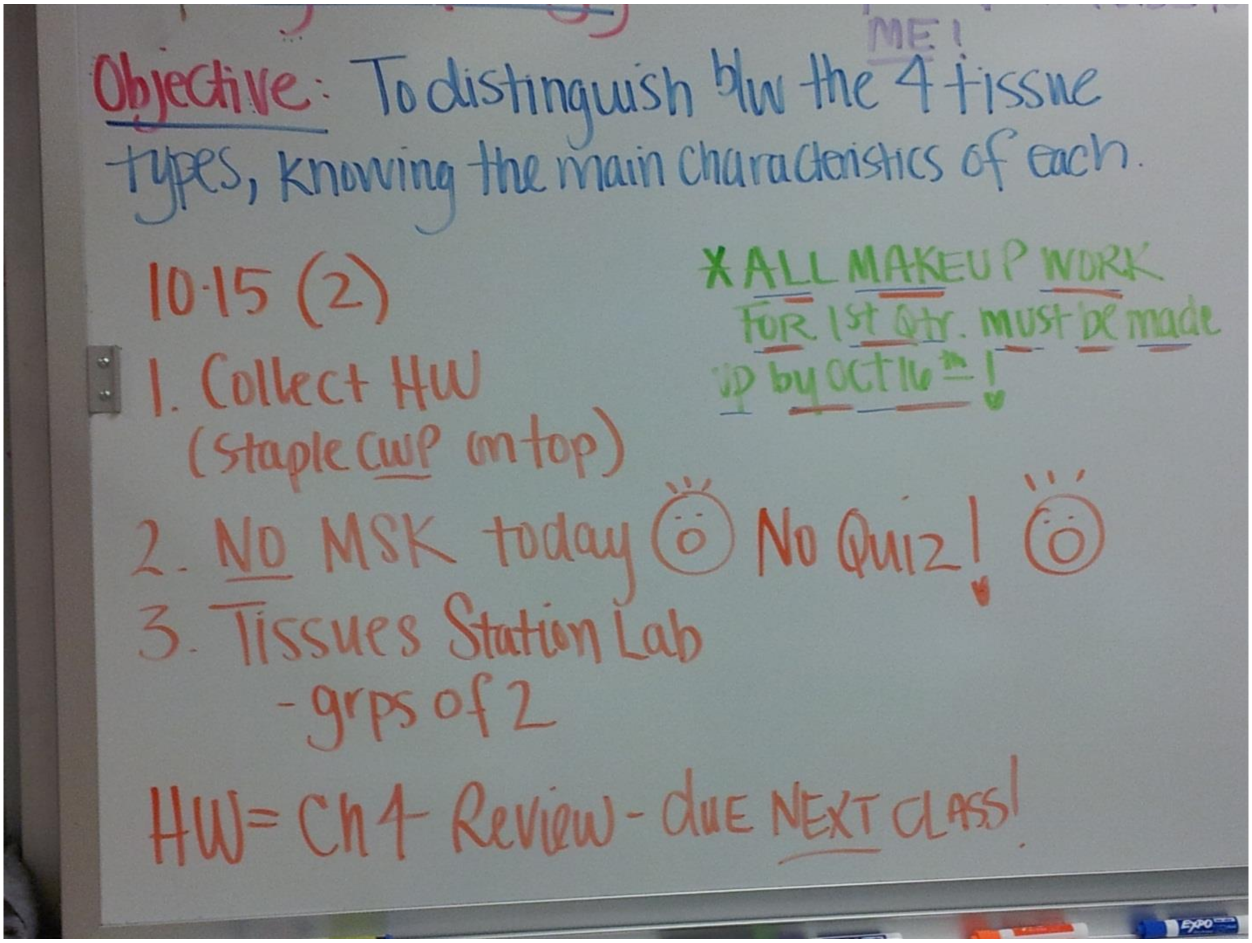
"She taught me everything I need to know." These words came from Christina Joy's principal when I asked him about his observation during today's block period. He was telling me about the Marzano accountability system and said something to the effect of, "everything I am observing her on, she was the one who taught me everything I need to know." That's the kind of teacher Christina Joy is. During today's class, students worked in pairs to distinguish tissue types according to size, shape, function and other features. Additionally, students were continually asked to elucidate their rationale for making specific statements, which Christina Joy insisted they produce "scientific reasons" that include the correct usage of terminology. Christina Joy is clearly the director in this class ("follow me with your eyes"), which makes the environment feel like (just my speculation) a place where the commander successfully leads her pupils. This was evidenced through little waste in instructional time (Christina Joy moves quickly and effectively through tasks, though it does not feel hurried), students working collaboratively and depending on one another as opposed to Christina Joy. During the station activity, Christina Joy continually circulated among student pairs to clarify procedures and ask comprehension questions. Additionally, Christina Joy consistently provided specific, positive feedback to her students. She delivers explicit directions and provides examples of quality ("Instead of saying 'it looks like the picture', you could say….") and inadequate work ("If it looks like [her son] sketched it, then that's a problem"). Furthermore, Christina Joy repeatedly sends positive messages that position students as college-bound ("You spend a lot of time in college doing this – sketch what you see, sketch what you see"). One thing I would like Christina Joy to continue doing is providing plentiful opportunities for students to share their diverse perspectives on the science content under examination. During the first observation, this really came through, and I imagine that it is a common occurrence in class. However, I was not able to see this today.

Classroom Environment:
There is new student work on the walls since I was last here (see below).
2nd period anatomy and physiology (7:30a-9:10a)
Today 23 students are present. 13 females; 10 males. They are pretty diverse in terms of student ethnicity. A teacher's aide (junior in high school) is present also, but she does not interact with the students.

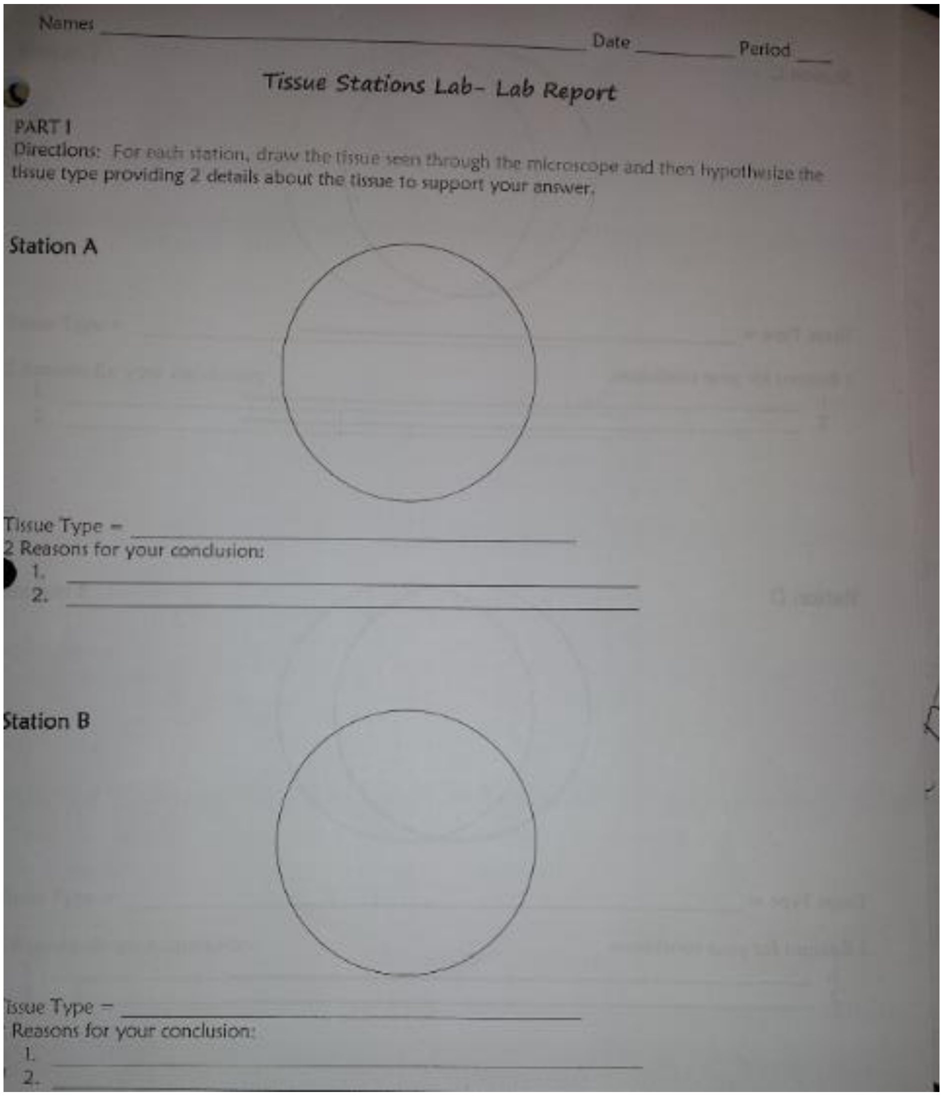




Agenda:
Tissue Stations Lab today
Today students are working in pairs in stations to “distinguish between the 4 tissue types, knowing the main characteristics of each”



Chronological Breakdown:
Christina Joy begins class right on time
Explains clearly that Part 4 of the assignment will be done on their own
They will do the first three sections on their own
They will work with a partner in the stations



Name: ______________________ Date ________ Period ___

Tissue Stations Lab- Lab Report

PART 1

Directions: For each station, draw the tissue seen through the microscope and then hypothesize the tissue type providing 2 details about the tissue to support your answer.

Station A

Tissue Type = ______________________

2 Reasons for your conclusion:

1. ______________________
2. ______________________

Station B

issue Type = ______________________

Reasons for your conclusion:

1. ______________________
2. ______________________

She has all the station materials ready to go
“Who can tell me what I would expect to find to help support epithelial tissue?”

“I’ve already set them up right where I want you to see it”
“Follow me with your eyes”
“There’s two things you are allowed to adjust, JUST two”

Ocular lenses
“Who remembers what the knob is called that focuses it just a hair?”
A few students answer: Adjustment

Then, she explains what they are to do with the knob

“You are going to sketch everything that… “

“This is something we do a lot in college

If it looks like [my son] sketched it (reference to her son), then that's a problem"

"How many of you are histologists?
I don't expect you to be experts just yet…"

"You have resources to help you…
Take your textbook, open up to Chapter 4"
(they do)
"I'm on page 129
Do you remember how we talked about how artistic impression is different than what you actually see?
Do you see that?"

"At every station
I've given you a hint"

Hint: contains adipocytes

"You must provide your rationale on why you chose that type"
(reason for claim)

So she models for them what she wants in a response:
Using students' names, calling on a variety of males and females
"What do you think I am looking for in a rationale?"
"Is your hint gonna help you come up with your answer?"
"Yeah
You could take the hints and use it as a rationale"
"That's fine"

"OK, go to part 2
If you look on pages 134-135 which one doesn't have striations, everybody?"
Choral response from several students, who are all looking at the book: smooth

"Look at the numbers on section 2 – ONLY do the numbers that are there"

T: Anybody have any questions? No…
T: Part 4 where are we doing that?
St: At home
T: In your
St: ISN (it's their interactive science notebook)

16 mins. into video 1

“Yes, use your book. Remember you are not yet histologists so use all the resources you can.”
You’re just kinda getting an idea…”

“Do you guys see where it says ‘quiz’?”
Christina Joy picks the student pairs and tells each pair at which station to begin

Christina Joy is moving around the classroom, helping students, checking that they know what they are doing

“You are going to draw exactly what you see, with the same exact colors”

To one pair of students: “Did you guys come up with a tissue type yet?”

“How are we doing over here? Good, good, good”

“I didn’t hear one comment about no quiz today, what’s up with that?” Laughs

“Do you guys hear me just fine from there?”

“You guys followed the directions, thank you for that.
You guys know you’re only handing in one, right?”

One female student (raises her hand)
Miss [Christina Joy]…
Immediately she responds, “I’ll be right there; just let me put the attendance in one second…”

“The question in the back, was that you [Female student]?”
“No, that was me”
“Oh, [another female student] I am sorry”

Takes about 15 seconds to answer her question
“Yes, purpley brown. That’s a really good question”

Facilitating and positive feedback
“Your conversation looks *so* good, I was gonna get a picture of you in action [which she uploads to her Instagram account; she has many student followers who post back]
Your conversation was awesome, so I know you’re on the right track”
“*These* are the nuclei, no in the blue
So what are these?”
“You are exactly right”

Christina Joy stops for a brief second to take pictures of the students
She will upload these to Instagram

“Hey this is a good day for nerd day [school spirit themed day]. You guys are all looking over the microscopes”

Positive reinforcement, which is focused on attention to detail and proper use of academic language.
“Do you see where I have the two pointers pointing?
You guys, your vocabulary is fantastic…
I want you to look right between the two pointers”

6 mins into video 2
“Alright you guys, are you about ready?
If you made the microscope move, just call me over
[to a H male student] I like how you are thinking…”

“No, but you see where I have the arrows? In between there I want you to identify it”
[to another H male student] “And do you have a good rationale?
Tell me about it”
“It’s just *two* layers?? Are you sure?
Are *all* the cells squished??”

“Make sure your rationale is scientific… provides two examples…it’s gotta be scientific”

“Only one is going to be graded, so you can swap…”
[B female student] Do we do the write-up?

…also transcribed/highlighted video 2: 13:00-17:44:
Student-Student Conversation while looking at prepared slides of adipose tissue.
2 B female students
St 1: OK, what’s the reasons again?
…Wait she said something about…
St 2: They look like that’s a…
…How do you change it? (about the microscope focus)
…Wait, the *outline* is pink *not* the center
…Do I have to make *all* these circles?? Ugh…
St 1: Where does it say C?
St 2: Right there (looking away from scope and pointing to worksheet)
St 1: OK, so I just locate…?
…Oh, yep, I know
…All those pretty circles (now looking through microscope)
…Oh, they look so pretty, yeah yeah look at it again. Fat looks pretty? (expression of disbelief)
St 2: Wait what did you get for A, I mean for C?
Adipose?
St 1: Yeah, definitely adipose

Student-Student Conversation
(So this is a nice instance of two students persisting through the site without immediately running to the teacher for help)

Two students at computer, H male and H female, working on epithelial cell virtual lab:
F: Okay, now search histology
F: Virtual lab
F: Epithelial tissues
F/M: e-p-i-t-h-e-l-i-a-l [Female st helping male st at computer spell]
F: click on the first main link that one …biology.com
F: it says review the webpage and…
M: this looks like
it tells you

[they are clicking and looking in silence]
F: now it says click on….and…
M: Where is it?
Can we go back and view it?
F: I don't know where it's at…
[Now they are searching in silence about two minutes go by and he says,]
M: I got it
I think stratified

Christina Joy repeats "Your rationale needs to be scientific…*please* make it scientific
Instead of saying it looks like the picture, you could say…[she provides an example]."

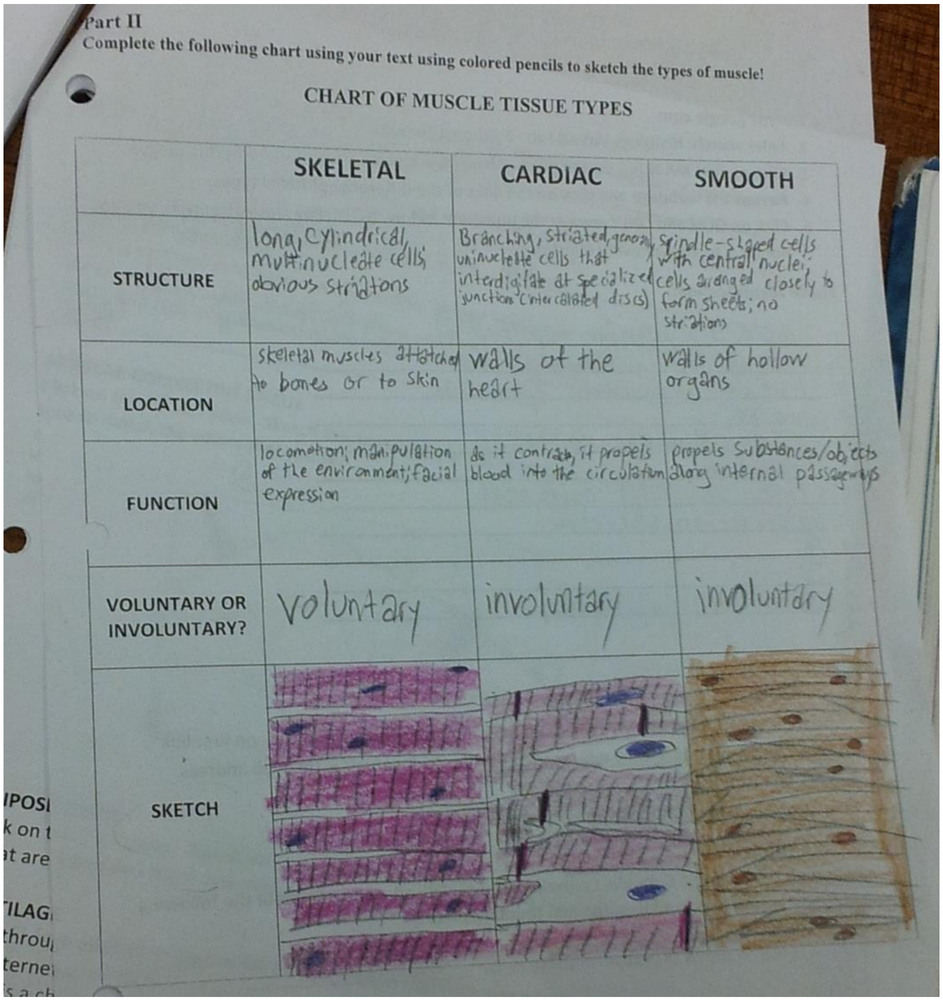
[Christina Joy is on to another group – checking to see their rationales]
"Make sure you give scientific reasons, you never want to say…[inaudible]"

Says out to class: "Scientific rationales everybody…"

Positive praise
"Did you see that? [referring to a B female helping a H male] That was so kind. You got caught doing a good thing; that was lovely. Help out your peers, alright."

Now on video 3
High Expectations and Care
"You spend a lot of time in college doing this – sketch what you see, sketch what you see"
(positive message that they are acting like college students)

Into 3rd video, at 8:32, Christina Joy sits down for the *first* time. She is up and moving throughout the entire class. I ask a H female if I can take a picture of her work from the stations:


Part II

Complete the following chart using your text using colored pencils to sketch the types of muscle!

CHART OF MUSCLE TISSUE TYPES

	SKELETAL	CARDIAC	SMOOTH
STRUCTURE	long, cylindrical, multinucleate cells; obvious striations	Branching, striated, generally uninucleate cells that interdigitate at specialized junctions (intercalated discs)	spindle-shaped cells with central nuclei; cells arranged closely to form sheets; no striations
LOCATION	skeletal muscles attached to bones or to skin	walls of the heart	walls of hollow organs
FUNCTION	locomotion; manipulation of the environment; facial expression	as it contracts, it propels blood into the circulation	propels substances/objects along internal passageways
VOLUNTARY OR INVOLUNTARY?	voluntary	involuntary	involuntary
SKETCH			

“Why’s there three of you at one microscope? Oh okay, thank you for being helpful.”

Note: Students have sustained their work during this *entire* class period to this point (well over an hour, without getting too loud or off-task)

The student-student I recorded the conversation of earlier are still working on their computer search.

8:50am – need to leave and head to [Zane’s] class

Christina Joy says this lab they will probably get 75% done today and will take about half a period for the next class. They will then discuss and compare their results.

Sometimes they are working in the ISN and sometimes they are working in the lab sheet.

Part 4 of the station lab worksheet is the reflection and THIS will go into their labs
Example of a reflection: How difficult was it to identify each feature? What could have made the process less difficult?

Responses will be separate (the worksheet and the lab report ISN)

APPENDIX E
CRIOP INSTRUMENT

Culturally Responsive Instruction Observation Protocol
Revised Edition

Originally Developed by: R. Powell, S. Cantrell, Y. Gallardo Carter, A. Cox,
S. Powers, E. C. Rightmyer, K. Seitz, and T. Wheeler

Revised by: R. Powell (Georgetown College), S. Cantrell (University of Kentucky), V. Malo-juvera (UNC-Wilmington),
D. Ross (University of Florida) and R. Bosch (James Madison University)

School (use assigned number):____________________________ Teacher (assigned number): ________________

Observer:_________________________ Date of Observation: ___________ # of Students in Classroom: ___________

Academic Subject: ___________________________________ Grade Level(s): _________________________________

Start Time of Observation: ____________ End Time of Observation:_________ Total Time of Obs: ________________

DIRECTIONS

After the classroom observation, review the field notes for evidence of each "pillar" of Culturally Responsive Instruction. If an example of the following descriptors was observed, place the field notes line number on which that example is found. If a "non-example" of the descriptors was observed, place the line number on which that non-example is found.

Then, make an overall/holistic judgment of the implementation of each component. To what extend and/or effect was the component present?

4 – To a great extent
3 – Often
2 – Occasionally
1 – Not at all

Transfer the holistic scores from pp. 2 through 9 to the table below.

CRI Pillar	Holistic Score
I. CLASS	
II. FAM	
III. ASMT	
IV. CURR	

CRI Pillar	Holistic Score
V. PED	
VI. DISC	
VII. SOCIO	

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I. CLASS CLASSROOM RELATIONSHIPS

Holistic score **4** To a great extent **3** Often **2** Occasionally **1** Not at all

CRI Indicator	For example, in a responsive classroom:	For example, in a non-responsive classroom:	Field notes: Line(s) of example	Field notes: Line(s) of non-example	Field notes: No example (✓)	SCORE for Indicator
1. The teacher demonstrates an ethic of care (e.g., equitable relationships, bonding)	Generally Effective Practices: • Teacher refers to students by name, uses personalized language with students • Teacher conveys interest in students' lives and experiences Practices that are Culturally Responsive: • Teacher differentiates patterns of interaction and management techniques to be culturally congruent with the students and families s/he serves (e.g., using a more direct interactive style with students who require it)	• Teacher promotes negativity in the classroom, e.g., criticisms, negative comments, sarcasm, etc. • Teacher stays behind desk or across table from students; s/he does not get "on their level" • Teacher does not take interest in students' lives and experiences; is primarily concerned with conveying content • Teacher uses the same management techniques and interactive style with all students when it is clear that they do not work for some				
2. The teacher communicates high expectations for all students	Generally Effective Practices: • There is an emphasis on learning and higher-level thinking; challenging work is the norm Practices that are Culturally Responsive: • There is a "family-like" environment in the classroom and there are group goals for success as well as individual goals; every student is expected to achieve • Students are invested in their own and others' learning • Teacher expects every student to participate actively and establishes structures (e.g., frequent checks for understanding) so that no student "falls through the cracks" • Teacher bases feedback on established high standards and provides students with specific information on how they can meet those standards	• Teacher has low expectations (consistently gives work that is not challenging) • Teacher does not call on all students consistently • Teacher allows some students to remain unengaged, e.g., never asks them to respond to questions, allows them to sleep, places them in the "corners" of the room and does not bring them into the instructional conversation, etc. • Teacher does not establish high standards; evaluation criteria require lower-level thinking and will not challenge students • Teacher feedback is subjective and is not tied to targeted learning outcomes and standards • Teacher expresses a deficit model, suggesting through words or actions that some students are not as capable as others				

3. The teacher creates a learning atmosphere that engenders respect for one another and toward diverse populations	Generally Effective Practices: • Teacher sets a tone for respectful classroom interaction and teaches respectful ways for having dialogue and being in community with one another • Students do not hesitate to ask questions that further their learning • Students interact in respectful ways and know how to work together effectively • Teacher and students work to understand each other's perspectives Practices that are Culturally Responsive: • Positive and affirming messages and images about students' racial and ethnic identities are present throughout the classroom • Teacher encourages students to share their stories with one another and to have pride in their history and cultural identity • Classroom library and other available materials contain multicultural content that reflect the perspectives of and show appreciation for diverse groups	• Teacher shows impatience and intolerance for certain student behaviors • Lack of respectful interaction amongst students may be an issue • Teacher establishes a competitive environment whereby students try to out-perform one another • Teacher does not encourage student questions or ridicules students when they ask for clarification • Teacher does not address negative comments of one student towards another • Posters and displays do not show an acknowledgement and affirmation of students' cultural and racial/ethnic identities • Classroom library and other available materials promote ethnocentric positions and/or ignore human diversity				
4. Students work together productively	Generally Effective Practices: • The teacher implements practices that teach collaboration and respect, e.g., class meetings, modeling effective discussion, etc. • Students are continuously viewed as resources for one another and assist one another in learning new concepts • Students are encouraged to have discussions with peers and to work collaboratively • Students support one another in learning and applying new concepts to assure that every student succeeds • Chairs/desks are arranged to facilitate group work and equal participation between teachers and students	• Students are not encouraged to assist their peers • Students primarily work individually and are not expected to work collaboratively; and/or students have a difficult time collaborating • Teacher dominates the decision-making and does not allow for student voice • The emphasis is on individual achievement • Classroom is arranged for quiet, solitary work, with the teacher being "center stage"				

II. FAM FAMILY COLLABORATION

Holistic score 4 To a great extent 3 Often 2 Occasionally 1 Not at all

NOTE: When scoring this component of the CRIOP, the family collaboration interview should be used in addition to field observations. Observations alone will not provide adequate information for scoring.

CRI Indicator	For example, in a responsive classroom:	For example, in a non-responsive classroom:	Field notes: Line(s) of example	Field notes: Line(s) of non-example	Field notes: No example (✓)	SCORE for Indicator
1. The teacher establishes genuine partnerships (equitable relationships) with parents/ caregivers	Generally Effective Practices: • Parents'/caregivers' ideas are solicited on how best to instruct the child; parents are viewed as partners in educating their child • There is evidence of conversations with parents/caregivers where it's clear that they are viewed as partners in educating the student Practices that are Culturally Responsive: • Teacher makes an effort to understand families and respects their cultural knowledge	• Parents'/caregivers' suggestions are not incorporated in instruction • No effort made to establish relationships with caregivers • There is evidence of a "deficit perspective" in which families and caregivers are viewed as inferior and/or as having limited resources that can be leveraged for instruction				
2. The teacher reaches out to meet parents in positive, non-traditional ways	Generally Effective Practices: • Teacher conducts home visit conferences • Teacher makes "good day" phone calls and establishes regular communication with parents Practices that are Culturally Responsive: • Teacher plans parent/family activities at locations within the home community • Teacher meets parents in parking lot or other locations that may be more comfortable for them	• Communication with parents/caregivers is through newsletters, where they are asked to respond passively (e.g., signing the newsletter, versus become actively involved in their child's learning) • Teacher conducts phone calls, conferences, personal notes to parents for negative reports only (e.g., discipline)				
3. The teacher uses parent expertise to support student learning and/or classroom instruction	Generally Effective Practices: • Parents are encouraged to be actively involved in school-related events and activities • Parents/caregivers are invited into the classroom to participate and share experiences Practices that are Culturally Responsive • Teacher makes reference to parents'/caregivers' careers, backgrounds, daily activities during instruction • Teacher identifies parents' "funds of knowledge" and incorporates into the curriculum and parents/caregivers are invited into the classroom to share their expertise	• Parents/caregivers are never involved in the instructional program • Parents'/caregivers' "funds of knowledge" are never utilized • There is no evidence of home/family connections in the classroom				

III. ASMT ASSESSMENT PRACTICES

Holistic score 4 To a great extent 3 Often 2 Occasionally 1 Not at all

CRI Indicator	For example, in a responsive classroom:	For example, in a non-responsive classroom:	Field notes: Line(s) of example	Field notes: Line(s) of non-example	Field notes: No example (✓)	SCORE for Indicator
1. Formative assessment practices are used that provide information throughout the lesson on individual student understanding; students are able to demonstrate their learning in a variety of ways, including authentic assessments	Generally Effective Practices • Teacher frequently assesses students' understanding throughout instruction • Students are able to voice their learning throughout the lesson • Informal assessment strategies are used continuously during instruction, while students are actively engaged in learning, and provide information on the learning of every student (e.g. "talking partners," whiteboards, journal responses to check continuously for understanding) Practices that are Culturally Responsive: • Teacher uses assessment to determine a student's potential for learning; teacher may implement "trial lessons" that use texts or require students to solve problems at a higher level than students' performance might indicate • Students with limited English proficiency and/or limited literacy can show their conceptual learning through visual or other forms of representation • Students can demonstrate competence in a variety of ways • Students' written and oral language proficiency is assessed while they are using oral and written language in purposeful ways	• Assessment occurs at the end of the lesson • Assessment is not embedded throughout instruction • Assessment is regarded as a set of evaluation "tools" that are used to determine what students have learned (e.g., exit slips, quizzes, etc. that are administered after instruction has occurred versus examining students' cognitive processing during instruction) • Teacher does not evaluate student understanding while engaged in challenging work in order to determine a student's potential • Most or all tests are written and require reading/writing proficiency in English • Teacher expects students to tell "the" answer • Students have a narrow range of options for demonstrating competence (e.g., multiple choice tests, matching, etc.) • Assessments measure discrete, isolated skills and/or use short, disconnected passages • Students' linguistic competence is evaluated solely through standardized measures				
2. Teacher uses formative assessment data throughout instruction to promote student learning	Generally Effective Practices: • Teacher modifies instruction or reteaches when it's clear that students are not meeting learning targets • The goal is student learning, and formative assessment data is used throughout the lesson to adjust instruction in order to assure that every student learns	• Teacher follows the lesson script even when it's clear that students are not meeting learning targets • The goal is to get through the lesson and cover the content versus assuring student understanding				

3. **Students have opportunities for self-assessment**	Generally Effective Practices: • Students are encouraged to evaluate their own work based upon a determined set of criteria • Students are involved in setting their own goals for learning Practices that are Culturally Responsive: • Students are involved in developing the criteria for their finished products (e.g., scoring rubrics)	• Assessment is always teacher-controlled				

IV. CURR CURRICULUM/ PLANNED LEARNING EXPERIENCES **Holistic score** 4 3 2 1

To a great extent Often Occasionally Not at all

CRI Indicator	For example, in a responsive classroom:	For example, in a non-responsive classroom:	Field notes: Line(s) of example	Field notes: Line(s) of non-example	Field notes: No example (✓)	SCORE for Indicator
1. The curriculum and planned learning experiences use the knowledge and experience of students	Generally Effective Practices: • Materials and real-world examples are used that help students make connections to their lives • Learning experiences build on prior student learning and invite students to make connections Practices that are Culturally Responsive: • Materials and examples are used that reflect diverse experiences and views • Families' "funds of knowledge" are integrated in learning experiences when possible	• No attempt is made to link students' realities to what is being studied; learning experiences are disconnected from students' knowledge and experiences • Skills and content are presented in isolation (never in application to authentic contexts) • Families' particular "funds of knowledge" are never called upon during learning experiences • Teacher follows the script of the adopted curriculum even when it conflicts with her own or the students' lived experiences • Learning experiences are derived almost exclusively from published textbooks and other materials that do not relate to the classroom community or the larger community being served				
2. The curriculum and planned learning experiences integrate and provide opportunities for the expression of diverse perspectives	Generally Effective Practices: • Students are encouraged to challenge the ideas in a text and to think at high levels Practices that are Culturally Responsive: • Texts include protagonists from diverse backgrounds and present ideas from multiple perspectives • Opportunities are plentiful for students to present diverse perspectives through class discussions and other activities	• The conventional, dominant point of view is presented and remains unchallenged • Few texts are available to represent diverse protagonists or multiple perspectives • Biased units of study that show only the conventional point of view (e.g., Columbus discovered America) are presented • No or very few texts are available with protagonists from diverse cultural, linguistic, and/or socioeconomic backgrounds • No opportunities are provided for students to present diverse views				

V. INSTR PEDAGOGY/ INSTRUCTIONAL PRACTICES

Holistic score	4	3	2	1
	To a great extent	Often	Occasionally	Not at all

CRI Indicator	For example, in a responsive classroom:	For example, in a non-responsive classroom:	Field notes: Line(s) of example	Field notes: Line(s) of non-example	Field notes: No example (✓)	SCORE for Indicator
1. Instruction is contextualized in students' lives, experiences, and individual abilities	Generally Effective Practices: • Learning tasks and texts relate directly to students' lives outside of school • Learning activities are meaningful to students and promote a high level of student engagement Practices that are Culturally Responsive: • Teacher builds on existing cultural knowledge and "cultural data sets" • Instruction is culturally congruent with students' culture and experiences	• Learning tasks and texts reflect the values and experiences of dominant ethnic and cultural groups • Learning activities are decontextualized from students' lives and experiences				
2. Students engage in active, hands-on, meaningful learning tasks	• Learning tasks allow students to practice and apply concepts using hands-on activities and manipulatives • Learning activities promote a high level of student engagement • Exploratory learning is encouraged	• Students work passively at their seats on teacher-directed tasks • Passive student learning is the norm (e.g., listening to direct instruction and taking notes, reading the textbook, seatwork, worksheets, etc.) • Exploratory learning is discouraged				
3. The teacher focuses on developing students' academic vocabularies	• There is an emphasis on learning academic vocabulary in the particular content area • Students are taught independent strategies for learning new vocabulary • Specific academic vocabulary is introduced prior to a study or investigation • The teacher provides many opportunities for students to use academic language in meaningful contexts	• Little attention is paid to learning academic vocabulary in the content area • New words are taught outside of meaningful contexts • Students are not taught independent word learning strategies				
4. The teacher uses instructional techniques that scaffold student learning	• Teacher uses a variety of teaching strategies to assist students in learning content (e.g., demonstrations, visuals, graphic organizers, modeling, etc.) • Teacher models, explains and demonstrates skills and concepts and provides appropriate scaffolding • Students apply skills and new concepts in the context of meaningful and personally relevant learning activities	• Teacher primarily uses traditional methods for teaching content (e.g., lecture, reading from a textbook) with few scaffolding strategies • Teacher does not always model, explain and demonstrate new skills and concepts prior to asking students to apply them • Students practice skills and reinforce new concepts in ways that are not meaningful or personally relevant to them				

5. **Students are engaged in inquiry and the teacher learns with students**	• The teacher engages students in the inquiry process and learns from students' investigations (e.g., project-based learning) • Students are encouraged to pose questions and find answers to their questions using a variety of resources • Student-generated questions form the basis for further study and investigation	• The teacher is the authority • Students are not encouraged to challenge or question ideas or to engage in further inquiry • Students are not encouraged to pose their own questions • All knowledge/ideas are generated by those in authority (e.g., textbook writers, teachers)				
6. **Students have choices based upon their experiences, interests and strengths**	• Students have multiple opportunities to choose texts, writing topics, and modes of expression based on preferences and personal relevance • Students have some choice in assignments • Students have some choice and ownership in what they are learning	• The teacher selects texts, writing topics, and modes of expression for students • All assignments are teacher-initiated • Students have no choice or ownership in topic of study or questions that will be addressed				

VI. DIS DISCOURSE/ INSTRUCTIONAL CONVERSATION

Holistic score 4 (To a great extent) 3 (Often) 2 (Occasionally) 1 (Not at all)

CRI Indicator	For example, in a responsive classroom:	For example, in a non-responsive classroom:	Field notes: Line(s) of example	Field notes: Line(s) of non-example	Field notes: No example (✔)	SCORE for Indicator
1. The teacher promotes active student engagement through discourse practices	• The teacher employs a variety of discourse protocols to promote student participation and engagement (e.g., call and response, talking circles, read-around, musical shares, etc.) • All students have the opportunity to participate in classroom discourse • The teacher uses various strategies throughout the lesson to promote student engagement through talk (e.g., partner share, small group conversation, interactive journals, etc.)	• The main form of classroom discourse is Initiate-Respond-Evaluate (IRE) where the teacher poses a question and individual students respond • The teacher controls classroom discourse by assigning speaking rights to students • Not all students have the opportunity to participate in classroom discussions • Some students are allowed to dominate discussions				
2. The teacher promotes equitable and culturally congruent discourse practices	Generally Effective Practices: • Students use collaborative, overlapping conversation and participate actively, supporting the speaker during the creation of story talk or discussion and commenting upon the ideas of others • The teacher uses techniques to support equitable participation, such as wait time, feedback, turn-taking, and scaffolding of ideas Practices that are Culturally Responsive: • Students speak in their home discourse when it is situationally appropriate to do so; there is an emphasis on developing proficiency in students' native language as well as in Standard English • Students are supported in their use of culturally-specific ways of communicating, such as topic-associative discourse, topic-chaining discourse, and overlapping discourse patterns • Classroom interaction patterns and communication structures match those found in students' homes and communities	• Discourse practices of various cultural groups are not used during instruction • Students are discouraged from using their home language or dialect • ELL students are discouraged from using their native language, both inside and outside of school • The teacher views topic-associative discourse, topic-chaining discourse, and overlapping discourse patterns as rambling talk • The teacher attempts to control and change student communication styles to match mainstream classroom discourse patterns				

3. The teacher provides structures that promote academic conversation	• Students engage in genuine discussions and have extended conversations • Students are engaged in authentic uses of language; structures are used that promote student talk • The teacher provides prompts that elicit extended conversations and dialogue • The teacher explicitly teaches and evaluates skills required for conducting effective academic conversations	• Students are discouraged from talking together, or conversations are limited to short responses • The teacher rarely asks questions or provides prompts that would elicit extended dialogue • The teacher does not teach skills required for academic conversations				
4. The teacher provides opportunities for students to develop linguistic competence	• The teacher develops language objectives in addition to content objectives, having specific goals in mind for students' linguistic performance • The teacher articulates expectations for language use (e.g "I want you to use these vocabulary words in your discussion; I expect you to reply in a complete sentence" etc.) • The teacher scaffolds students' language development as needed (sentence frames, sentence starters, etc.) • Students are engaged in frequent and authentic uses of language and content (drama, role play, discussion, purposeful writing and communication using ideas/concepts/vocabulary from the field of study) • Students are taught appropriate registers of language use for a variety of social contexts and are given opportunities to practice those registers in authentic ways	• The teacher does not articulate expectations for language use • The teacher does not establish language objectives for students; only content objectives are evident • Students' use of language is limited and they do not use language in authentic ways • The teacher does not scaffold students' language development • Students are not taught about the registers of language use; they are expected to use Standard English in all social contexts				

VII. SOCIO SOCIOPOLITICAL CONSCIOUSNESS

Holistic score	4	3	2	1
	To a great extent	Often	Occasionally	Not at all

CRI Indicator	For example, in a responsive classroom:	For example, in a non-responsive classroom:	Field notes: Line(s) of example	Field notes: Line(s) of non-example	Field notes: No example (✔)	SCORE for Indicator
1. The curriculum and planned learning experiences provide opportunities for the inclusion of issues important to the classroom, school and community	Generally Effective Practices: • Students are engaged in experiences that develop awareness and provide opportunities to contribute, inform, persuade and have a voice in the classroom, school and beyond • Community-based issues and projects are included in the planned program and new skills and concepts are linked to real-world problems and events Practices that are Culturally Responsive: • Students explore important social issues (poverty, racism, etc.) • Teacher encourages students to investigate real-world issues related to a topic being studied and to become actively involved in solving problems at the local, state, national, and global levels	• The focus of literacy and content instruction is to teach the skills and information required to "pass the test"; learning occurs only as it relates to the standard curriculum • Teacher does not encourage critical thought or questioning of social issues • Teacher does not encourage application to real-world issues; accepts or endorses the status quo by ignoring or dismissing real life problems related to the topic being studied				
2. The curriculum and planned learning experiences incorporate opportunities to confront negative stereotypes and biases	Practices that are Culturally Responsive: • Teacher facilitates students' understanding of stereotypes • Teacher encourages students to examine biases in popular culture that students encounter in their daily lives (TV shows, advertising, popular songs, etc.) • Teacher helps students to think about biases in texts (e.g., "Who has the power in this book? Whose perspectives are represented, and whose are missing? Who benefits from the beliefs and practices represented in this text?" etc.) • Teacher challenges students to deconstruct their own cultural assumptions and biases	• Teacher does not encourage students to examine biases in instructional materials or popular texts; texts are considered to be "neutral" • Teacher makes prejudicial statements to students (e.g., girls are emotional; immigrants don't belong here; etc.), and/or fails to challenge prejudicial statements of students				

APPENDIX F
RTOP INSTRUMENT

Reformed Teaching Observation Protocol (RTOP)

Daiyo Sawada — External Evaluator
Michael Piburn — Internal Evaluator

and

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

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

I. BACKGROUND INFORMATION

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

Location of class ____ (district, school, room)

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

Subject observed ____________________ Grade level ____________________

Observer ____________________ Date of observation ____________________

Start time ____________________ End time ____________________

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

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

Record here events that may help in documenting the ratings.

Time	Description of Events

III. LESSON DESIGN AND IMPLEMENTATION

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

IV. CONTENT

Propositional knowledge

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

Procedural Knowledge

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

Continue recording salient events here.

Time	Description of Events

V. CLASSROOM CULTURE

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

Student/Teacher Relationships

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

Additional comments you may wish to make about this lesson.

APPENDIX G

SAMPLE QUESTIONS FROM THE SEMI-STRUCTURED FOCUS GROUP INTERVIEWS

Focus Group Interview #1: October 12, 2013

- Tell me about how you've grown professionally since you began teaching?
- What has influenced your growth as a teacher?
- Imagine I were a fly on the wall in one of your classes. Describe what you think I would see in terms of teaching and student learning.
- What has the process of becoming a culturally responsive teacher been like?
    - In what ways do you see yourself as a culturally responsive teacher?
- How has STARTS supported your growth so far?
    - How can it better support your growth?
- How has your participation in the STARTS activities shaped the way you think about science teaching and your classroom practices?
- How has your participation in STARTS impacted the way you interact with your students?
- As you prepare to design your instructional materials, what activities do you feel will be most beneficial?

Focus Group Interview #2: November 16, 2013

- Tell me a little bit about the students in your focus group/focus class?
- What have you learned about them over time?
- What does a great biology teacher/ anatomy & physiology teacher look like to you?
- Have these characteristics changed over the course of STARTS?
- How do you know that you've been successful with your students?
    - How do you know you're doing a good job with your students?
- Tell me a little bit about your CRP Science unit plan at this point.
- As you begin designing lessons for your CRP Science unit, what has influenced your choice of activities/lesson content?
- Tell me about the process of designing these instructional materials:
    - What has been the easiest to include? The most challenging?
    - What are the lessons/activities you are the proudest of at this moment? Why?
- What STARTS-related tasks have you found most helpful as you design these materials?
- What additional support would you like as you finalize your lessons/ CRP Science Unit?

APPENDIX H
INITIAL CODE BOOK

Research Question 1

CRP Science conceptions

Aligning culturally responsive to classroom culture
Articulating different students' positive changes from CRP unit
Being culturally responsive is difficult
Being culturally responsive is rare
Being culturally responsive means creating hands-on lessons
Challenges to CRP
Challenging to find CRP topics within content areas
Challenging to implement CRP when on pace
Con of CRP activity in unit
Connecting CRP to group work and content vocabulary
Connecting CRP to student grouping
Connecting CRP to understanding content and showing relationships
Connecting CRP to using Prior Knowledge
Connecting CRP unit to related content
Cons of CRP
Contrasting CRP to t-directed instruction
Contrasting CRP to Teaching
CRP add-ons are instructional strategies
CRP as teaching practices that are differentiated
CRP changes means greater St. reliance to build a product
CRP counter to St. centered?
CRP instruction is interactive - hands-on labs activities
CRP instruction is new instruction
CRP instruction means making instruction relatable
CRP instruction means taking time
CRP instruction motivates Sts
CRP instruction required creating a new lesson
CRP instruction takes too much time
CRP integration depends on the science topic
CRP is an add on that is time consuming and frustrating
CRP is assessing st. understanding
CRP is attending to diversity
CRP is challenging work
CRP is collaborative work
CRP is constructing a product together
CRP is creating concept maps
CRP is eliciting prior knowledge
CRP is formative assessment
CRP is group work
CRP is hands-on
CRP is hands-on activities
CRP is providing multiple ways for sts to demonstrate proficiency
CRP is providing opportunities for participation
CRP is seeking prior knowledge
CRP is sharing ideas
CRP is time constraining
CRP teaching requires connecting sts to curricula
CRP Testimonial
CRP unit means changing strategies not lesson content
CRP unit Sts encouraging one another
Culturally responsive instruction includes many aspects
Describing st achievement with CRP
Doing CRP when not required to
Drawing line on CRP
Equating CRP to group work
Equating CRP with topics that science contextualized in

Equating cultural responsiveness to classroom culture
Equating cultural responsiveness to postsecondary prep
Equating culture to classroom culture
Equating my field notes content with desired CRP practices
Equating sociopolitical to family connection
Equating st centered to group work
Evaluating own lesson would allow seeing CRP in time
Fellows selecting which CRP skills R focuses on in observation
Identifying as already doing CRP
Identifying culturally responsive practices
Identifying other instruction that she has made CRP
Inquiry learning and CRP are insufficient for covering content
Instructional areas that CRP should translate to
Intending to continue CRP strategies
Looking at diversity is CRP
Modifying existing lessons for CRP - baby steps easing in
Modifying existing unit to fit CRP
Needing CRP
New teaching has a slower pace
no parent influence yet still culture?
Openness to learn about CRP
Perceiving herself as a culturally responsive teacher
Positioning CRP in contrast to lecture
Pros to CRP
Providing new learning experiences with CRP
Providing reward for engaging in CRP instruction
Rewarding to make CRP unit
Seeing a difference in sts through CRP
Seeing CRP as hands-on
Seeing CRP beyond ethnic lines
Seeing difference in students
St understanding through CRP strategy
Suggested practice leads to knowing sts better
Understanding HOW to facilitate CRP
Unit content was not an easy CRP fit
Using lesson study as time to try out CRP first

Awareness/ Beliefs

Acknowledging her scaffolding of self and Sts
Acknowledging importance of relevance in instruction
Admitting total change in conceptions
Affective dimension to seeing change happen in sts
Aware and motivated
Aware of students interests
Awareness
awareness and also stereotype threat
Awareness of available resources
Awareness of misconceptions
Awareness of setting and impact on sts
Awareness that prior position needed changing
Becoming aware of actions as a teacher
Becoming aware of how to purposefully consider background in classroom interactions
Becoming aware of students' perspectives over time
Becoming Color Conscious
Becoming confident
Being aware of perspectives students bring to cr
Belief - Great teachers are organized and prepared
Belief - Great teaching is caring
Belief - organization leads to great management
Belief- Great teaching is interactive
Belief- Great teaching is offering hands-on activities

Beliefs about salient questioning strategies
Believing good teaching is being dependable
Believing in her students
Believing sts like to know she is actively working to know more about them
Believing that knowledge must be imparted to students
Better teaching means better explaining
Better teaching means better focusing
Building Emotionally Safe Classroom Community
Building relationships with sts leads to change
Care is required for students to trust
Care is responsible for positive St-T rel'n
Changing color-blindness
Changing in awareness and care
Changing teaching practices requires awareness and dissatisfaction
Connecting awareness to other UF course readings
Considering sts as same is fair
Discerning students' struggles
Discerning that implementation produced learning
Forcing to think about students and not just content
Getting better means new activities teaching practices
Getting better means trying new things
Getting deeper understanding of WHY to make instructional strategies
Identifying a struggle in the classroom
Knowing sts better impacts them in a positive way
Learning about misconceptions
Learning about students classroom preferences
Learning about students' lives
Learning led to action in classroom
Looking at bigger picture through CTS
Making personal connections with reflection activity
Perceives that grouping and attitude are related
Perceives that grouping promotes better work
Perceiving family education as low
Perceiving that relevance led to better scores
Perceiving the classroom as not natural
Realizing after the fact
Realizing core teaching technique through course reading
Recognizing a need in students
Recognizing it's about connections
Recognizing that power differential must be maintained
Recognizing that several practices are already culturally responsive
Seeing old way of questioning as invasive
Seeing student relevance as off-topic
T belief - care and respect
T care produces positive St experiences in classroom
T caring produces st learning
T feeling empowered must occur before sts have choice
T knows more what's best for sts
Tension between what's perceived as needed and what she likes

Connecting instruction with students' lives.

Acknowledging but not building on students' sharing
Addressing sociopolitical is difficult and uncomfortable
Aware of students' interests
Confidence in Connecting to Sts Lives
Connecting lesson to cater to students
Connecting to Sts Lives
Connecting to students' prior knowledge
CRP teaching requires connecting sts to curricula

Deliberately selecting topic based on st backgrounds
Delivering surveys to learn about interests
Desiring students make connections between science & real world
Encouraging more student-based learning
Equating sociopolitical to family connection
Having goal in mind when learning about sts lives
Hoping that ethnic ties yield greater engagement
Integrating Content w Sts interests is Beneficial
Integrating St interest w Content produces St excitement about learning
Integrating w Sts is sometimes difficult given topic
Intending to connect instructional topic to sts
Knowing sts better impacts them in a positive way
Knowing students backgrounds
Knowing students needs
Learning about sts is time consuming
Learning about students classroom preferences
Learning about students makes a better teacher
Learning about students' lives
Making instruction rigorous to content takes tweaking and input from students
Making personal connections with reflection activity
Not connecting learning to sts lives o/s school
Not desiring to know more about her students
Not employing sociopolitical consciousness
Not knowing about sts leads to disconnection from their needs
Not knowing about students leads to disconnected lessons
Not trying to make content personal - past
Perceiving sts lives as making it difficult to raise sociopolitical issues
Personal connection yields positive st outcomes
Providing real-world examples to students
Recognizing a need in students
Recognizing it's about connections
Seeing family connections through science topics
Seeing sociopolitical as controversial topics
Seeing sts interests as topics to be covered
Shifting from T Centered to St Centered
Shifting from T-centered to St centered
NOT STARTS
Still desiring to learn how to connect their lives to science
Talking about pulling content and student elements into instruction
Uncertain with connecting diverse experiences in science
Uncertain with connecting science to students' lives
Using sociop as a platform to help others appreciate what they've got
Vehicle for connecting across lessons

Student grouping.

Articulating goals for group work
Assigning roles in groups
Breaking group work into chunks
Connecting CRP to student grouping
Contrasting student arrangements
CRP is collaborative work
Changing group interaction
Connecting CRP to group work and content vocabulary
CRP is group work
Equating CRP to group work

Equating new group work with student creation
Equating old group work to lab activities
Great teaching is active - group workstation labs
Group actions not expected
Group grading-accountability
Group work forces sts to be responsible for learning
Group work wasn't always beneficial
Increasing group work hands-on
Perceives that grouping and attitude are related
Perceives that grouping promotes better work
Physical arrangement limits st groupings
Reading content inappropriate for group
Seeing group organization as challenge in classroom setup
Seeing strengths and needs in focus group students
Shifting group work activities
St grouping goes in the beginning of the semester - most valuable
Sts encouraging one another
Sts enjoy group time
Sts requiring group work

Changing instruction.

Acknowledging her scaffolding of self and Sts
Acknowledging importance of relevance in instruction
Adding new information to preexisting materials
Adjustments are necessary when trying something new
Admitting total change in conceptions
Aligning culturally responsive to classroom culture
Applying general learning to classroom practice
Applying instructional strategy from course reading
Applying previously modeled strategy
Attempting sociopolitical
Being able to contrast T practices
Building on her previous successes
Building on product through entire unit
Changing group interaction
Changing in awareness and care
Changing instruction means moving learning activities around
Changing practice as a result of seeing benefit in class
Changing teaching practices requires awareness and dissatisfaction
Citing st data as evidence of change
Citing st data as evidence of change
Co-developed with ideas from Fellow
Connecting classroom practice to CTS learning
Connecting T practice to course reading
Connecting to students' prior knowledge
Consistent T encouragement led to decreased reliance
Constrained by N of 6
Continuing specific practices
Continuing to use resource beyond assignment
Contrasting CRP to Teaching
Contrasting new and traditional practices
Contrasting old and new practices
Crediting new lessons to increased st engagement and understanding
Describing her change as baby steps
Describing plans for modifying her instruction
Describing typical teaching practice
Designing instruction that is not monotonous
Developing new teaching strategies
Discerning that implementation produced learning
encouraging more student-based learning
Equating new group work with student creation

Equating old group work to lab activities
Expanding from state to national education standards
Explicitly showing sts that instruction strategy is from research
Feeling good about st success when implementing something new
Finding difficulty with new T because limited examples to share
Finding tension between ideal T view and resulting practice
Forcing a connection to practice led to implementation
Forcing to think about students and not just content
Fusing course reading into instruction
GAIn connections facilitated success with unit and Sts
Getting better means new activities teaching practices
Getting better means trying new things
Getting deeper understanding of WHY to make instructional strategies
Getting ideas for implementation from Fellow
Giving credit for idea to another Fellow
Great ideas fall short when no connections to practice can be made
Identifying new techniques
Identifying other instruction that she has made CRP
Identifying previous practices
Implement learned practices
Implement the practices i was learning
Implementing modeled strategies
Implementing new activities
Implementing new techniques requires creativity
Implementing new techniques takes time
Implementing practice based on facilitator feedback
Implementing T strategies from multiple sources
Increasing group work hand-son
Increasing hands-on
Increasing reflection about practice and impact on students
Increasing reform-based science teaching
Increasing self esteem
Increasing st communication
Increasing student action in classroom
Instruction does not get top bill if not pacing guide
Instructional areas that CRP should translate to
instructional strategies produce measurable st outcomes
Instructional strategy produces st engagement
Integrating Content w Sts interests is Beneficial
Integrating St interest w Content produces St excitement about learning
Integrating techniques is new goal
Integrating w Sts is sometimes difficult given topic
Intending to connect instructional topic to sts
Intending to continue CRP strategies
Introduced in STARTS modified by Fellow then accepted by another
Job-embedded and connected to practice
Job-embedded creates new meaning to activities
Lacking time for design
Learning did not lead to action in the classroom
Learning led to action in classroom
Learning new strategies is most valuable
Learning new strategies that will be implemented
Linking instructional strategy to gauging st awareness
Making instruction rigorous to content takes tweaking and input from students
Modifying existing lessons for CRP - baby steps easing in
Modifying existing unit to fit CRP

Modifying instructional strategy based on st needs
Modifying over time - it's natural to build from preexisting lessons
Normally the topic is fly by
Not just identifying issues but also devising solutions
Old way was easier - this is more difficult
Plans to extend current practices
Pride in sts decreasing reliance
Providing deeper understanding of what st collab looks like
Providing example questions toward end goal
Providing more group work
Providing more hands-on activities
Providing multiple ways for sts to demonstrate proficiency
Providing new learning experiences with CRP
Providing real-world examples to students
Reading connected to classroom practice
Realizing core teaching technique through course reading
Reflecting on strategy use in the classroom produced changes in practice
Reformed T as a result of STARTS
Relating new learning suggestion to what's worked in the past for her
Requiring learning to be applied to practice
Saying sts love activities
Seeing a difference in sts
Seeing a difference in sts through CRP
Seeing a difference in sts when providing high expectations
Still one correct answer though
Still wanting to cover content but not in a t-directed way
Sts and T growing together
Successful collaboration leads to T having deeper roles with sts
T learning a new technique and seeing it in action
T must teach the district's way
Teacher designing lessons with relevance
Teaching in new ways
Teaching is telling
Teaching is Telling is learning
Teaching topic in old way was lecturing
Thinking outside the box
Though same unit different foci
Timing with pacing
Trying a new lesson
Trying new activities
Trying out new activity with unit
Trying to decrease T-centered
Unsure why grouping causes excitement
Using an instructional strategy to overcome difficult area
Using course readings - resources - to analyze integration
Using encouragement to facilitate success with new strategy
Using evidence to make a claim
Using funds of knowledge to achieve success
Using st reflection alongside new instructional strategy
Using st reflection as way to involve them in adopting new strategies

Family connections.

Articulating comfortable ways to establish family connections
Assuming family will not want relationship
Connecting gut to family visits
Deficit perspective of family?
Desiring connection with family with parameters
Desiring to work with parents to FIX them

Discomfort with visiting families
District discourages connection to family
Do family article in summer or connect it to classroom practice
Equating sociopolitical to family connection
Family can feel uncomfortable but not me
Family connections are for science topics
Family connections beyond visits
Family Connections is impossible with 155 sts
Family knowledge as a weapon
Family meetings should happen on school turf
Family reading should come first
Fear of safety visiting families
Fearing negative consequences of family visits
Feeling comfortable meeting family in safer academic spaces
Involving family in at-home activities
Learning about students' lives
Not reaching out to family
Open to connecting with family
Perceiving family education as low
Principal urging teacher not to visit family
Seeing family connections through science topics
Seeing family expertise as topics incongruent to science
Seeing family from deficit lens
Students excited when T meets family
Teacher teaching teachers
Visiting families feels illegal
Visiting family is uncomfortable
Visiting family is weird
Visiting family when student is bad
Viewing family resources as content on which to build science

Research Question 2

Collective participation.

Collab sessions forces focus
Collab Sessions structured for brainstorming and work
Collective Participation
Collective participation bouncing ideas is valuable
Collective participation impacts practice in REAL TIME
Collective Participation occurs in many spaces
Collective participation solves problems
Desiring more feedback on teaching practices
Fellows influence on activities
Fellows selecting which CRP skills R focuses on in obsv
Fellows' suggestion - Reference time
Incomplete monitoring of student roles
Lesson Study must be designed during Collaboration Time
Outcome of collaboration
Partner should not be involved in the planning and mock teaching
Partnership can be negative
Quality PD
Role Playing - Treating like St when different content area
Role playing better when partner has not been involved in planning
Saturday Collaboration Sessions
Suggesting same school
Superficial feedback about practice
Teacher mock monitoring
Viewing each others' practices
Working with peers is best for learning new ideas and practices

STARTS by activity.

Actual example prompts critical reflection on practice
Applying course reading to CRP practice
Applying instructional strategy from course reading
Catching on to purpose of Saturday Sessions
Collab session CTS prompts T to action
Collab session forces focus
Collab sessions promote professional conversations and brainstorming
Sessions structured for brainstorming and work
Collaboration eases overwhelming feelings
Collaboration is easy
Connecting classroom practice to CTS learning
Connecting course content to suggestion
Connecting course reading to needing relevance in classroom
Connecting GAIn findings to unit instruction
Connecting schooling to course reading
Connecting strategy to course reading
Connecting T practice to course reading
Course reading
course reading provides example
Course reading missing explicit and needed links
Course readings were most frequently adopted
CTS connection
CTS experience and T talks about teaching bigger picture
CTS influenced to want to teach inductively
CTS is a one stop shop
CTS is hard
CTS led T to desire to identify misconceptions and address in instruction
CTS puts resources in one place
Describing PD influence
Exploring ways to integrate reading with practice
Forced to engage in a task that was rewarding as it unfolds
Forcing a connection to practice led to implementation
Forcing to analyze teaching practice
Forcing to think about students and not just content
GAIn
GAIn 2 was intense
GAIn connection
GAIn connections facilitated success with unit and Sts
GAIn connections through language and vocabulary
Wanting to break GAIn 1 and Lesson study
Identifying limited benefit from CTS
Implementing modeled strategies
Introduced in STARTS modified by Fellow then accepted by another
Lengthy articles are negative
Lesson Study after GAIn 1 as good introduction to the whole program
Lesson Study must be designed during Collaboration Time
Lesson Study too early leads to uncomfortable teaching
Like the timing of CTS
Limited information
Mock T is better when not same topic
Not following facilitation guide decreased the effectiveness of the PD activity
Role playing - difficulty positioning T as St
Role Playing - Treating like St when different content area better
Role playing better when partner has not been involved in planning
Want RWP before lesson study in redesign

Seeing value in CTS but not finding it personally
Need time to get to know sts
Setting parameters with GAIn 2
Small gains from CTS
St grouping chapter is TOO Long
St grouping goes in the beginning of the semester - most valuable
Structure increases efficiency
The GAIn really connected once I did the CRP science unit
Time to reflect on practice
Too big of an activity for the first time out
Using course resources to analyze integration
Using PD time to brainstorm new lesson ideas

Job-embedded.

Activity-based PD provided thoughts for new lessons
Actual example prompts critical reflection on practice
Applied PD task to grad class
Applying course reading to CRP practice
Applying instructional strategy from course reading
Believing PD activity met its goals
Contrasting previous PD experiences to STARTS
Feeling that the PD is designed to have purpose for THEM
Finding tension between ideal T view and resulting practice
Finding that the PD activity constrained opportunities for CRP connections
Finding value in being forced
Finding value in PD task
Finding value in the task for linking to classroom
Introduced in STARTS modified by Fellow then accepted by another
Job-Embedded
Job-embedded - STARTS makes connections between T learning and classroom practice
Job-embedded and connected to practice
Job-Embedded creates new meaning to activities
Job-embedded makes explicit connections and deepens understanding for WHY teaching
Job-embedded makes it connected
Learning did not lead to action in the classroom
Needing different support than novice teacher
PD activity led to aha
PD activity led to developing a new practice
PD activity pushes teachers
PD led to better focus on sts needs
PD task enables issue addressing
PD task forced cohesive unit design
PD tasks move from realization to reflection to implementation
PD tasks reveal information about T practices
Planning to continue using strategies - practical
Prior knowledge came from PD tasks
Quality PD
Reading time was too late after construction of unit
Realizing core teaching technique through course reading
Referring to former professional developer as source of related activity
Reflecting on strategy use in the classroom produced changes in practice
Reflection led to feeling more comfortable
Reflection should extend beyond own experience
Reflection yields insight into improvement
Reformed T as a result of STARTS

Relying on Fellows
Relying on Fellows and R
Relying on us during REAL TIME
Seeing change in students is a measure of PD effectiveness
Seeing purpose in STARTS assignments
Sharing tool kit with other teachers
Tacit to explicit leads to purposeful changes in instruction
Teacher mock monitoring
The GAIn wasn't connected until the CRP science unit
Using recording to reflect on practice
Wanting a BANK of items to draw from
Wanting direct connection to classroom
Wanting labs examples to take and use
Wanting lessons and strategies to take back to the classroom
Wanting to compare her practice at different times
Wanting to connect ENTIRE curriculum to CRP practices to decrease chance of fallout
Wanting to connect PD to student outcomes
Wanting to know how to incorporate issues into classroom

Observing/modeling.

Believing PD activity met its goals
Beneficial to visit Fellows classrooms
Connecting course content to suggestion
Decreased value on BOTH sides - modeler and observer
Desiring to see T-st interaction to learn practices
Desiring to watch Fellows across subject areas
Desiring to watch same subject teacher in action
Encouraging new teacher
Encouraging one another
Encouraging participation
Equating my field notes content with desired CRP practices
Evaluated by group did not impact preparation
Evaluated by group is motivating
Feeling more accountable to group
Feeling motivated from another Fellow
Getting ideas for implementation from Fellow
Getting two perspectives
Giving credit for idea to another Fellow
Good timing with the observations
Identifying sticky points in lesson
Increasing accountability when evaluated by group
Increasing authenticity
Learning by modeling
Learning through modeling
Modeling
Modeling arrangement
Modeling arrangement increases authenticity
Modeling can take place in person or online
Noticing interactions when watching video recording
Observing T in action
Viewing each others' practices

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BIOGRAPHICAL SKETCH

Julie C. Brown received a Bachelor of Science Degree in Animal & Veterinary Sciences from the University of Rhode Island in 2003 and a Master of Education Degree in Science Education from the University of Florida in 2006. Dr. Brown has taught high school biology, physics, and integrated science; undergraduate and graduate courses in science and mathematics education; and coordinated the elementary science program at the P.K. Yonge Developmental Research School in Gainesville, FL. She entered the science education Ph.D. program at the University of Florida in 2010.

Dr. Brown's research focuses on the design, development, and evaluation of learning environments that prepare culturally responsive science and mathematics teachers. She has made numerous presentations at international science education conferences and has publications in the *Journal of Science Teacher Education, Research in Science Education, The American Biology Teacher*, and *Science Scope*. In the fall of 2014, Dr. Brown will join the faculty of the University of Minnesota, Twin Cities as an Assistant Professor of STEM Education.