CONTEXTUALIZING PROFESSIONAL DEVELOPMENT FOR ENHANCING HIGH SCHOOL BIOLOGY TEACHER PROFICIENCY IN STANDARDS-BASED INSTRUCTION

by

MARION MCCOY REEVES

(Under the Direction of Thomas R. Koballa, Jr and Janette R. Hill)

ABSTRACT

Mandated changes in practice often leave experienced teachers in need of professional development. During the ten years prior to this study science teachers had been involved in implementing new state standards based on national standard models that called for an inquiry approach to instruction. Within the same time frame, accountability testing, including end of course tests administered by the state was also implemented, including Biology classes. The resulting scores served as a part of students' course grades. Testing accountability has been shown to be a factor in preventing full implementation of standards-based instruction. Professional development models provided to date have not fully developed teacher fluency in standards-based teaching. The participants in this study were experienced Biology teachers in a large, diverse urban school system. Prior to the professional development, participants described their practice as teacher centered, focusing on test success for students. They then engaged in a model of professional development that used reflective practice within the participants' school settings. Over the course of this study participants maintained lesson logs, taught standards-based lessons followed by lesson reviews with the professional developer, and reflected on the sequencing of Biology instruction. Case studies of these participants described individual changes in thinking and practice. Cross-case analysis examined the professional development model as a means of facilitating standards-based inquiry instructional thinking and practice on the part of experienced teachers. The findings of the analysis indicated that participants became less focused on content, and more aware of teaching all aspects of science. Participants were more aware of their own practices, and made personal decisions regarding changes in practice that would align more closely with standards-based instruction.

INDEX WORDS: professional development, inquiry, science teaching, science standards

CONTEXTUALIZING PROFESSIONAL DEVELOPMENT FOR ENHANCING HIGH SCHOOL BIOLOGY TEACHER PROFICIENCY IN STANDARDS-BASED INSTRUCTION

by

MARION MCCOY REEVES

B. A., Pfeiffer University, 1969

M. A. T., University of North Carolina, Chapel Hill, 1972

Ed. S., Georgia State University, 1994

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2011

CONTEXTUALIZING PROFESSIONAL DEVELOPMENT FOR ENHANCING HIGH SCHOOL BIOLOGY TEACHER PROFICIENCY IN STANDARDS-BASED INSTRUCTION

by

MARION MCCOY REEVES

Major Professor: Thomas R. Koballa Jr.
Janette R. Hill

Committee: Michael Dias
J. Steve Oliver
Norman Thomson

Electronic Version Approved:

Maureen Grasso

Dean of the Graduate School

The University of Georgia

December 2011

DEDICATION

With gratitude to George Reeves, who read every word in each draft, corrected the grammar and made sure that explanations made sense to the reader.

ACKNOWLEDGEMENTS

I would like to thank Melissa Freeman, Janette Hill, Kathleen deMarrais, and Judith Preissle who opened my eyes to the opportunities to learn from qualitative research, and then provided me the skills to go about doing it. I also thank the Science Education faculty at the University of Georgia who helped me merge my lifelong experience in the practice of science education with a theoretical understanding of the field.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Introduction and Context

…the data show that the demand for new teachers, and subsequent staffing difficulties, is not primarily due to student enrollment increases, nor to teacher retirement increases, but to pre-retirement teacher turnover. That is, most of the hiring of new teachers is simply to fill spots vacated by teachers who just departed. And, most of those departing are not doing so because of gray hair. (Ingersoll, 2003, p. 11)

Forecasts of what work will be like in the 21st century calls for a re-examination of prior held conceptions regarding teaching as a lifetime career. An individual will no longer spend a career in one organization. "The career of the 21st century will be protean, a career that is driven by the person, not the organization, and that will be reinvented by the person from time to time, as the person and the environment change" (Hall, 1996, p.8). Peske, Liu, Johnson, Kauffman & Kardos (2001) found in their study of fifty first and second year teachers that this forecast was true within the teaching profession. "While there were respondents who planned to make teaching a life-long career, they were surprisingly few in number" (p. 305). Data shows that 46% of teachers leave the profession within five years of entering it (Ingersoll, 2003; Stinebrickner, 2001). The percentage of experienced teachers remaining in the profession is becoming less and less. Between the 1999-2000 and the 2007-08 school years the percentage of secondary teachers with less than ten years experience increased by seven percent and those with more than twenty decreased by almost ten percent (National Center for Educational Statistics, 2011). It appears that the teaching profession is undergoing the same career trends that are being forecast for the 21st century work force in general.

Part of the reason for multiple career paths is the expectation that the rate of change within organizations will be accelerated.

> As technologies change, as organizations attempt to become more competitive, as information technology makes new organizational forms possible, and as social values shift priorities, it is becoming more and more difficult to discern what a given job should consist of…(Schein, 1996, p. 87)

It will be necessary for employees to be able to keep up with the changes if they are to remain productive employees. When the professional no longer can fulfill the requirements of a particular career, forecasters expect them to have multiple careers in the future as individuals look for careers that match their interest and skills. Peske and colleagues (2001) argued that "teaching appears to be one of the few lines of work that has maintained a static conception of career (p. 305)". Perhaps this is because in the business world when the responsibilities for a job are altered, it is viewed as a different job and assigned a new title. Expectations of performance for teachers and the environment in which they perform their work are changing. Unlike other fields however, instead of renaming the job, it retains the same title of teacher.

Broussseau et al. (1996)) described four types of career concepts: linear, expert, spiral, and transitory. Each concept is defined by the direction of movement, duration of stay and key motives. In this model the traditional teaching career has been an expert one with little movement, a lifelong stay, and the motivators of expertise and security. In the 21st century new professionals entering teaching appear to have more of a transitory concept with movement in a lateral direction, a three to five year stay, and a desire on the part of the individual for variety and independence. The degree of bureaucratization of education reinforces the expert career seeker since it provides stability and slow changes, providing the security the expert career seeker prefers. However this is contrary to the transitory career seekers because it tends to limit their need for independence and variety. In their study, Peske et al. (2001) found that the majority of beginning teachers had the mindset of teaching from a transitory point of view rather than expert. The teaching profession is becoming a blend of teachers from both mindsets regarding their career paths.

As has been true in the past, employers will set the performance expectations for workers during the 21st century. It will be the responsibility of the individual to determine how to develop the skills needed to make themselves relevant and productive from the employers perspective (Brousseau et al., 1996; Hall, 1996;Schein, 1996). Darling-Hammond & McLaughlin (1997) emphasize the role of school reformers in setting the vision for how schools will function and the need for teachers to respond to those expectations. “The vision of practice that underlies the nation’s reform agenda requires most teachers to rethink their own practice, to construct new classroom roles and expectations about student outcomes, and to teach in ways they have never taught before…(p. 597)”. This early description of the national reform agenda has continued to hold true into the 21st century, with even greater control of expectations from those outside the teaching profession.

One of the biggest changes foreseen for 21st century careers is the demise of the idea that employers will be caretakers of individuals’ careers (Brousseau et al., 1996; Schein, 1996). The change in relationship between the employer and employee has implications for job retraining. The responsibility for being prepared to perform a job will rest on the employee (Brousseau et al. 1996; Hall, 1996; Schein, 1996). “Formal training and retraining programs will be less relevant to the continuous learning process, as they are not only expensive but too cumbersome, too time-consuming to produce…" (Hall, 1996, 10). This trend is becoming evident in education with the increased decentralization of teacher professional development. Professional development within education is becoming more individualized and tailored to the context in which teachers work. Individual responsibility for managing learning career skills is becoming the norm. "Since the new career will be increasingly a continuous learning process, the person must learn how to develop self-knowledge and adaptability (Hall, 1996, p. 11)". Teachers will need to develop an awareness of needed understandings and skills, and access the professional development that fits their need.

Lynn (2002) has proposed that the model of teacher career can no longer be seen as the linear series described by Burke, Fessler & Christensen (1984). The linear series consists of eight parts: pre-service, induction, competency building, enthusiasm and growth, career frustration, career stability, career wind-down and career exit. Lynn argues that teaching careers go through cycles of changes as they "move in and out of career stages in response to personal and organizational environmental conditions" (p. 182). The manner in which teachers manage the changes in conditions will determine how many cycles of growth can happen before the teacher reaches the point of career wind-down and exit. This can be accelerated if at the stage of career frustration the teacher is unable to develop the new understandings and skills needed for the enthusiasm and growth portion of the career cycle to reemerge.

Several variables can determine whether the teacher leaves the profession or as Ingersoll (2001) has discussed migrates to different teaching situations. Three major variables determine the teacher turnover in Ingersoll's analysis. The characteristics of the teacher, the characteristics of the school, and the organizational conditions all interact with each other. If teachers cannot figure out how to negotiate these three variables, then they will either migrate to another setting, or leave the profession. Either way, it will affect the local school. Creating professional development opportunities that help teachers develop personal understandings and skills for managing these variables will not only reinvigorate their career, but also have a positive effect on the stability and growth of the local school.

Career longevity as a teacher thus depends on the ability of the individual to repeatedly re-enter the cycle when conditions change and rebuild the competencies needed for success. When this no longer happens the cycle will move forward toward a career exit. Hall (1996) describes a career path that is no longer measured in a lifelong manner, but rather in the length of time that particular career has been pursued. “The career of the 21st century is not measured by chronological age and life stages, but by continuous learning and identity changes” (p. 9). These cycles consist of four parts: exploration, trial, establishment and mastery. In terms of the teaching career, this would mean that an individual would need to reenter the trial stage when the mastery of understandings and skills was no longer sufficient if teaching is to remain the career path.

Professional development will continue to be an integral part of the field of education. Because of the diverse approach teachers take to their careers, it is clear that two features will be needed in solid professional development programs. First, the professional development will need to be more personalized than has been the traditional pattern. Loucks-Horsley, Stiles, Mundry, Love & Hewson (2010) describe the current state of professional development practice as being disconnected from our knowledge about the need to make learning personal. “..yet too much of…teacher professional development is still not interactive or reflective and remains disconnected from practice” (p.53). Teachers will need to be engaged with professional development that supports them as individuals and allows them to be reflective as they grow in their teaching practices. Second, whether the teacher is approaching the career with an expert or a transitory mindset, it will be important to emphasize their primary responsibility of helping students be successful learners. Focusing on the context in which they work allows teachers to consider the three variables Ingersoll (2003) identified as critical factors in determining career changes. It will be important for teachers to determine ways in which they can personally grow as professionals to better meet student learning needs within their school and also meet the organizational expectations for success.

This kind of professional development has the potential to increase the retention of transitory minded teachers, as well as increase the relevance of the expert minded teachers. Continuous re-examination of teaching practice within the context of work will possibly help the transitory teachers realize that although the title of teacher may remain the same, the changes in context, calling for new understandings and skills make the career an ever changing one. The expert teacher will have opportunities to re-examine their practice in light of the changed context. The support provided through the individualized professional development will facilitate the developing of new skills when needed.

In both cases, the important step will be the willingness of individuals to accept the responsibility for altering their own teaching practice to keep up with the changes. The rate of changes in the 21st century will call for this mindset on the part of teaching professionals. It also calls for a new mindset for those who plan and deliver professional development. Personalized and varied opportunities for professional growth within the work context provide the best means to support teachers wherever they find themselves in the career cycle.

Problem statement

Research has indicated that although science standards have been implemented for almost fifteen years, high school Biology teachers are not employing a standards-based form of instruction. The implementation of accountability testing has been shown to be a factor in the lack of full implementation of standards-based science instruction. Models used for professional development on standards-based instruction have not been sufficient or appropriate for developing standards-based instruction skills. High school Biology teachers continue to need to enhance their teaching skills if they are to provide standards-based instruction while also meeting testing accountability requirements.

Purpose and rationale

Research has shown that if teachers are provided with appropriate professional development, many are able to develop the skills and mindset necessary to implement standards-based instruction. Additional models of professional development are needed to meet the multiple learning needs of teaching professionals. The purpose of this study was to design and implement a model of professional development that embedded three principles proposed for effective professional development. The professional development was contextualized within the classrooms of the participants as they worked with their own students. Participants had repeated opportunities to practice standards-based instruction in a class modifying instruction between the sessions. Participants were offered multiple means of reflecting on their practice throughout the professional development.

Phase I was used to define the context within which the participants were working from their perspective. The research questions guiding Phase I of this study were:

1. Which set of expectations more strongly influence these Biology teachers' planning and instruction?

2. How much does the final test and system requirements for implementation influence classroom their practice?

3. How much of their understanding of standards–based (inquiry) teaching including characteristics and nature of science do they implement in the classroom?

Once Phase I was completed, a professional development model was designed and tailored to meet the context defined during the analysis of Phase I of the study. The following questions guided Phase II:

1. What changes occur in teacher thinking about standards-based instruction during the course of the professional development?

2. How do contextualizing reform expectations support teacher willingness to practice standards-based instruction?

3. In what ways are teacher practices altered through sequences of practice and reflection?

How does a professional development model employing cycles of practice and reflection within the classroom context support the enactment of standards-based instruction in high school Biology?

Multiple forms of data were collected in order to evaluate the effectiveness of the professional development model in meeting the purpose of supporting the development of standards-based instruction skills on the part of the high school Biology teachers who participated.

Overview of theoretical framework

Three areas of research were used to inform the development of this study. The standards movement began with the publications of *Benchmarks for Science Literacy* (1993) and the *National Science Education Standards* (1996). As these became widely accepted in the science education community, state standards were written that aligned with these national standards. By the early twenty-first century these state standards were found in many states including Georgia, where the research in the study took place. Although the standards described a form of teaching known as inquiry, many teachers, as well as researchers have found this difficult to define.

In approximately the same time frame, testing accountability was implemented and began to be enforced through legislative mandates. Teachers were expected to prepare students for mass testing at the end of courses. High school students taking Biology in the state of Georgia had to take an End of Course Test, which was included as part of their grade in the course. Gradually these test scores came to be used not only for student performance evaluation but for teacher, school and system accountability measures.

The first two areas: (1) standards-based instruction and (2) accountability testing would seem to be natural fits with each other. However research in the two areas indicates that the science standards in use at the time of the study required at student-centered, constructivist mode of instruction, while teachers under strong test accountability tended to resort to a teacher-centered, didactic form of instruction. Research on the best form of professional development to support teachers as they tried to implement standards-based instruction indicated that the traditional large group dissemination model was not effective at making the change in practice. Professional development that was contextualized within the teaching setting, offered opportunities for teachers to try implementation, with reflection following worked best at supporting teacher change in practice toward a more standards-based instructional model.

Overview of the methodological framework

This research consisted of two phases. During Phase I data was collected in order to define the setting in which the professional development model would be researched. The setting was defined through analysis of participants' response to an inquiry questionnaire, a semi-structured interview, and a sample lesson. The interview was coded following Charmaz's (2006) model of grounded theory. Examining the results of the questionnaire and the components of the sample lesson also helped form the definition of the setting within which the Biology teaching participants worked.

Phase II consisted of implementation of a personalized, reflective professional development model designed with the setting of the participants as part of the model. A variety of data generated from the model's activities were used to develop case studies of the four participants. This data included: a lesson log maintained for at least four weeks, two lesson observations followed by reflective lesson reviews, three reflective reviews of the lesson logs, an initial and final reflective semi-structured interviews, and lesson handouts for each lesson observed. Field notes were maintained and later expanded for each observation and reflective lesson log reviews. All interviews and lesson reviews were recorded and transcribed.

A cross case analysis of the professional development model was conducted using the written cases. The original data was revisited with new analysis of the professional development model. This cross case analysis led to an evaluation of the components of the professional development model and its overall success as a form of professional development.

Definition of terms

Several terms used routinely in the dissertation need definition. They have been grouped conceptually for better understanding.

Standards

AAAS Benchmarks – published in 1993 with an emphasis on the knowledge needed for scientific literacy.

National Science Education Standards – published in 1996 with an emphasis not only on the knowledge that should be taught in grades K-12 to achieve scientific literacy, but also emphasized appropriate pedagogical and program standards.

Georgia Performance Standards (GPS) – published in 2004 based on the two national standards above consisting of two sets of co-requisite standards to be taught simultaneously.

Characteristics of Science Standards – one set of co-requisite standards in the GPS consisting of habits of mind (process skills of science) and nature of science standards

Content Standards – one set of co-requisite standards in the GPS consisting of the content knowledge appropriate for inclusion in a given course.

Tests

End of Course Test (EOCT) a state of Georgia administered test in Biology and Physical Science at the high school level. The tests are graded at the state level and results are returned to schools to be used as 15% of the total in calculating final course grades. State Board of Education rules require that any student taking Biology or Physical Science at the high school level must take this test and have it included in the grade.

Georgia High School Graduation Test (GHSGT) a state of Georgia administered test, beginning in the junior year of high school. Four content areas are included: language arts, mathematics, science and social studies. A student must have passed each portion for a high school diploma to be awarded in the state of Georgia. The science portion consists of biological and physical science content.

Instruction

Inquiry a manner of teaching science that is student centered and focuses on allowing students to develop both content and process skills of science, in addition to an understanding of the nature of science.

Standards-based a manner of teaching that follows an inquiry model of instruction.

Strategies instructional activities selected and used by teachers such as: labs, worksheets, discussion, etc.

Summary and preview

Teaching science in a manner that applies the principles embedded in standards documents has proven to be a difficult task in the high school Biology classroom. Chapter two provides some research regarding the difficulty teachers have experienced implementing standards-based (inquiry) instruction and how testing accountability has influenced teacher practice. It also examines the research on effective professional development that supports teachers as they implement standards-based instruction. Chapter three describes the principles of design and analysis used in this two-phased approach to research. Phase I consisted in defining the teaching setting through the participants' viewpoints, as described in Chapter four. Phase II consisted of implementing a professional development model designed to fit the context and participants in the research. The experience of four participants is described using case studies in

Chapter five. Chapter six analyzes the effectiveness of the professional development model. Upcoming science standards will call for further changes in science teaching practices. The findings of this study can be used to inform practice in professional development in light of current changes in the science education field. Chapter seven relates the study to future changes anticipated in science standards and implementation.

CHAPTER 2

Biology Teachers as Reflective Practitioners

> *The crisis of confidence in the professions, and perhaps also the decline in professional self-image, seems to be rooted in a growing skepticism about professional effectiveness in the larger sense, a skeptical reassessment of the profession's actual contribution to society's well-being through the delivery of competent services based on special knowledge. Clearly, this skepticism is bound up with the question of professional self-interest, bureaucratization and subordination to the interests of business or government. But it also hinges centrally on the question of professional knowledge. Is professional knowledge adequate to fulfill the espoused purposes of the professions? Is it sufficient to meet the societal demands which the professions have helped to create? (Schön, 1983, p. 13)*

Coping with change in a profession requires the ability to be reflective both during the practice and outside the practice (Schön, 1983). In recent years the science teaching profession has undergone changes in expectations for performance from within its field, from the society, and from the government. Experienced teachers have found that the technical skills they developed as they prepared for the profession and the practical skills they have developed over time often are no longer sufficient for supporting student success.

Science teaching has been impacted within the last 15 years by two sets of professional expectations developed through collaboratives of scientists and educators. The publication of *Benchmarks for Science Literacy* in 1993 and *National Science Education Standards* in 1996 defined expectations for both science content and recommended pedagogy that would best support student learning. These reform documents focused expectation for student learning of content as well as characteristics and nature of science. The wide acceptance of these two documents in the science education community led states to rewrite and align their standards to them. Implementing these new standards called for revised thinking on the part of teachers about how science would be taught in the classroom, often associated with the term inquiry. Teaching in an inquiry manner required incorporation of more student focused activities, and less teacher focused learning. Experienced teachers who had been teaching for many years in a teacher focused environment were called on to alter their classroom practices in order to teach in a manner expected by the national and state standards.

Not long after this movement began, the federal government passed the No Child Left Behind Act (NCLB) in 2001 and states began to consider the impact of this legislation on their classrooms. It soon became apparent that testing of students to document academic progress would be a critical component of meeting the requirements of this law. This accountability in many states, including Georgia, places a Biology course at the center of documentation of high school science learning. Indeed in fifteen states, Biology is the only science listed by name as a graduation requirement (National Center for Education Statistics). In Georgia, this requirement has made it the only science course all high school students must take for graduation. All Biology students in Georgia are required to take an End of Course Test (EOCT) that is used for student, teacher, and school accountability purposes.

Both of these changes have impacted the practice of experienced high school biology teachers. As the reform documents were implemented in the late 1990's the expectations that teachers implement inquiry-oriented teaching was reinforced not only through the change in standards, but through follow-up professional development. As teachers began this shift in classroom practice, NCLB's testing accountability was also implemented. This accountability brought with it a strong focus on examining test data and meeting testing goals. Once again this was reinforced through district and school goals as well as professional development.

The emphasis on science standards and accountability testing are not necessarily incompatible in classroom practice. However, they have been implemented consecutively in short periods of time. The professional development model used for each has been, for the most part, large group instruction, with little individual follow-up in the classroom with practitioners. Teachers have been expected to respond and adjust their instructional practice twice, to address expectations for inquiry teaching and the demands of high-stakes accountability, with little time for individual reflection and feedback on the success of implementing the changes in their classroom settings.

Standards-based (inquiry) instruction

In the process of implementing the national and state standards science educators have attempted to describe and define the most appropriate teaching practices for achieving the kind of learning envisioned for students in these documents. The most common term used to describe these practices is inquiry teaching. However, as can be seen in the next section, there have been multiple interpretations of this translation from standards-based definition to inquiry practice.

A vision for science education. The two major reform documents in science education, Benchmarks *for Science Literacy* (1993) and *National Science Education Standards (NSES)* (1996) differ in their attempt to articulate a vision of science education for America. Both are cited in research literature on inquiry teaching; however the NSES have gained greater prominence in its use by science educators. An examination of the nature of each document shows the reason for this increased use of the NSES by the science teaching community.

Benchmarks focuses on the literacy portion of reform. It defines the foundational knowledge all students should have in grade spans of K-2, 3-5, 6-8, and 9-12. For example within each category of information the phrase "By the end of the 8th grade, students should know that" (p. 7) appears. The document focuses on knowing traditional content knowledge as well as what is defined as the nature and characteristics of science. The amount of "content" listed in the document is extensive, and in many ways contains value-laden language. In the chapter on the designed world the following standard is listed for grades 9-12 under agriculture: "Government sometimes intervenes in making agricultural supply to demand in an attempt to ensure a stable, high-quality, and inexpensive food supply. Regulations are often also designed to protect farmers from competition by farmers in other countries" (p. 186). Much of the material listed is beyond the usual expectations for the K-12 curriculum, and the examples of pedagogy are directive of specific conceptual development sequences. "In the beginning, children can focus on any attribute – size, color, limbs, fins, or wings - but then should gradually be guided to realize that for purposes of understanding relatedness among organisms, some characteristics are more significant than others" (p 101). The guidance is about the topics that should come before others, but not how to work with students in the classroom to help develop the understanding of these topics.

The *National Science Education Standards* includes far more than *Benchmarks.* The chapter on content standards encompasses one hundred pages out of the two hundred and sixty plus page book. Its grade breaks come as K-4, 5-8, and 9-12, which is less closely aligned with how K-12 schools are organized. However, the NSES does address in more specific ways a vision of teaching practices, assessment in science, professional development for science teachers, program standards and system standards. It is far more inclusive of the process of education. NSES is broad enough to set guidelines, yet not prescriptive in its suggestions. There is room for interpretation and personalization, which is useful in thinking about teaching science as inquiry.

Both guidance documents were considered limited by the publishers soon after the date of publication. The broad visions left a great deal of room for interpretation. Both were involved in follow-up publications that were intended to enhance explanations found in the original documents. In the *Atlas of Scientific Literacy* (2001) the American Association for the Advancement of Science (AAAS) continued its focus on the content again providing little help with pedagogical approaches. The document is useful for discussing content sequencing and possible misconceptions, but little support in discussions centering on the process of teaching in ways that help students develop understandings about the nature of science and the work of scientists.

Science reform literatures since the publication of *Benchmarks for All Americans* and *National Science Education Standards* has proposed that the best practice for instruction is inquiry. For example, the follow-up book to the NSES, *Inquiry and the national science education standards: A guide for teaching and learning* (2000) presented a means of defining what a classroom engaged in scientific inquiry would look like. It altered the focus from specific pedagogical activities practiced by the teacher to the outcome of those activities as expressed in the culture established in the classroom and student behaviors within that culture.

Other scholars have also discussed the importance of inquiry. As stated by Bybee (1997): “Using inquiry to describe teaching methods shifts the focus from students’ ability and understanding to the teacher's strategies and methods" (p. 111). Teachers have been called on to change instructional practices in order to guide student learning in ways envisioned in both national and state standards. The guidelines offered in the NSES leave open for interpretation by science educators the best means of implementation of these standards. Often the definition given for inquiry by the science teaching community has been that it is open and student driven. Settlage (2007) makes the case that part of the difficulty in making the changes to inquiry teaching in the classroom is what he calls the myth of inquiry. In looking for evidence of inquiry as a better way of teaching Settlage argues: "We may hear anecdotal evidence about open inquiry and its power…but solid documentation is hard to come by" (p. 465). Deboer (2002) emphasized the difficulty in moving toward a form of inquiry that is completely student centered when there are content standards that are also a part of the expectations for teachers. In his criticism of the NSES strong encouragement of the inquiry classroom that is focused on addressing student interest he stated: "What is not addressed, however, is how such openness to student interest is possible in an environment where the learning outcomes are so clearly defined in advance" (p. 412).

Deboer was stating one of the critical questions in implementing inquiry teaching, which is how does the science teacher create a student centered classroom called for in NSES and still ensure that students have opportunity to learn the science content standards also presented in the same document. Yet, the general consensus is that inquiry is the preferred manner for successful teaching in science. "…inquiry strategies demonstrated a statistically significant positive influence when compared with traditional teaching methods used in instruction of the control groups" (Minner, Levy, & Century, 2010, p. 492). This conclusion came from a study of four hundred forty-three research studies done between 1984 and 2002. It appears that the efforts to define and implement inquiry instruction support student success, and makes them a worthwhile goal for science instructional practices.

Models of inquiry practice. Teachers' interpretations of what standards documents are advocating whether they are national or state, is often complicated by the day-to-day issues they face as they work in classroom settings. As stated by Anderson and Helms (2001):

> Since so much of what is advocated as reforms (e.g. in the *National Science Education Standards*) is understood by its audience only in the abstract without a clear understanding of how it appears in practice, practitioners are left with a large amount of understanding which they must construct without sufficient assistance from the advocates of reform (p. 8).

Research on inquiry teaching and learning has had the same difficulty defining what is meant by day-to-day implementation in the classroom. In examining research on inquiry teaching, it is difficult to find commonalities and relationships between studies because of the use of multiple definitions for the term inquiry. "…inquiry seems to be used in a variety of ways without careful distinction as to the difference" (Anderson, 2002, p. 3). NSES led to some of this confusion with the various uses of the word inquiry. "Inquiry is a set of interrelated processes by which scientists and students pose questions about the natural world, and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts" (p. 214). NSES then described three ways in which inquiry could be defined: the way the scientific community works, the way learning is to take place and the way teaching is to be practiced in science classrooms. Anderson (2002) explained that because different researchers define inquiry based on their personal criteria, comparison of research is difficult thus each researcher's definition must be read. In a review of an international science symposium on inquiry teaching

Abd-El-Khalick et al. (2004) reported nineteen phrases used to describe the role of inquiry teaching in the classroom. Blanchard et al. (2010) found this to be true as they worked to define inquiry for their study. “As we look across the mass of research on inquiry-based instruction, we find that both the research methodologies and findings are mixed. This situation, as noted earlier, is further confused by a lack of shared terminology with regard to discussions of what constitutes inquiry” (p. 585). As many researchers who study inquiry teaching have realized, I too must define inquiry as it will be used in this study. I will return to my definition after some discussion of what can be found in the literature.

The first differentiation in inquiry is between the levels of student and teacher control of what happens during science lessons. Colburn (2000) describes this as three levels tied to inquiry instruction: open, guided, and structured. Blanchard et al. (2010) add one more layer to this, which they do not consider to be inquiry, but a completely teacher directed activity. They sort these into the categories based on the criteria seen in Table 2.1 based on the amount of student choice in the lesson.

Table 2.1

Levels of Inquiry

Level	Question posed	Materials	Procedures	Data Interpretation
	Teacher	Teacher	Teacher	Teacher
Structured	Teacher	Teacher	Teacher	Students
Guided	Teacher	Teacher	Students	Students
Open	Students	As requested	Students	Students

Blanchard et al. found in their study that compared a lesson taught on the same topic through direct instruction versus a guided model that there were differences in successful learning between middle and high school students. High schools students were more successful at long term retention using a guided rather than a direct instruction model, whereas middle school students were more successful using the direct instruction. This seems to indicate that the level of inquiry could be related to the background knowledge of students, and some levels may be better suited for use in differing circumstances.

Several modes of inquiry instruction have been developed to help teachers implement inquiry teaching in their classrooms. Each is intended to move instruction from a teacher directed classroom, to a more student directed form of instruction. Deboer named problem- and project-based models, engineering design problems, and guided open inquiry around topics as some examples. There are several premises that guide these approaches. First, teaching of science is to happen through setting of problems or tasks by the teacher that link scientific knowledge to application. Second, in order to succeed students must use skills of research and argumentation. Third, assessment of success is based on the products or artifacts produced by students during the solving of the problem or accomplishing of the task.

There are several challenges to this way of inquiry teaching. Marx et al. (1997) summarize that instructional time is a challenge seen in many studies. “Investigations and discussions often take longer than anticipated. Also, in-depth exploration of ideas takes longer than the more familiar broad and superficial survey of concepts” (p. 347). Other researchers clearly identify time as in issue in this kind of instruction. Polman (2004) described a single challenge for students that took nine weeks to implement and Barron et al. (1998) described two activities each of which required one month to implement.

An issue identified in common to all three studies was meeting the curriculum requirements for students. Because such a large amount of time is spent on so few topics, the current requirement of teachers for meeting standards is challenged by such a form of instruction. Polman's (2004) study was conducted in a class without curriculum or testing requirements. During the nine weeks of his study each group of students investigated a different topic. There was no congruence of content being learned throughout the nine weeks among the students.

The final issue all three studies found in common was the difficulty in implementing good problem- or project-based courses due to the constraints of teacher skills and the complexity of developing challenges tied to instruction of content. Teachers are called upon to serve as guides and students are given a great deal of freedom to choose the topics for research. In all cases the studies described the role of the teacher as a guide to the processes of learning by and through inquiry. All admitted to the difficulty of creating projects or problems that were sure to move students toward an understanding of the content of a curriculum. Although advocating for the use of problem- or project-based learning, each study included portions of learning time devoted to more traditional instruction that focused on content understanding apart from the inquiry portion of instruction. In studies describing implementation of these kinds of inquiry the topics for research were, for the most part defined by the curriculum used. Deboer summarized the issue by stating: "Student-directed learning becomes student learning directed at what subject matter experts say should be learned" (p. 412).

One model of inquiry instruction seen in many research documents is the learning cycle format. "Inquiry in science is the pursuit of coherent, mechanistic accounts of natural phenomena" (Hammer et al., 2008, p. 150. In this broad definition of inquiry Hammer et al. go on to say that it then allows for a large range of ways to go about helping students with learning. Many activities, if conducted appropriately would be able to meet the criteria. This openness is called for because of the complexity of the total classroom environment. Abrams et al. (2008) describe some of the variables that come into play when a teacher is determining how to approach inquiry teaching in science. The blend of these variables determines what form the inquiry activity will take in that teachers' class. These variables are logistical such as the amount of time and resources available, the socio-cultural setting, the cognitive ability and skills of the students, the nature of the content under study, the teacher's content knowledge and the goals for a particular lesson. Their definition of inquiry takes these variables into account "Any cognitively appropriate activity that echoes some subset of the practices of authentic science in which students are expected to engage with resources (literature, people, environment) around the generation or answering of questions or the solving of problems" (p. xxxiv).

These more open definitions of inquiry allow teachers to use creativity in developing lessons and do not tie them to any one strategy. The learning cycle approach offers an inviting entrance into inquiry teaching. Teachers are not asked to abandon all strategies and skills they have developed over time; instead they are asked to be reflective about how to use those strategies with students to accomplish the goal of inquiry learning. Granted, these changes do come with altering expectations for the roles of the teacher and student in the classroom, but the system does not have to be completely redesigned as a problem-based approach might take.

Two inquiry teaching models that employ a learning cycle are the Biological Sciences Curriculum Study 5E model developed in 1985 and propagated through the writings of Rodger Bybee and a current model proposed by Lee Meadows (2008). In both models students are active learners and the teacher guides the students through the thinking process. Both models allow for the flexibility described above and can be adapted for use in multiple settings. Students are given opportunities to develop explanations based on evidence and reasoning, and are then asked to extend and justify answers to applications of that knowledge. Both models align well with a constructivist approach to teaching. Bybee’s 5E model and Meadows’ model follow the same sequence of instruction, however Meadows incorporated the essentials of inquiry as described in *Inquiry and the National Science Education Standards a Guide for Teaching and Learning*. Table 2.2 shows the alignment of the two with the five essentials features of inquiry found on page 25 of *Inquiry and the National Science Education Standards a Guide for Teaching and Learning*.

Table 2.2

Learning Cycle Models and Features of Inquiry

Bybee	Meadows	Features of Inquiry student evidence
Engage	1	Engaged by scientific question
Explore	2	Priority given to evidence
		Formulate explanations
Explain	3	
		Evaluate explanations based on alternate explanations
Elaborate	4	Communicate and justify explanation
Evaluate	Student understandings	

These models allow teachers freedom and flexibility with how they focus their instruction on science standards. In describing a constructivist approach to instruction Windschitl (2002) summarizes the freedom, but also the challenge to teachers implementing inquiry following this model;

> Teachers, for example, must learn to capitalize on, rather than suppress, differences in students' existing understandings due to background; they must become critically conscious of the dynamics of their own classroom culture; and they must attend to patterns of classroom discourse as well as to the thinking that goes with them. (p. 160)

If the focus then is on what students are engaged in doing in the classroom, then the discussion of inquiry is no longer centered on the mode of delivery or the learning cycle.

Integrating inquiry practices. There is some congruence of thought regarding inquiry teaching among science educators. The focus is moving toward a deeper look at what is happening in a classroom during inquiry teaching. "…inquiry is not pedagogy but rather a student skill set" (Settlage, et al., 2008, p.207). This definition of inquiry moves the focus of classroom dynamics from the teacher to students. There are some teaching skills that can enhance the probability that inquiry teaching can take place in classrooms. In a study of diverse students' success in science, the results indicated that the foundation needed was the teacher preparation to deliver the inquiry instruction (Lee, et al., 2006). The teacher preparation provided to participants was not simply the skills to teach the units, but the conceptual understanding of what inquiry looked like in the classroom. Support was provided for reflective growth on the part of the teacher to enhance the development of the beliefs and values for this kind of teaching. The results indicated improved student success in all aspect of science learning, especially the inquiry abilities of students. The study indicated that the student growth in inquiry was related to the teacher's ability to teach in an inquiry manner.

Anderson (2002) emphasizes that research shows the importance of altering teacher beliefs and values about students and instruction if change is to take place in teacher practices toward using inquiry instruction. In the study conducted by Blanchard et al. (2010) comparing student success with inquiry lessons compared to traditional, the teachers selected to teach the guided inquiry lesson had experienced six weeks of professional development on inquiry instruction. By all measures in the study the students in the classrooms where the teachers were implementing inquiry practices scored higher on the pretests of the unit taught, grew in understanding over the short term, and retained the new learning for a longer time.

Teachers who philosophically embed inquiry into their thinking about instruction interact with students differently from a traditional mode of science teaching. Abrams, Southerland, and Evans (2008) describe these interactions as:

> Teacher behaviors that engender a "climate of inquiry" may include a respect for student ideas (giving students ownership), the ability to listen and ask reflective questions, genuine interest in student thoughts, flexibility, giving thoughtful and regular constructive feedback, confidence in students' abilities, and the ability to be fallible as the expert. (p. xxx)

Teachers in these classrooms expect students to work in ways that model the scientific community. The role of the teacher is no longer the traditional source of knowledge, and students no longer are viewed as receivers of this knowledge. Students become engaged in developing conceptual understandings of science, therefore the teacher no longer gives information as much as guides students toward understanding.

Inquiry teaching aligns well with the research on learning. Bransford , Brown, and Cocking (2000) identified three key findings from research which should guide teaching and learning. First, students arrive with misunderstandings that must be addressed in order to modify thinking. Second, students must develop conceptual frameworks regarding knowledge in order to best retrieve the information learned. Third, teachers should teach in a metacognitive way in order to facilitate the students' ability to take control of their learning. These three understandings both guide and form the research basis for inquiry teaching which focuses on the student building understanding and skills.

Classrooms have a culture, which is strongly influenced by the way in which the teacher manages the interactions within the room. The National Research Council (2000) describes five essential features of a classroom in which inquiry is taking place:

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

These features are evidence of a student focused classroom culture. The culture of the inquiry classroom is set by the kinds of activities planned and interactions within the room between the teacher and the students. Abrams et al., (2008) indicate that the inquiry teacher is the facilitator of student-directed learning.

The standards call for scientific understanding of both the content and characteristics and nature of science, and teachers must include these understanding goals as a part of their practice. In their study Palsey, Weiss, Shimkus & Smith (2004) examined data from the National Survey of Science and Mathematics Education conducted in 2000. Their examination led them to conclude that a focus on student learning needs to be primary, rather than on specific teacher practices.

> Rather than focusing so much attention on which instructional strategies teachers use, student understanding would more likely be enhanced by ensuring that whatever strategies are used, instruction is purposeful, accessible, and engaging to students, with a clear and consistent focus on student learning of important science concepts. (p. 10)

Arriving at a broader interpretation of inquiry would then involve an understanding of the purposes and intent of teacher instructional strategies, rather than specific defined strategies or models of instruction being designated as inquiry.

In the day-to-day practice teachers “must interpret the learning goals of the curricular designers in light of their beliefs and goals for their students (McDonald Songer, 2008, p. 985). They went on to conclude that the vision of inquiry teachers implement in their classroom involves trade-offs as they take the various variables in their setting into account. The teacher and the circumstances then interact to create the model of inquiry that is implemented. A rigid interpretation of inquiry teaching appears to limit both research and teacher practice. Brickhouse (2008) has suggested that based on studies of inquiry teaching that there needs to be more openness in the definition.

> Perhaps we need to think in terms of multiple models of inquiry that serve different purposes. In models of inquiry that are focused on generating new knowledge, then the

> generation of first-hand data may be of considerable importance. In models of inquiry that are more focused on applications, generating first-hand evidence may not be nearly as important as critical reading or understanding of how scientific institutions operate. (p. 287)

It appears that the whole of the classroom practices make up the orientation to inquiry on the part of the teacher. Selecting the appropriate instructional strategy or approach, and using them at appropriate times are what creates the culture of inquiry learning. Windschitl (2008) suggests that there are multiple teaching strategies that can create the inquiry classroom. “The point here is that inquiry experiences should foster a deep and well-integrated understanding of important content, as well as the reasoning skills and practices of science – the separation of ‘learning content’ and ‘doing inquiry’ is entirely unnecessary” (p. 3). This kind of thinking about inquiry instruction presents the manner of instruction as less critical than the goal of achieving scientific understanding on the part of the students.

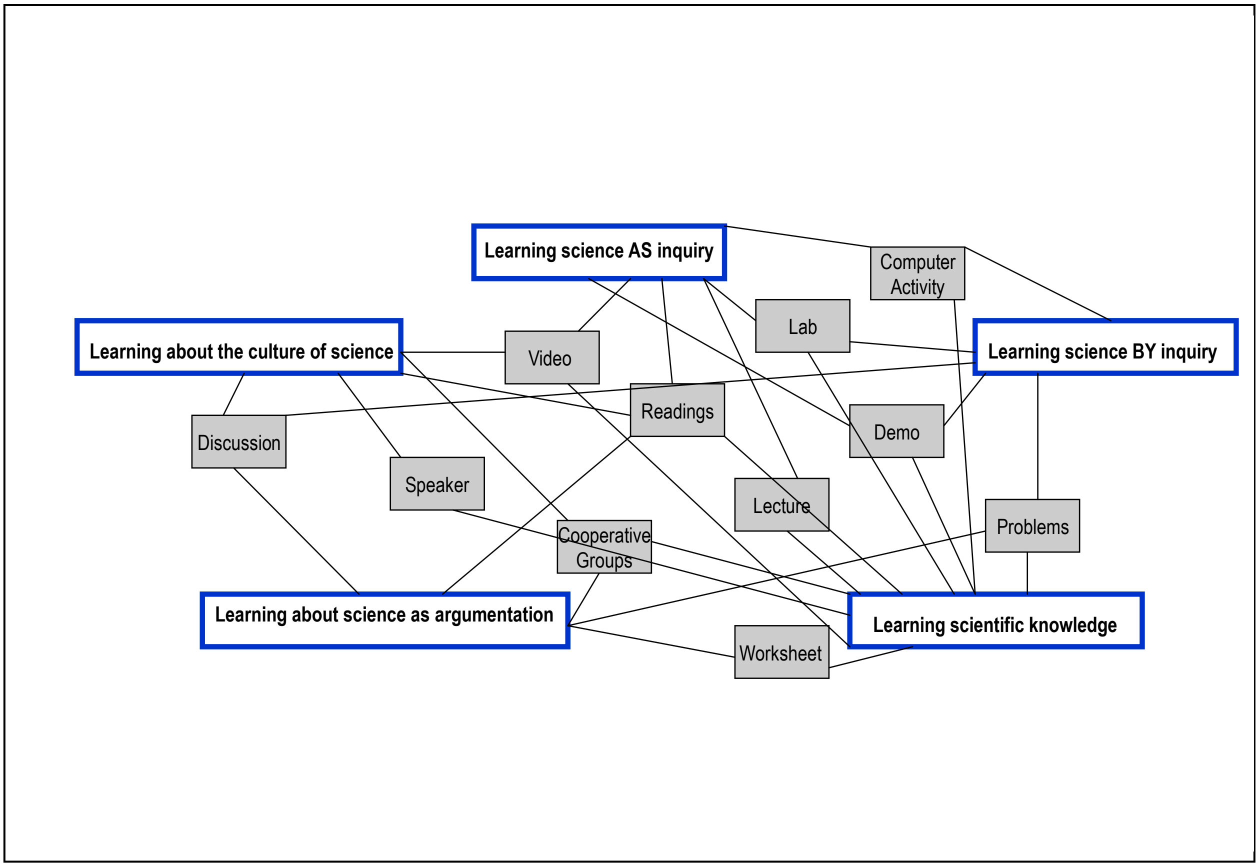
Discussion of levels of inquiry, problem-based instruction, and cycles of learning in many ways led teachers to believe that their instructional practices needed to be radically altered if they were to be successful science teachers. “ When teachers cannot easily imagine how they would organize this less-familiar kind of instruction or specify in some detail what the learning looks like when it happens, reform teaching becomes a high-risk venture” (Windschitl, 2006, p. 351). Implementation of inquiry oriented teaching became dependent on curriculum changes and special inquiry models of instruction rather than integrating and enhancing skills teachers already had in new ways of approaching the teaching of science. Schmoker (2011) in his discussion of how to improve student learning reminded the readers that literacy practices are important even in the inquiry science classroom.

> In this chapter we'll see – against the conventional wisdom – that an overemphasis on activities may be interfering with what matters most in science learning: opportunities for repeated reading, discussion, and writing about essential science content. These are finally being acknowledged as the core of authentic, *inquiry-based* science and are vital to critical thinking and reasoning in the sciences. (p. 164)

Inquiry teaching includes the totality of activities in the classroom, not simply the data collecting and processing ones, which often have led to the debates regarding open inquiry as an effective means of student learning.

The framework developed by Koballa, Reeves & Atkinson's (2008) includes a model of inquiry that integrates classroom practices and the standards, both state and national, in their definition of inquiry. Teachers conceptualize learning of science through the lens of inquiry. In this model there are five important features that guide how teaching of science happens in the classroom: learning scientific knowledge, learning about science as argument, learning about the culture of science, learning science as inquiry and learning science by inquiry. Each of these is important, and opportunities for students to acquire these understandings are provided. Note in Figure 1 that there are not specific teaching strategies tied separately to a feature. For example, there are seven strategies possible for learning scientific knowledge, one of which is the use of readings. Reading for students as a strategy is tied to all of the other features as well. How a strategy is used in the classroom determines the feature of inquiry instruction the teacher is embedding during the lesson.

Figure 1 Relationship between the features of classroom inquiry and strategies used



The feature emphasizing <u>learning scientific knowledge</u> is where most science teachers start their planning. The NSES group these under the category of Content C (p. 184-187), and the Biology GPS contains Content standards SB 1-5 that emphasize the importance of this goal. Most teachers will begin there with planning for instruction, whether their focus is inquiry oriented or not. The inquiry oriented teacher however takes great care with the sequencing of this content. Since students will be involved in active learning, sequencing in a manner that allows for building conceptual understanding is a prime consideration.

<u>Learning science BY inquiry</u> is not simply the lab component of most traditional science course work. How the data are used, and the setting of the lab is very different in an inquiry

classroom. Students are asked to make meaning from the data, not to necessarily verify concepts, but to construct their understanding. Learning by inquiry is not restricted to lab. What is required for this is that students practice the kind of thinking used in science for solving problems. This can be seen in the NSES in Content A (p. 175), and in the Biology GPS in standards SCSh 2, 3, 4 and 5.

<u>Learning science AS inquiry</u> requires that students begin to differentiate the way knowledge is acquired and retained in the sciences. This would include some understanding of the history and development of scientific understanding, not just the current state of understanding. The foundational way in which the field of science is involved in gathering knowledge is important for students to understand. The NSES describe this in Content A (p. 176), and the Biology GPS as SCSh 7.

<u>Learning about the culture of science</u> would require that students consider why scientists function as they do in various fields. This would include helping students understand the tentative nature of scientific understanding as well as the processes of research and application of knowledge which would include engineering of all kinds. Students would appreciate the work of scientists and engineers, whether they choose to enter those fields as a career or not. The NSES describes this in Content G (p. 200-20)1 and the Biology GPS as SCSh8.

<u>Learning about science as argumentation</u> would involve students in problem solving through the use of data and understanding of scientific principles. They would have an opportunity to think and discuss issues and concepts in ways that mirror argumentation in the scientific community. Students would understand the difference between winning a debate versus presenting reasoned arguments and counter arguments for discussion. The NSES describes this in Content A (p. 175-176) , and the Biology GPS as SCSh 6.

This model of inquiry embeds the theoretical into the day-to-day practices of the classroom. The focus is on the purpose of the instructional activities, rather than kind of instructional activity. Inquiry is an epistemological approach to teaching that guides students toward the five important understandings about science called for in the standards. There are many paths to these understandings negotiated by the interactions in the classroom between the students and the teacher.

Testing and Accountability

The standards described above were designed to focus science teaching on all aspects of Biology. Beyond the content, there are values and practices of the field that the science teaching community considers critical for a deep understanding of science. Because of the ongoing nature of scientific knowledge, an understanding of how it is generated and disseminated in the scientific community is seen as a critical component of student understanding of science. Testing this kind of understanding can be costly and time-consuming. The National Assessment of Educational Progress (NAEP) given in 2009 embedded some of the understandings beyond factual content. Even this assessment, which is done through sampling, not testing of all students, could not include all the standards envisioned for full science understanding. “Yet, like any large-scale assessment that requires standardization and limited student response time, NAEP cannot capture all important outcomes regarding depth of knowledge and aspect of inquiry” (Fu, et al., 2009, p. 1637). This version of the test included three content areas, and added four science practice areas. These new areas involved using concept maps, clustering of content items, questions calling for application of content understanding, hands-on lab work, and computer interactive questions. Although this test allowed for increased understanding of student breadth of scientific knowledge several limitations to full understanding were identified by Fu et al.. One of the most critical was "Limited resources and time prevent measurement of all important outcomes, limiting the definition of scientific inquiry and technological design" (p. 1638). A second significant factor that impacts the use of a more open testing format in accountability testing was "considerable time and cost for development, administration, scoring, and analysis" (p. 1638). If a test such as the NAEP, given to limited number of students has limitations such as these, it is clear that the annual accountability testing given to all students will have even more limitations to its ability to implement test questions that probe the full science understanding. Linn (2006) described the movement for use of performance based tests in the 1990's as fading due to lack of funding and the technical difficulty of creating such tests. Thus the testing field reverted back to multiple choice as a test format.

Purpose and implementation factors. The use of standardized testing has been a factor in American education for a long time. According to Linn (2000) several factors make the use of testing attractive as an accountability tool, such as low cost, the ease of mandate compared to other possible changes, speed of implementation and visibility of results. Efficiency in testing is more easily achieved by focusing on content. This efficiency is contrary to assessing full scientific understanding called for in science standards.

> Traditionally, large-scale assessments have relied on conceptually disconnected, multiple-choice and short-answer items, efficient for assessing recall of discrete facts, application of appropriate formulas, and critiquing writing procedures. However, these are not ideal for assessing such practices as relating multiple concepts, explaining scientific phenomena, conducting a physical investigation, and manipulating variables in a dynamic simulation. (Fu, et al., 2009, p. 1637)

The increased accountability associated with the testing has stemmed from legislative mandates, not from the education community. The desire for fast results from testing for accountability purposes then moves the test toward the multiple choice format and away from the in-depth, open questions that could more fully align with the standards.

Although the use of testing allows for a comparison of school, teacher and student achievement, there is a question of the validity of this data for making the comparisons. In a comparison of NAEP test results and state test results for the percent of students who were showing proficiency on the tests there were discrepancies between the two results. In a 1997 report Linn (2000) noted that Georgia had a forty percent proficiency rate on the state tests, yet only a twenty-five proficiency rate on the NAEP. This discrepancy is even greater in other states, so the question of which test should be used to validate student achievement could be raised.

Part of the concern about using testing as a valid measure is that the process of learning and education is too complex to be assessed with a single measurement, no matter how easy and cost effective (Abrams et al.. 2003, Ogawa et al. 2000, Seashore et al. 2005). "Oversimplifications could misinform policy makers and practitioners alike" (Ogawa et al., 2000, p. 204). In a study of teachers in North Carolina done by Jones et al. (1999) following implementation of curricular reform with mandated testing, the overall consensus was that the control of what was taught was no longer being determined by educators, but rather by legislators and policy makers. There is concern among educators that policy decisions could be made using incomplete data for decision-making if only test scores are used as the basis for these decisions. Because so many factors influence achievement such as previous student knowledge and socio-economic status Linn (2006) concludes "Consequently, differences in achievement at a fixed point in time simply do not provide a defensible justification for the causal inference that school A is more effective than school B" (p. 18). Penfield & Lee (2010) raise the question of validity of science tests when there is a great diversity of students being tested with the same test materials. "…it allows for the possibility that scores may be valid for one student group (or one purpose) but not for another student group (or another purpose)" (p. 11). They are concerned that policy decisions might be made regarding educational issues based on tests results that might not have been validated for the population or purposes of the test.

The mandated testing leads to interpretation and regulation by the leadership of states and local districts. The local regulations and interventions may focus well on raising test scores, but in the process not implement the intended purpose of the testing. The purpose described by those creating the regulations is to improve access and raise standards of learning for all students. The implementation can often alter the intent of the original mandated purpose (Seashore et al. 2005, Valli & Buese 2007).

> First, there is often much to admire in school district designs to implement rigorous curriculum and monitor student achievement. However, if these designs make multiple and simultaneous demands on teachers, especially in a short period of time, the consequences may be quite different from the desired outcomes. (Vallie & Buese, 2007, p. 542)

The focus on improving test scores can interfere with increased learning of content on the part of students because of the redirection of teacher work toward ensuring that students meet state and local mandates, rather than focusing on deep learning on the part of students. "Policies that establish consequences for students on the basis of their test performance may create a focus on having students obtain the minimal skills required for graduating" (Muller & Schiller, 2000, p.

211). The increased test scores are not indicative of increased overall learning of the intended content on the part of students (Abrams et al. 2003, Au 2007, Cuban 1995, Diamond 2007, Linn 2000, Ogawa et al. 2000, Seashore et al. 2005). "…focusing on specific tested material can lead to the inflation of test scores without enhancing students' learning" (Diamond, 2007, p. 295). Linn (2006) described the increase in test scores after repeated administration of the same test, yet when new tests were implemented, a drop in test scores was seen. This suggests that improved tests scores when instruction is directed at specific tests, does not lead to overall increased learning on the part of the students.

Effect on classroom practice. The goal of having all students learn standards is often diverted by the classroom practices that are implemented when the focus is on testing accountability. Results from a study done by Muller & Schiller (2000) indicated that the greater the testing accountability in a state the more likely there would be increased stratification of students as seen in mathematics course selection at the high school level. This tends to undermine the goal of ensuring that all students learn higher levels of mathematics. Because standardized tests are given at specific times during the academic year diversification of practice in the classroom is difficult since all students must be ready at the same time. The focus becomes more on the success of the group, and the individual needs of students can become secondary (Hilliard 2000, Seashore et al. 2005). In their study of the influence of assessment on teaching and learning Valli & Buese (2007) found that having rigidly paced curriculum increased this tendency. The teachers in their study complained that the rigid testing schedule" had a negative impact on teaching and learning because the focus was 'not on the child' but on the information due date" (p. 538).

Research has indicated that teachers alter their teaching in ways that focus on test preparation (Abrams et al. 2003, Au 2007, Cuban 1995, Diamond 2007, Hilliard 2000, Ogawa et al. 2000, Seashore et al. 2005). This is seen in increased time allotment for test preparation and the continuous focusing of student attention on the upcoming test. In his study of elementary teachers implementation of language arts, mathematics and science lessons, Diamond (2007) found they reported spending a great deal of time on test preparation activities as a part of instruction. "…the sequencing and pacing of instruction were influenced by testing and that instructional time that could be spent on other topics was spent on test-preparation activities" (p. 297). In an article examining how accountability had altered instruction in schools Cawelti (2006) referred to a study that indicated teachers no longer taught creatively, but rather spent increased time on practice problems for the upcoming standardized test. Jones et al. (1999) found this focus on test preparation a major factor in their study of North Carolina teachers' practices with high testing accountability. "Eighty percent of the teachers indicated that students spend more than 20% of their total instructional time practicing for end-of-grade tests" (p.201). Although it is important for students to be familiar with the testing format the amount of time spent practicing this format appears to skew instruction toward test preparation and away from the curricular standards.

One of the changes seen in the alteration of classroom practice is a subversion of the standard curriculum. The focus of instruction becomes narrowed to the content that will appear on the test rather than the entire curriculum which includes expectations of depth of knowledge, characteristics of science, as well as higher order thinking. Students experience a decrease in content learning (Cuban 1995, Diamond 2007, Linn 2000, Valli & Buese 2007). In the qualitative meta synthesis of forty nine studies Au (2007) found that the majority of teachers faced with accountability testing focused on “fractured” knowledge rather than “integrated”. The topics were taught as sections of material to be learned for the test, rather than as a coherent whole. Valli & Buese (2007) found that teachers referred to their practice as “…’hit or miss’ and ‘drive-by’ teaching” (p. 533). In Wideen, O’Shea, Pye & Ivany’s (1997) study of how Canadian instruction changed in high school science classrooms after implementation of accountability testing they observed the same changes.

> In the Grade 12 classes, on the other hand, we sensed a strong need to process a great deal of material very quickly. The single-mindedness of the enterprise was underscored by the impatience students demonstrated when the teacher withheld answers or ventured into territory that would not appear on examinations. (p. 436-437)

Yet in classrooms they observed without the accountability testing they found the pace of instruction allowed for exploration of a greater number of topics. Jones et al. (1999) found that teachers in North Carolina focused their instruction on the material that would be tested, and often neglected the problem solving and higher order portion of the curriculum, believing the content information would be the focus of the tests. In their national study Abrams et al. (2003) concluded that state tests had a stronger influence on teaching practices than the content standards did.

The effect of accountability in testing has in many ways countered the intent of the standards because teachers often revert to a teacher centered classroom (Au 2007, Diamond 2007, Valli & Buese 2007). Instead of the student focused learning called for in standards, teachers opt for the teacher centered teaching because it is seen as a more efficient way of delivering the information needed within the time constraints of a testing schedule. Abrams et al. (2003) argue that often the implementation of mandated testing has “…in effect, led to a deprofessionalization of teachers" (p. 20). Teachers follow rigid pacing charts and plans that have been created for them by leadership in their systems and feel a loss of control in their classroom of the ability to determine the sequencing and progress of students toward the curriculum requirements. The authors differentiate between high stakes and low-stakes testing requirements in the study of the effect of testing on teacher practice yet find that in both cases there is a change in teacher practice. . "…the substantial proportion of teachers in both types of testing programs (76% of high-stakes teachers and 63% of low-stakes teachers) who reported that their state testing program has lead them to teach in ways that contradict their own notions of sound educational practices" (p. 23). In Diamond's (2007) study analysis of data from classroom observations indicated that 93% of the questions asked were either only or mostly by the teachers they observed. Only 26% of the feedback to students was intended to explore their knowledge or provide clues for further thinking. Wideen et al. (1997) in their study of the science teacher's practice found that the Grade 12 teachers who had the accountability test relied on direct instruction, seatwork, discussion and lecture as their primary means of instruction, in spite of standards that called for a more inquiry-based instruction.

The meta synthesis conducted by Au (2007) of teaching in a high–stakes testing environment indicated that factors tended to interact. "Overwhelmingly, the prevalent triplet in the qualitative research was the combination of contracting curricular content, fragmentation of the structure of knowledge, and increasing teacher-centered pedagogy in response to high-stakes testing" (p 263). Valli & Buese (2007) indicated that this change was not always the one teachers would prefer, but they made it because they saw these as the way to improved test results for their students. "…teachers had to work hard to keep their personal and pedagogical relationships with students from being marginalized in this new era of accountability, often having to engage in practices that were antithetical to their beliefs about a good instructional environment" (p.542). Teachers, science and otherwise, are preparing students for tests success, rather than for broad conceptual understanding. The research indicates that even when they follow practices that lead to student test success, teachers are not following the pedagogical practices they would prefer to use with their students.

Reflection through professional development

Changing to an inquiry model of instruction calls for teachers to rethink their role in the classroom as well as develop new skills in classroom practice. These changes in teacher science classrooms have been as difficult to implement, as evidenced by other curricular reforms, such as those in mathematics (Little, 1993; Simon and Tzur, 1999; Franke et al., 2001). Little (1993) described the central issues teachers faced as they tried to implement reform practices in mathematics.

> To make sensible critiques of proposed reforms requires getting at their underlying assumptions, their social and historical context, and the degree to which they are congruent or not with the teachers' existing beliefs, commitments, and practices, their probable consequences for students and the ways in which they vary or converge across communities (p. 130).

Changing to new orientations to teaching envisioned by both the mathematics and science reform documents had caused teachers to consider far more than changing instructional strategies. It has caused them to have to rethink their approaches and purposes for instruction.

Implementations of science reform practices have proven to be difficult for many of the same reasons. "Teachers considering new approaches to education face many dilemmas, many of which have their origins in their beliefs and values. It is not unusual to think of learning to teach through inquiry as a matter of learning new skills. It is that, but it is also much more" (Anderson, 2002, p. 7). Moving from a teacher-centered traditional science teaching mode to a student-centered inquiry teaching mode requires reflective professional development. This can facilitate the process teachers to through as they re-conceptualize their approach to instructional practices. Simply providing new instructional practices, or curriculum materials has not proven to be effective in bringing about a change to inquiry teaching.

The complexity of the changes called for in teaching under the reforms in science, often leave teachers feeling deskilled, even after attending traditional professional development. Often, these experiences have been based on a single event with a knowledgeable expert providing the information that the teachers lacked. Kelly (1999) pointed out that "the inadequacies of the traditional approach to staff development is widely evidenced by the lack of change in teacher behaviors that it sustains…"(p. 427). She pointed out one of the fundamental impediments was the purpose for these professional development activities. They had been designed to "fix up teacher weaknesses, traditional teacher training also has many inherently negative overtones" (p. 427). Sykes (1996) described the traditional form of professional development as highly structured and institutionalized at all levels and that the system was "powerful, resistant to change" (p. 464). Classroom teachers need a different form of professional development if they are to be successful at making the changes in practice called for by the standards.

Research on models of professional development supports the need to personalize the activities if change in practice is the goal. Desimone et al. (2002) conducted a three-year longitudinal study of the effects of Title II professional development activities, which strongly impact math and science instruction. They examined the effects of length of time in the professional development, as well as differences between what they defined as traditional and reform professional development. The traditional professional development fell into three categories: within-district workshops, conferences, and college-credit courses. The reformed were in five categories: study groups, collaborative, mentoring, internships and resource centers. The research sampled teachers from ten districts across five states for self-reported data on the change in instructional practice. They concluded that the study "…provided evidence of the link between focusing on specific teaching practices in professional development (content focus) and having teachers use those specific practices in the classroom" (p. 102). The characteristics of professional development that led to the greatest change in teacher practice toward a reform model of instruction were related to the individualization of the experience.

> Our longitudinal data indicate that professional development is more effective in changing teachers' classroom practice when it has collective participation of teachers from the same school, departments, or grade; and active learning opportunities, such as reviewing student work or obtaining feedback on teaching; and coherence, for example, linking to other activities or building on teachers' previous knowledge. Reform type professional development also had a positive effect. (p. 102)

The researchers then suggest that if success in changing teacher practice was to happen, school systems needed to change professional development from a large group format and focus more specifically on individual practice.

Desimone et al.'s study indicates that the issue to be resolved for professional developers was the impact and cost of moving to fewer teachers receiving this kind of professional development. Other studies also illustrate this challenge. In a study of the impact of state mandated accountability using samples from three different states Seashore et al. (2005)

examined teachers' responses to these reform requirements. As they examined the various institutional factors that supported the change, they found one lacking. "While teachers referred tangentially to workshops or other opportunities to address state standards, we did not see evidence of sustained, job-embedded professional development directed toward understanding and implementing standards" (p. 199). Unfortunately, the support for the teacher as they begin to enact reform standards in their classroom at an individualized level is not the standard model in current use within state and school system professional development opportunities.

Within science reform several models of professional development have been proposed and developed. The studies described are representative samples of these professional development experiences. Table 2.3 summarizes the features and results of some of these models.

Table 2.3

Models of Inquiry Professional Development

Model	Summer events	School Year events	Improved Inquiry Practice	Reference
Participating in scientific research	Research w/scientist + Pedagogy		Neutral	Blanchard et al. (2009)
General skill development	Pedagogy		Neutral	Lotter et al. (2007)
General skill development with curriculum implementation	Pedagogy	Curriculum implementation	Partially successful	Blanchard et al. (2010)
General skill development with support	Pedagogy	Community of Practice ongoing	Improved inquiry practice	Akerson et al. (2009)
General skill development with curriculum	Pedagogy + curriculum		Improved inquiry practice	Jeanpierre et al. (2005)
PBL skill development with curriculum and support	Pedagogy + curriculum	Ongoing support	Neutral	Marx et al. (1997)
ESL skill development with curriculum and support	Pedagogy + curriculum	Follow-up support	Improved inquiry practice	Lee et al. (2006)
PBL skill development with curriculum and support	Pedagogy + curriculum	Follow-up support	Neutral	Schneider et al. (2005)
Curriculum implementation skill development	Pedagogy of curriculum Year 1 Issues w/ curriculum Year 2	Curriculum implementation	No general inquiry practice improvement	Fishman et al. (2003)

All the models in the set of research have a summer large-group component to the professional development that precedes any further work. The ones without school year support (Blanchard et al. 2009, Blanchard et al. 2010, Jeanpierre et al. 2005, and Lotter et al. 2007) provided the summer opportunity for professional development and then conducted a study of the instructional practices of the participants. Akerson et al. (2009) had an intensive summer program that was followed up with support as teachers attempted to implement what they had learned. The follow-up allowed for individual reflection and group support for the change in practice. Three models that offered specific additional support either with a model of inquiry or a focus on student needs (Marx et al. 1997, Lee et al. 2006, and Schneider et al. 2005) had a summer component and then focused their school-year support on implementing the model or curriculum taught in the summer. The final model (Fishman et al. 2003) was strictly focused on teaching a specific set of lessons. The follow-up during the second summer was to improve success with these lessons. Except for Jeanpierre et al. (2005) there was no improvement seen in inquiry practices following the models using general practices preparation without follow-up during the school year. Ackerman et al. reported that a great deal of support was needed during the follow-up year as they created communities of practice, with support from the professional developers. The teachers struggled implementing the general preparation, and the ability to communicate with others and reflect on their practice led to greater implementation of inquiry practices in their classrooms. Lee et al. (2006) followed up a summer focus on specific curriculum with general support for inquiry and ELL students in the school year workshops. Their study of student success indicated that teachers successfully were able to implement inquiry lessons with ELL students in their classrooms. Marx et al. (1997) and Schneider et al. (2005) focused on preparing and supporting teachers as they implemented specific Problem

Based Learning modules. They met with varied success, depending on the orientation of the teachers as they entered the process. "Findings also indicate that materials alone are not sufficient. Professional development is essential to help teachers plan for and reflect on classroom enactments. This support should include how to use and learn from reform materials designed to support teacher thinking. Reform efforts also must include efforts to create systemic change in context and policy to support teacher learning and classroom enactment" (Schneider et al., 2005, p. 307). Without the broader general orientation to reform teaching, implementing specific curriculum could be done, but it did not change the teacher general orientation to instruction. This was seen in the Fishman et al. (2003) study that focused on developing teacher skills for implementing a specific unit of instruction. Based on student success the first year on the unit of instruction, follow-up professional development the second summer was designed to better support the delivery of problem areas of the unit. Teachers improved the delivery of instruction in the one unit of instruction, but no evidence of general overall improvement of inquiry instruction was provided.

Research on facilitating teacher implementation of reform based instruction, in this case inquiry, indicates a set of characteristics that best support teachers in making the transition to practice. Huffman, Kell & Lawrenz (2003) studied one hundred twenty eight science and mathematics teachers who underwent five forms of professional development: immersion (doing science), curriculum implementation (using new materials in class), curriculum development (creating new materials for use in instruction), examining classroom practice, and collaborative work (including mentoring and classroom observations). They found that the types of professional development that best predicted the use of standards-based instruction were curriculum development and examining practices. The successful teachers in the study were engaged in professional development in the context of their instruction, and within their own classrooms. Other studies support these results. Locating the professional development as close to the local level as possible enhanced context support for change (Wood, 2000; Little, 1993; Desimone et al., 2002; Blumenfeld et al., 1994; Strahan, 2003).

Research has shown that allowing teachers deep reflection on their practice through interviews or narratives was important in the development of new skills (Artzt et al., 1999; Day, 1993; Stanley, 1998; Wood, 2000; Simon & Tzur, 1999; Blumenfeld, 1994). Schön (1983) described two forms of professional knowledge. There was the formal knowledge passed on through training, and the knowledge needed to implement the profession in situations that differ from the formal training. He considered the higher ground of the profession where a direct application of the learned theory is simply applied. But he also described the swampy areas where direct correlation to theory is not possible because the situational and contextual nuances. "The difficulty is that the problems of the high ground, however great their technical interest, are often relatively unimportant to clients or to the larger society, while in the swamp are the problems of greatest human concern" (p. 42). This is especially true of the science teaching community as reforms are being implemented. Teachers are being asked to modify their model of instruction, while maintaining student success.

Over time Schön said professionals develop specialties and become more and more oriented to one way of solving job related problems. If new problems arose that did not fit the categories developed, the professional discovered a roadblock, and had no solution. The professional then developed "selective inattention to phenomena that do not fit the categories of his knowing-in-action" (p. 61). For Schön the solution was reflection on the part of the professional. The reflection happened in two ways, during the process of performing the task of professional work, and after it was over. So how well the professional could think on their feet to problem solve situations and how well they thought about what happened to modify practice both were factors in being successful professionals.

Providing teachers opportunities for reflection on their practice enhances the ability to change. Stanley (1998) described that the beginning of developing reflection practices required a great deal of energy and time on the part of the teachers. A supportive and guided process helped teachers develop the skills for reflection and made the possibility of continued reflection on their own more likely. Simon and Tzur (1999) described the use of teacher narratives of their classroom lessons as ways of gaining insight into the teacher's thinking as a comparison to the goals of the professional developer, or researcher. From examining these differences, the professional development for the teacher was optimized to address issues revealed through the narrative of the teacher. The narrative dialogue between Wood (2000) and the participant in her research led to powerful growth in teacher practice and approach to the classroom.

Opportunities to actively implement inquiry practices with reflection and change before the next implementation have proven to support changes in practice. Blumenfeld et al. (1994) described a study of a process of helping teachers move from a traditional classroom to inquiry teaching as one of collaboration on planning, implementation, reflection on the implementation. Participants cycled through the process repeatedly over a year. As this sequence happened, the participants gradually developed confidence and skill in delivery of instruction in an inquiry manner. The researchers described their model of professional development: "the model presented here requires time for teachers to experience cycles of collaboration, enactment and reflection in which peers and others with a range of expertise provide considerable support" (p. 548). In a study of three elementary schools that beat the demographic odds for success

Strahan's (2003) study found that in each setting, various forms of cycles of collaborative planning, implementation and reflection brought about the change in classroom practice needed for improved student success.

Experienced teachers have become comfortable with the pedagogy used in their classrooms. Yet not all have had the opportunities to grow and develop new pedagogy as their career has unfolded. With the changes standards implementation and accountability have expected, opportunities to grow need to be provided through professional development. In a longitudinal study of teachers over their careers, Levin (2003) concluded that three components were essential to support growth in pedagogy over a teacher's career. First they need to be offered support, second they need to be encouraged to remain learners, and third they need to be reflective about their work. These factors focus on the individual development of teachers, not a collective, which has implications for professional development. Marczely (1996) emphasized the need for the professional developer to focus on individual teacher growth. "Each teacher is affected by a unique combination of personal, organizational, and professional factors that form the context in which professional development must take place. Meaningful change begins with the individual" (p. 5). She encouraged the professional developer to view teachers as individuals and provide tailored support.

Loucks-Horsely et al. (2010) reminded the professional developer that teachers involved in professional development are learners. All the best practices of teaching should be evident within the professional development. Their framework for designing professional development is aligned with the research supporting growth in inquiry teaching and personal development. It begins with getting a solid understanding of the knowledge of the field that includes factors such as adult learning, change processes, and the nature of science. That foundation is brought into focus by analyzing the context in which the professional development is to take place so that appropriate goals can be set. Once that is done planning and implementation occurs. However, that is not the end of the cycle. It is important that the entire process be evaluated and revised before beginning the next round of professional development. Diamond (1993) summarized the goals for anyone guiding a professional development experience. “The challenge for in-service teacher educators is to help teachers to see themselves as capable of imagining and trying alternatives – and eventually as self-directing and self-determining” (p. 52). When teachers are able to reach this vision of themselves managing changes in expectations for performance becomes a natural part of their self-reflective growth as a professional.

Defining the research

Making the transition from a traditional science teaching to a more inquiry centered teaching requires changes in teacher thinking about their practice. Anderson (2002) indicated that the difficulty in changing to inquiry teaching is internal to the teacher. Although there are skills that can be learned, the context of the teaching setting also influences how the teacher will practice inquiry teaching. Given all the contextual variables, the values and beliefs of the teacher will determine the practices in the classroom. Leonard et al. (2005) argued that the use of the standards curriculum does not guarantee implementation as designed. Those who are able to negotiate the change “report that they see increased enthusiasm in their teaching, fewer management problems, and more real science in their classrooms” (p. 74).

If inquiry teaching had been the only focus for change it would be feasible to expect that these practices might be prevalent among science teachers after 15 years of national standards with the state standards reinforcing the expectations over the last five years. The difficulty with making changes in practice were first experienced in the area of mathematics as Little (1993) described the conceptual changes needed to alter mathematics instruction was one of the difficulties implementing changed practices. Anderson (2002) explained in his work that the science teaching community is having difficulty defining inquiry, which has led to multiple interpretations without a clear direction of how to implement inquiry teaching in the classroom. Anderson & Helms (2001) found the abstractness of the definitions of inquiry an impediment to teachers understanding how to implement the practices on a day-to-day basis.

The research indicates that the pattern of instruction in classrooms when high testing accountability is present negates the emphasis on inquiry teaching. As Valli & Buese (2007) found in their study, the focus on individual students becomes changed to a group mindset when accountability testing becomes the norm. Research also indicates that the pressures of testing accountability counter inquiry teaching. As Au (2007) found in his meta synthesis of change in teacher practice, the content becomes narrowed to tested material, teacher-centered practices predominate, and topics are taught in a fragmented rather than conceptually related manner.

As Table 2.4 summarizes the issue, Biology teachers, as other science teachers, have found themselves negotiating between standards that call for inquiry practices with the immediacy of testing accountability as they implement instruction in the classroom.

Table 2.4

Teaching Practices Comparison

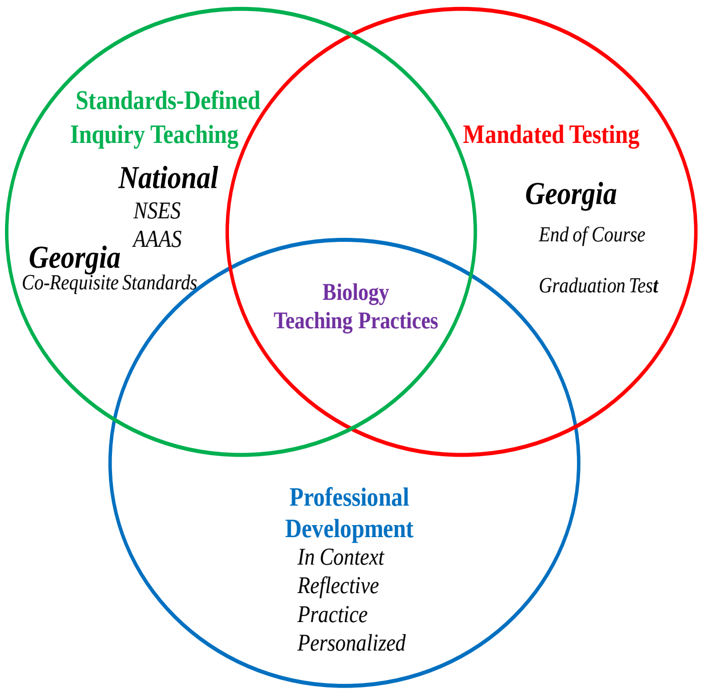
Science Standards	Accountability Testing
Student centered	Teacher centered
Guided instruction	Direct instruction
Conceptual development	Topic focused
Characteristics, nature and content of science	Content of science

The dual approach to teaching has placed science teachers in daily practice needing to negotiate preparing students for test success with expectations of inquiry teaching with full conceptual development of learning in a student-centered manner.

There have been multiple models of professional development designed and implemented to facilitate teacher success with inquiry teaching. Some features of professional development models include outcomes, activities, topics, interactions with and among participants and timelines. These features are organized and implemented in designs that reflect the professional developer's definition of inquiry teaching. As the studies in Table 2.3 indicate, not all have met with full success as teachers interacted with students following the professional development. As Huffman, Kell, & Lawrenz (2003) found in their large study, professional development that incorporated practice in the regular context of instruction helped teachers improve their skills in mathematics and science standards-based instruction.

The professional development model used in this study was designed to help teachers negotiate the perceived different expectations for teaching found in the standards and expectations of student success on accountability tests. It included opportunities for teachers to reflect on their practice as they taught Biology within the context of their daily work. Since the definition of inquiry instruction in this study was oriented toward an epistemological approach to standards-based inquiry instruction this model emphasized the importance of individual growth and personal reflection on the part of the participants. Participants were encouraged through the professional development; as they examined the co-requisite standards to consider three components of science instruction: (1) What do we know in science? (content); (2) Why and how do scientists go about their practice? (characteristics of science); and (3) How do we know what we know in science? (nature of science). Figure 2 shows the intersection of the two expectations, with the professional development model designed to support teachers negotiate the expectations within their daily classroom practice through reflection on their work.

Figure 2 Focus of study



Phase I of the research developed an understanding of the setting in which participants work based on their description of it. Appropriate professional development could not be planned without first establishing the contextual variables. A critical component was to understand how the participants were negotiating these dual expectations prior to the professional development implementation. The research questions for Phase I were:

1. Which set of expectations more strongly influence these Biology teachers' planning and instruction?

2. How much does the final test and system requirements for implementation influence classroom their practice?

3. How much of their understanding of standards–based (inquiry) teaching including characteristics and nature of science do they implement in the classroom?

Only once these questions were answered could a professional development model focused on enhancing standards-based (inquiry) teaching be created tailored to meet these participants' needs. The purpose of Phase II was to examine a professional development model designed to enhance teacher use of inquiry-based instruction. The overall analysis was made through case studies of the individual participants' experience of the professional development model. The questions for the case study of the individual participants were:

1. What changes occur in teacher thinking about standards-based instruction during the course of the professional development?

2. How do contextualizing reform expectations support teacher willingness to practice standards-based instruction?

3. In what ways are teacher practices altered through sequences of practice and reflection?

Once these were complete a cross case analysis allowed for an examination of the professional development mode itself. The research question about the model was:

How does a professional development model employing cycles of practice and reflection within the classroom context support the enactment of standards-based instruction in high school Biology?

If the orientation to teaching inquiry is an epistemology, teachers will need opportunities to rethink their practices in supportive professional development models such as the one used in this study.

CHAPTER 3

Research Design

> *The challenge for in-service teacher educators is to help teachers to see themselves as capable of imagining and trying alternatives-and eventually as self-directing and self determining. (Diamond, C.T.P., 1993, p. 52)*

This study consisted of two phases. Developing individualized professional development required an understanding of the setting in which it would take place. The first phase of the research was done to determine the setting in which the participants worked. The participants' descriptions served as the basis to define this setting. The second phase was an examination of the participants' teaching practices and thinking as they engaged in an individualized professional development experience. The design of the professional development focused the participants' thinking around the Georgia Performance Standards co-requisites for Biology as implemented in the participant's classroom. Each phase is described in the following sections.

Phase I – Defining the Setting

In 1975 Stephen Richer made the case that quantitative analysis of school data was not leading to an understanding of what was going on in schools. "Such designs are also, of course, incapable of handling the dynamic process of teacher-student interaction which some argue is the essence of learning" (Richer, 1975, p. 388). Richer made the case that looking at variables out of context would not help understand what was happening within a school. "…what is important about schools will be reflected in the conversations of these people…" (Richer, 1975, p.391). Following Richer's advice, the major source of data in this part of the research was interviews with Biology teachers. The interviews were designed to develop an understanding of how they thought about their classroom practices. The second piece of data, a questionnaire, was used to to gain insight into the participant's theoretical understanding of inquiry. Participants selected a sample assignment from the unit they had chosen to discuss during the interview and shared it as an example of their work. These examples gave concrete evidence of the practice described in the interviews.

Locating the study. Jones (2002) recommended that the researcher have an understanding of the research setting. For this reason participants were selected from high schools in an area near a large urban center where I have worked for over thirty years. The system selected was demographically diverse. Data from the Governor's Office of Student Achievement (2009-2010) described the following demographics for the over eight thousand students who took the Biology End Of Course Test (EOCT) in this system:

Table 3.1

Biology EOCT Demographics for the Year 2009-10

Asian	Black	Hispanic	White	Multiracial	ELL	Economically Disadvantaged
4%	78%	8%	9%	1%	7%	70%

Participants in the study taught in a variety of high schools within the system that reflected the diversity of the student population. The four high schools were demographically diverse: a school with an 85% Hispanic population, many of whom participated in the ELL program; a school located in a White upper middle class community; a school located near a university with a highly diverse population approximately 50% African-American, 35% White and the remainder Asian and Hispanic; and a school located in mixed income neighborhood with mostly African-American students. Overall the system had had an average failure rate on the Biology EOCT of fifty percent. The schools represented by the teachers ranged in failure rates from thirty to fifty percent over the previous three years.

Biology was taught in multiple settings and yet teachers were required to work toward the same expectations of success at the end of the course due to the common state mandated end of course assessment (EOCT). The system was not only diverse, but contained more than twenty high schools which had led to additional benchmark testing aligned with the school system paced curriculum. These tests were administered across the schools in an effort to ensure students throughout the system progressed at an equitable pace toward the end of course assessment. As the district high school science supervisor (personal communication, December 16, 2009) explained the process; the need to follow the pacing chart and sequence was reinforced by a series of benchmark tests teachers administered within a small window of time matching the five instructional units of the pacing chart. The units were based on the state curriculum (Georgia Performance Standards) and closely aligned with one of the State Department of Education proposed frameworks for the course.. The benchmark test scores were then reported centrally, and individual teachers' results were scrutinized for the achievement of their students on these tests, as well as the teacher's progress through the curriculum recommended by the system pacing guide. Sequencing, pacing, and the test schedule were determined at the system level. These five benchmark tests were not intended for use as student course grades. In this system testing accountability for teachers happened six times per course, the five benchmarks and the EOCT.

I had worked most of my career throughout this urban area. Through my work I had an understanding of the characteristics of the schools where the participants taught. Although my acquaintance with the participants through previous work helped with access, I was viewed as a peer by these teachers. I was careful however, throughout the research process to remain in my role as researcher rather than fellow science educator.

Participants. The seven participants in the study were experienced Biology teachers, each with at least 12 years in the classroom, five of whom had over twenty years experience. They had all majored in Biology, with two earning their education degree as an undergraduate and four following a career in a science field before becoming teachers. The group consisted of three White females, two African-American females, one White male and one African-American male. Table 3.2 summarizes the demographics of the participants of Phase I of the study.

Table 3.2

Participant Demographics for Phase I

Name*	Ethnicity	Gender	Years of teaching experience	Academic preparation
Anna	White	Female	20+	Biology major/Science career/Later Certification
Dot	African-American	Female	12-20	Biology major/Later certification
Flossie	White	Female	20+	Biology major/Science career/Later Certification
Jessica	African-American	Female	20+	Biology major/Science career/Later Certification
Jimmy	African-American	Male	12-20	Biology major/Science career/Later Certification
Paul	White	Male	20+	Biology & Education major
Sarah	White	Female	20+	Biology & Education major

*Self selected by participants

All participants were fully qualified with a Biology content preparation as well as fully certified to teach, many with graduate degrees in science education earned as a part of the certification process. The participants were experienced teachers who had begun teaching before the development of teaching standards or testing accountability.

Data collection and analysis. Participants were asked to be reflective about their thinking as Biology teachers both through the questionnaire and the questions during the interview. The

Inquiry Conceptions Questionnaire (ICQ) (Appendix A) was administered at the start of the interview session. The questionnaire was designed by Koballa, Reeves & Atkinson (2008) for measuring the three orientations described in their inquiry framework. The series of forced choices called for the participant to define their understanding of standards-based, inquiry teaching in an abstract manner. The questionnaires were later scored using the ICQ Scoring Key (Appendix B). The score in each column indicated the participant's theoretical orientation toward inquiry teaching. Column I would indicate an orientation aligned with the teaching practices focused on content acquisition. Column III would indicate an orientation more closely aligned with standards based instruction. The questionnaire was administered prior to the interview so that questions under discussion during the interview would not affect the choices on the ICQ. The results were later analyzed to determine the general orientation of each teacher toward standards-based Biology instruction and the alignment of this orientation with their practices as discussed in the interviews.

Seidman (2006) indicated that the goal for interviewing was to allow the participants to "reconstruct his or her experience within the topic under study" (p. 15). This practice would allow the researcher to view the thinking of the participant from his or her point of view. Although the goal was to understand the participant's viewpoint, Seidman reminded us that the interviewer is a part of the process and the interactions between the researcher and participant can be affected by their relationship and that interviewing acquaintances must be done carefully. Because the participants were acquaintances, gaining access was facilitated. However, as a researcher I had to be aware of two issues Seidman raised. First I had to be sure we did not assume understandings between us. Clarifying questions were used, to be sure that the explanation of the participants' thinking was clear. Secondly, I had to be careful that answers were true to the participant's understanding, not to what they expected me to hear. My understanding of best teaching practices was fairly well known through my work as a professional developer. The design of the questions as seen in the Setting Interview Protocol (Appendix C) was intended to focus on the participants' thinking about their work. I was careful at all times to let them know that the interview was about their own thinking.

Seidman's (2006) suggestions regarding the three levels of listening helped me maintain my understanding of the interviews. The first level was to listen to the substance of what is being said for understanding. The second was to look for the inner voice and not let participants get away with the public voice which "reflects an awareness of the audience" (p.78). The third was the technically challenging one of remaining in the role of researcher and remaining aware of the process, and the participant's frame of mind as the interview progressed.

These interviews which followed the protocol for the Setting Interview (Appendix C) were audio recorded and later transcribed for analysis. The analysis was done following the principles of grounded theory. In 1965 Glaser described the grounded theory method of analysis as consisting of four stages. "…(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimiting the theory, and (4) writing the theory" (Glaser, 1965, p. 440). Although each stage led naturally to the next, the process would not be linear, therefore the researcher should continuously reenter any stage as new thoughts emerge. This was possible because the researcher continuously wrote memos to herself as she went through the analysis. Glaser's ideal was that when the researcher was ready to define the theory "the discussions in the memos provide the content behind the categories, which are the major themes of the theory" (Glaser, 1965, p. 443).

As I followed a grounded research method of analysis, I relied on current writing by Charmaz and.Saldaña. The start of coding the data is described as "initial coding" by Charmaz, or "patterns" by Saldaña. At this step the researcher is encouraged to "stick closely to the data" (Charmaz, 2006, p. 47). Saldaña describes coding as "…an interpretive act" (Saldaña, 2009, p. 4). I examined the interview transcripts through my lens as an educator, sticking closely to the language the participants used to describe their classroom practices. After forty years of experience working in the K-12 system, I was familiar with the professional language used by teachers as they described their work. As I listened carefully to the teaching language of the participants I developed a common set of codes that were used for the seven interviews. The codes were tallied to see which participants had included the code, as well as to see the frequency of the codes. Some codes appeared in all interviews, some on most, and a few were unique to the participant. This can be seen in Appendix L.

This tally helped with the next step called "focused coding" by Charmaz or "categories" by Saldaña, I looked for ways of grouping the initial set of codes developed into broader categories. The frequency as well as the kind of code helped me group them into broader categories. The categories were centered on major factors that impacted their teaching, both positively and negatively. These common factors among the seven participants, revealed independently of each other, began to paint a picture of the context in which they worked.

Participants were asked to select a sample assignment from the instructional unit discussed in the interview. The choice of this assignment was open. The assignment was coded for analysis based on the following criteria: kind of assignment, whether it was teacher or student focused, the number of Biology terms involved, and the conceptual level. This portion of the data was studied after the analysis of the interviews, which guided some of the coding.

Throughout the various stages of analysis I followed the process of memo writing. As Charmaz (2006) suggested, I allowed the information embedded in the data and the organization of the categories into an analysis of relationships. “Memo-writing encourages you to dig into implicit, unstated and condensed meanings” (Charmaz, 2006, p.83). When a new relationship not explicitly stated in the data became apparent, I stopped and captured this through memos.

Over the course of the seven interviews, participants often referred to the expectations of the school system for their work. As I analyzed the data and began to process the categories, it became clear that in order to fully develop the context, I would need to understand the school system sequencing, pacing, and benchmarking of the Biology course. This led to an interview with the system high school science supervisor for clarification of the policies regarding curriculum sequencing, pacing, grading, and benchmark testing.

As I reached the third step known as “theoretical coding” by Charmaz and “concepts” by Saldaña, I developed some abstract relationships between the groups of code. The final memo took the form of a presentation for a class regarding the process and results of the analysis. At this point the dual impact of the two initiatives (standards based instruction and testing) and the factors that determined teacher implementation became clear. I developed a model of the variables that influenced the teaching practices described by the participants. This model took into account the current issues raised by the participants in broader categories. These broader categories were able to accommodate the variables to form a description of the context. Should conditions change, and the variables alter, the model would still be valid for interpreting the context in which teachers described their work.

Phase II –Implementing and Examining a Professional Development Model

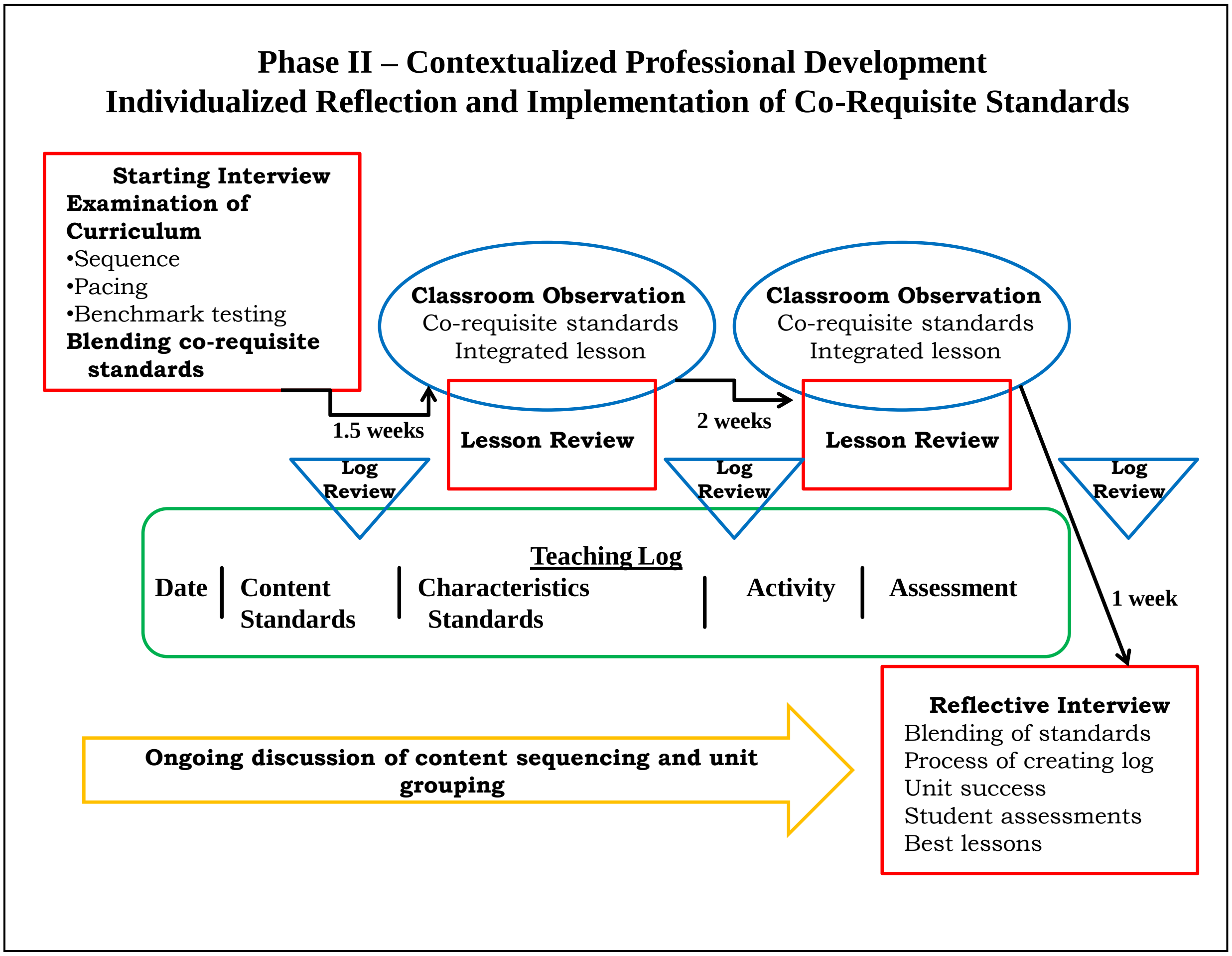
Professional development model. Following the analysis of the context, I designed a professional development model and operationalized it. This plan followed the recommendation of Loucks-Horsley et al. (2010) when they stated :

> Plans are made and implemented based on a solid understanding of contextual factors such as available time, resources, leadership, and school culture and are evaluated in part, by the extent to which these and other context factors are positively impacted. (p. 20)

The plan included three of the practices recommended in the research that support teacher implementation of inquiry teaching, context, reflection and repeated opportunities for implementation. The professional development model implementation took place within the school setting. Teachers focused on their teaching practices as they worked within their classroom to implement the co-requisite standards with their students. Secondly, the teachers were encouraged to reflect on the implementation of co-requisite standards. They examined their planning, teaching and assessment with the co-requisite standards as their focus. Finally, the teachers had opportunities to implement a lesson, reflect on it and later implement another lesson. This gave them the opportunity to refine their practice.

The components of the professional development model can be seen in Figure 3.

Figure 3 Professional Development Model Timeline



All participants from Phase I were contacted an offered an opportunity to participate in continuing research. The general outline and timeline for the continuing work was in the invitation. Five participants responded positively to the invitation and were involved in Phase II of this study. They were a representative group both as teachers and of the demographically diverse schools in the system. There were two African-American women, two White women and one White man located at four different schools in the system. Only the two at the same school were aware of the other's participation in the second phase of the research. The research spanned five weeks of instruction, with the Reflective Interview and Log Review #3 occurring after the end of the time the log was maintained.

Instruction during the second phase of the research followed the recommended curriculum sequence and timeline set by the school system. Participants worked within their regular schedule with the students in their classes. As they created lessons that included co-requisite standards participants did so within the context in which they were working. Participants had to consider ways to make instruction that included both co-requisite standards work within their setting, thus contextualizing their thinking regarding inquiry instruction. Planning two specific lessons that they knew would be observed helped focus the thinking on the students in their classroom. Maintaining a lesson log required planning the sequence of lessons and assessments that would take place with the students.

There were a variety of opportunities for teacher reflection throughout the professional development experience. Following each classroom observation, the lesson review allowed the participants to be reflective about their implementation of a lesson planned to integrate co-requisite standards. Although the logs appeared to be simple documentation of progress, the three reflective reviews of the logs gave participants opportunities to think about how the activities and assessments addressed the co-requisite standards. The final interview allowed the participants to consider the professional development experience as a whole. They considered the effect focusing on the standards had on their planning, sequencing of the unit, and their student assessments. Each participant selected three effective lessons, and described their reasons for selecting those lessons as models of standards-based instruction.

Teaching two standards-integrated lessons, one at the beginning of the time and one at the end gave teachers an opportunity to refine their practice between the lessons. The refining was based on the lesson review of the first lesson as well as the log work. Keeping the log helped the teachers focus on the manner in which they would coordinate their strategies (listed as activities and assessments) with the implementation of the standards. Having three e reflective visits to examine the logs gave teachers opportunities to refine their selection of strategies throughout the time of the professional development model being researched.

The embedded nature of the research about the influence of a professional development model on teacher thinking and practice called for the use of case studies. Yin (2009) suggested that selecting the form of research was dependent on three factors, the form of the question, the control over behavioral events and the focus on contemporary events. Case studies should be used when

> A ‘how’ or ‘why’ question is being asked about
>
> ○ a contemporary set of events
>
> ○ over which the investigator has little or no control (p.13)

Examining the participant response to ongoing process of the professional development was a natural fit to the use of a case study. Yin (2009) emphasized that the use of case study structure for research was particularly effective when it was to be conducted within the day to day events of the participants, and embedded in the context of their work.

> ○ investigates a contemporary phenomenon n depth and within its real-life context especially when
>
> ○ the boundaries between phenomenon and context are not clearly evident (p. 18)

Observing teachers within their classroom, and reflecting together on their ongoing work with students made the boundaries difficult to separate because of the complexity of the classroom and school setting. Events beyond the professional development impacted and surrounded the research in ways that were outside the scope of the questions being examined. These events needed to be acknowledged, yet separated from the focus of the study.

Data collection and analysis of individual responses. The examination of the manner in which the individual teachers responded to the professional development experience followed an intrinsic case study design as defined by Stake (1995). The purpose was to examine each participant's response to the professional development. Although the first phase of the research had helped understand the general context within which they worked, the freedom to develop teaching practices was in the hands of the individual teacher. Since the professional development experience based on the model of context developed in the first phase was designed to facilitate and empower a change to a more standards-based classroom, each participant's response would be unique. Following Yin (2009,) the scope of the study was limited to examining the "phenomena in depth and within its real-life context" (p. 18). In this case the phenomenon was the participant's experience of the professional development as they worked and reflected within their classrooms.

As Yin (2009) indicated the boundaries between the context of their work and the professional development were blurred. Data were collected from multiple sources following Yin "with data needing to converge in a triangulating fashion" (p. 18). Both Yin (2009) and Stake (1995) warned the case study researcher that the amount of data collected in the course of case study research needed to be extensive and varied. Yin described six kinds of sources of evidence, of which I collected five during the course of the research. "In fact, the various sources are highly complementary, and a good case study will therefore want to use as many sources as possible" (p. 101). The only kind of evidence described by Yin not collected was physical artifacts.

As can be seen in Table 3.3 of the summary of the evidence collected for each participant, sorted into Yin's categories not only were data collected in each of the various categories, more than one kind of data was collected within the categories. Direct observations were those in which I did not interact or influence what I observed, but simply made note of what was happening. During participant-observations, I interacted with the participants and influenced their responses. These were intended to help expand and develop the participants' understanding of standards-based instruction, and the discussions were based on consideration of the alignment of the lessons observed, or data in the log with standards-based instruction. In addition to the data above I took multiple pictures of each teacher's classroom without students present.

Table 3.3

Inventory of Data Collected for Each Participant

Category	Data Collected
Documentation	Lesson log
	Lesson handouts
	Curriculum sequences
Archival records	School system curriculum
	Georgia Biology Performance Standards
Interviews	Initial interview
	Two lesson reviews
	Three log reviews
	Reflective interview
Direct observation	Formal structured – two lesson observations
	Informal – field notes during all visits
Participant-observation	Two lesson reviews
	Three log reviews

Each of the following paragraphs describes in more depth the protocols of each portion of the professional development model and how the data collected were analyzed. It should be noted that only four of the five participants participated fully in Phase II of the research. It became clear, fairly early in the research that Anna was not maintaining the lesson log which would guide much of our discussion, as well as provide data for later analysis. I continued the work with her, but realized that there would not be sufficient data to write a clear case when done. “Not all cases will work out well” (Stake, 1995, p. 7). Stake recommended making an early decision about the probability of success of a case, so that modifications can be made. Since the other four were working well for data collection, I continued working with Anna following the same protocols as the other four.

The Initial Interview (Appendix D) asked the teachers to examine their thinking about how learning is sequenced in a Biology course. One issue that arose during the analysis of the first phase of the research indicated that the teachers did not think sequentially about the implementation of concepts within a unit of instruction. This interview encouraged the participants to consider how they planned and taught the co-requisite standards simultaneously. The questions were designed to focus attention on the co-requisite set of standards and the interview was done prior to the distribution of the log so that the components of the log would make sense. The interview was developed so that it could set the direction of participant thinking for the professional development. Participants began working on an ideal content sequencing at the time of this interview. The participants marked system curriculum from the previous year with a preferred numbered sequence. The interview was recorded and transcribed. A summary of the answers was later given to each participant to confirm their responses. Some made a few clarifying changes, and all approved the summary.

Following this interview each participant was given a logbook which consisted of multiple pages formatted for simple record keeping of the daily lessons. The page format is found in Appendix E. The log had a cover and was spiral bound; at the back it included a copy of the Biology GPS so that references to the standards could be done more efficiently. Participants were asked to keep a daily record of their instruction, listing their curriculum sequence. The entries required were simple and asked the teachers to spend little time each day completing the record of their instruction. At the end of the second phase of the study, I collected these logs for analysis. These logs were then analyzed in several ways. The content and characteristic of science standards being used in the various lessons were tallied. The frequency and form of reference in the lesson log as analyzed. Analyzing the instructional strategies used as teacher centered or student centered then allowed an alignment of strategies identified with the standards identified for each kind of lesson. I also noted the changes in notations based on reflection activities throughout the professional development experience.

Three visits for short discussions about the contents of the log were distributed throughout the second phase of the research. The first consisted of an analysis of the logistical maintenance of the log to verify that each participant understood how to record entries. The second came after the first observed lesson. We compared the standards marked in the log by the participants for that lesson, and those I marked based on my observation. During the third visit the participants confirmed their ideal course sequence that they had been refining during the time of the research. The topics were grouped into units, and the participant determined the unit that was taught during the major portion of the time the log was maintained. Following this we discussed the sequencing of topics and activities during the unit and their reasoning for this sequence. I took condensed field notes in the research journal, and then expanded and transcribed them following each visit.

Each participant selected a day for me to observe his or her first lesson with the understanding that they would choose a lesson that they perceived integrated the co-requisite set of standards well. All first observations happened within three weeks of the start of the second phase of the research. I took condensed field notes of the observations focusing on the factors described in Appendix F. Following Stakes's (1995) recommendations it was important that a careful note taking occurred. "During observation the qualitative case study researcher keeps a good record of events to provide a relatively *incontestable description* for further analysis and ultimate reporting" (p. 62). So the notes were then transcribed and expanded shortly after the observation. Within one or two days of the observations I returned to conduct lesson reviews with each participant following the protocol in Appendix G. These reviews were recorded and transcribed. The second observation and lesson review followed the same procedures as the first about two weeks later. At the end of this second phase the transcribed field notes were used for analysis using the various features listed on the observation protocol in Appendix F. The handouts given to the students on the day of the observation were also included as a part of the lesson analysis. Following this close observational analysis the overall lesson was analyzed using the Essential Features of Classroom Inquiry (National Research Council, 2000, p. 29) as found in Appendix H for its characteristics of inquiry teaching.

The Reflective Interview (Appendix I) was designed to enable reflection on the overall professional development experience. The teachers examined the effect of maintaining the co-requisite standards as a focus on their teaching practices: planning, implementing and assessing of students. They compared their practices teaching this unit to the manner in which they had taught the unit in previous years. They considered the effect of teaching in with both sets of standards in mind had on student learning. Finally they were asked to reflect on any insights into their own teaching or student learning they gained over the course of this professional development experience. These interviews were recorded and later transcribed for analysis.

As part of the analysis, I created a visual representation of each of the three interviews, including the setting interview from Phase I. On these representations I included the following categories which I had seen present in all interviews: pressures mentioned, structure of the classroom, instructional strategies, comments about the classroom work, how Biology topics were related to each other, kinds of assessments used, and incidences of specific Biology vocabulary used. These representations provided a means of comparing the way the participants described how they functioned as instructors the classroom. A representative sample of Dot's analysis can be seen in Appendix N.

As I analyzed the language used throughout the interviews, lesson reviews, and terms used by participants captured in the field notes I also tracked changes in thinking. For example the following progression in conversations occurred with Flossie. Table 3.4 cites simple phrases from the discussion related to the Characteristics of Science co-requisite standards. She started the professional development unable to describe the Characteristics of Science co-requisite standards. As the discussions progressed Flossie continued to struggle with determining which standards she had even taught in a lesson, or how to record them in the lesson log. Toward the second lesson she was considering the effect of using Characteristics of Science standards on the student response to the lessons. At the reflective interview, Flossie was able to discuss the standards by referencing them not by number, but by the descriptors within the standards such as the ability to use graphs. Not only was Flossie describing the value of teaching in ways that embedded characteristics of science as "anchors" for learning for the test, she was describing the need to think greater than test preparation as she taught Biology to her students.

Table 3.4

Change in Use of Language Regarding Characteristics of Science

Activity	Phrases used by Flossie
Initial Interview	Can't remember which one is which Scientific method stuff Read articles Lab
Log Review 1	Not understand how to mark characteristics of science
Lesson Review 1	Do lab Touching stuff Setting it up properly Next time have students make more predictions
Log Review 2	Agreed she had not noted characteristics of science standards that were present in the lesson observed Thought familiarity with the lab interfered with looking at the detail Agreed to examine the standards more closely
Lesson Review 2	Getting hooked on doing They might be intrigued
Log Review 3	Start the year with experimental design Still working on ideas for the course with fellow teacher
Reflective Interview	Love the nature of science Best way to get information to students is through nature of science Not just lab, but a better lab

Use lab as anchors for content
Found herself reminding students of the need for data
Looking for improved quality in lab reports
Wanted better graphs from her students
Had shuffled characteristics to one side, but wanted to go beyond test preparation
Students had not retained information from one class to next because she had not used features in characteristics of science in teaching lesson
“This is the coolest stuff ever” teaching science

A similar analysis of language progression was done for each participant.

In-depth analysis. Up to this point, I have described the individualized component analysis based on the form of the data collected. However, separately they did not create an understanding of the response to the professional development model as a whole. At this point I had to find a way to make sense of the varied and large amount of data collected for each participant. Both Yin and Stake described the lack of protocol for developing case analysis. “There is much art and much intuitive processing of the search for meaning” (Stake, 1995, p. 72). Witz (2007) describes the need to look beyond the language of the actual data for the larger understanding of the participant.

> Then, after prolonged immersion and absorption, concept formation starts in a major way when the investigator suddenly ‘awakens to’ or gets an intuition of something larger, intangible, with the insight often precipitated by specific strong expressions of feeling, overall tone, or the like on the part of the participant. (p. 243)

The term immersion fit well with the advice of Yin that although each researcher may have a different style as they approached this analysis, each called for careful thinking about the data.

I began by reading all the data collected in chronological order for an individual participant. Since the research was about the response to a professional development model experience that occurred over time, it had become clear that the logical way to describe the case was going to be through a chronological description. Among Yin's (2009) recommended analytic techniques is what he referred to as a "time-series" analysis. This facilitated the presentation of the data within the case, although the various components of the professional development did interact with each other, the professional development did have a timeline sequence that I had followed with each participant.

Examining the aggregate of data was the last step before writing the case. Thomas (2010) described the creation of the case story as the analysis: "It is the putting together of related information to make a story" (p. 579). This was the procedure I followed. Remaining close to the data was essential for generating good case analysis and descriptions (Flyvbjer 2006, Stake 1995, Thomas 2010, Yin 2009). The process of writing became part of the analysis because it was through this that the data became integrated, as recommended by Moran-Ellis, et al. (2006). "Integration denotes a relationship among objects that are essentially different to each other when separate, but which comprise a coherent whole when they are brought together" (p. 50). The process of writing the narrative of the case was a major part of the analysis.

Each case was analyzed individually following the description given above. Only after a complete case had been analyzed and written, did I move to the next set of data. Therefore the process of case analysis occurred four times in repeated cycles. This allowed me to focus as Thomas (2010) recommended on the participant's context and practice. "…uniqueness to the particular situation and one should seek to understand this…"(p. 580). Although I would later be returning to analyze the professional development experience by comparing the cases, at the time of analysis of each case, I focused on the individual's response.

Analysis of the professional development model. This portion of analysis reflects Stake's (1995) concept of an instrumental case study. The individual case in itself was not as important as the understanding of the phenomenon of the professional development model. Yin (2009) considered that the use of multiple cases strengthened the analysis of the phenomena. "Single-case designs are vulnerable if only because you will have put 'all your eggs in one basket.' More important, the analytic benefits from having two (or more) cases may be substantial" (p. 61). The question associated with this portion of analysis focused on the professional development model. Following Yin's advice, I treated each case as a separate study of the professional development model, and looked for similarities among the four cases.

Throughout the research process I maintained two sets of field notes. The first journal was divided by participant, and contained all field notes related to each participant collected into one section of this divided journal. These notes were used for the individual analysis as I focused on the unique cases. The second fieldwork journal maintained a record of my thinking and actions throughout the study. In this journal I noted all research memos to myself, a record of meetings and events chronologically related to the study, and captured possible themes for the cross case analysis as they became evident while I worked on the four cases. I placed this information on themes in this journal so that I could return to the work on the individual cases and have the themes captured for a later time.

I began the evaluation of the professional development model through an examination of the responses of the participants. Since the data were analyzed twice, I needed to differentiate the common themes from those that were unique to the circumstances of the individual participants. Ayres, Kavanaugh & Knafl (2003) emphasized the need to differentiate these two kinds of themes when conducting cross-case analysis. "In the course of their analyses, qualitative researchers must distinguish between information relevant to all participants and those aspects of the experience that are exclusive to particular informants" (p. 871). As I began I reread the four cases written during the individual analysis looking for common themes to add to those that had already been captured in the fieldwork journal during the earlier analysis.

Following the generation of possible themes, I revisited the original participant data. I examined the language of the field notes and transcribed interviews looking how the participants or field notes had described the experience. Specific incidences of data needed to be identified that matched the themes. If data could not be found for multiple participants, then the theme was not used, since it was unique to the individual experience and not to the professional development model. Sorting the data this way blended participant data together around the themes, and in effect created new context for the data around the professional development model rather than the individual participant. Ayres et al. (2003) described this as decontextualizing the data and then recontextualizing it within new patterns. "These data are decontextualized because they are separated from the individual cases in which they originated. Data are recontextualized as they are reintegrated into themes that combine units of like meaning taken from the accounts of multiple research respondents" (p.872). Checking to ensure that the data supported the themes is one of the critical principles Yin (2009) recommended for high quality analysis.

Since the professional development model included the three features of context, cycles of practice, and reflection, I also examined the data from the four participants for evidence about each of the features. During this process, I looked for examples of both how the feature supported or impeded the success of implementation of the model. These examples were examined in the context of the literature supporting their inclusion in the model. This followed a second critical principle Yin recommended which is that rival interpretations need to be examined during analysis, not simply confirmatory information. Doing this required using a third principle Yin recommended which is to use my prior expert knowledge as part of the analysis.

The final analysis was to consider how participants responded to the various components of the professional development. I examined the lesson logs to compare how the participants had completed them. I compared the field notes from the second and third log reviews to compare the response of the participants to those visits. I looked for the major points of discussion in each of the lesson reviews. A matrix of these major points for the first reviews was compared to a similar matrix of the points of discussion during the second reviews. Using the reflective interview, I analyzed the participants' direct responses about what they had learned during the process for common understandings. I also created a matrix of the twelve lessons designated in the reflective interviews, and the components identified by the participants that had caused them to select those as model lessons.

As can be seen in Table 3.5, the data from all four cases had now been analyzed for their contribution to the whole of the professional development model. This had decontextualized the data from the participants who had helped generate it.

Table 3.5

Cross-case Analysis Activities

Analysis	Focus	Data identified
Four cases	Common themes	Support of common themes
Literature-based features	Context, repeated practice, reflection	Support success of feature Impede success of feature
Components of professional development	Lesson log and reviews Lesson reviews Reflective interview	Build comparative matrices

The final analysis was building a narrative about the professional development model as a whole. The data was recontextualized as part of an examination of the process of conducting such a model of professional development through the lens of what participants had learned through participating in the study. This broadly followed Yin's analytic technique of pattern matching. "In a multiple-case study, one goal is to build a general explanation that fits each individual case, even though the cases will vary in their details" (p. 142). Describing the participants' learning in this narrative created an explanation of how the components of the professional development model interacted.

Reliability and Validity of Data

Collecting data to examine one phenomenon (the professional development model) in the midst of the daily ongoing process of the school required careful planning. In order to ensure that the data could be used to examine the professional development model apart from the daily work of teachers, several factors had to be taken into account. The methods used needed to provide data that could focus on the questions being asked, without getting lost in the context. Yin (2009) emphasized the importance of having a protocol in place before research is begun on a case. "..it is essential if you are doing a multiple-case study" (p. 79). The protocol served as a guide through the research and helped increase the reliability of the case study. With five people, each undergoing the various portions of the professional development model experience at their own pace, the protocol I designed ensured that as I interacted with each participant, I used the same procedures. Before each interview, log review, and lesson review I printed the protocol and carried it with me to the session. I took notes on the printed protocol, to help remind me of critical points in the interaction. These printed pages were retained and kept in the file with the transcribed interviews or field notes.

Each method used for data collection had its own embedded theoretical perspective which gave it both strengths and weaknesses (Moran-Ellis et al., 2006, Yin, 2009, Maxwell, 2005). Validity was enhanced by selecting the means of collecting data based on the questions of the research (Cho & Trent, 2006; Maxwell, 2005; Holliday, 2007). Case study research required a great deal of data in order to fully develop the descriptive narratives. During the design of the professional development model, I identified the kinds of data that would be generated and collected at each step. I selected methods that best fit the questions I was asking.

Cho & Trent (2006) described a transactional approach to validity that involved an interactive process between the researcher, the participants and the data. This approach required continuous interactions with the participants using such methods as member checking interviews, and extensive records that were to be later verified through conversations with the participants. The methods selected in their model of validity needed to include multiple forms of data selected to match the kind of research being done. Of the five types of research they described, the case study research I did falls in the category of “thick description”. “Validity as a process in the thick description purpose is holistic and necessitates prolonged engagement” (p. 129). To achieve this form of research validity they expected diverse sources of descriptive data that can be triangulated, an accurate knowledge of the daily life of the participants, and repeated member checks. Validity of data was increased through aligning the kind of data selected for use with the method used (Flick, 2007; Cho & Trent, 2006). In all cases the ability of the data to provide a rich description of the research from several sources and points of view enhanced the validity of the data.

Maxwell (2005) provided a practical checklist of how to create this diverse source of data to help with validation of the research conclusions. “The overall point I want to make about these strategies is that they primarily operate not by *verifying* conclusions, but by *testing* the validity of your conclusions…” (p. 109). He suggested eight strategies that would enhance the validity of the research, of which I used six: long term involvement, rich data, respondent validation, intervention, triangulation and searching for discrepant evidence and negative cases. These strategies were a natural fit to the professional development model and it guided the decision about the research methods I would use to generate data.

Time became an issue since permission for research was slow in coming. However, Stake reassured the researcher that in case studies, time is always an issue.”There is always too little time” (p. 51). Because of the complexity of case study, the data collection needed to create a thick description narrative, so it required substantial amounts as well as varieties of data. Stake also reminded the reader that the researcher at some point has to reach an end and work with the data available. Maxwell (2005) described the need for repeated observations and interviews in order to keep from making inferences based on incomplete data. The protocol I developed called for repeated visits with the participants. During the course of the research period of seven weeks, I conducted two lengthy interviews, observed two full class sessions, conducted two half hour lesson reviews, and discussed the log three times with each participant. This allowed me to make at least nine visits to each participant's school and classroom. Although the data collecting time frame was less than two months long, the number of visits to each participant allowed me to amass a large collection of data and sufficient time to make a wide variety of detailed observations.

Thick description narrative required that the data collected be not only varied, but rich. Field notes needed to include detailed descriptors (Maxwell, 2005, Stake, 1995) that focused on the kind of information that would inform the research. As I observed the classes I kept in mind the kind of information I had identified in the protocol for observation and took careful, continuous notes. Shortly after the observation I expanded those notes while the details that filled in the notes were still fresh in my mind. Because so many observations were done so close together, the field notes were transcribed prior to making other observations, so the expanded field notes focused on the class observed or log review. Stake emphasized the importance of complete notes for later analysis. "the qualitative researcher keeps a good record of events to provide a relatively *incontestable description* for further analysis and ultimate reporting" (p. 62). I kept the language of the expanded field notes descriptive and non-evaluative. Quite often the lesson reviews would expand the understanding of the lessons observed, and keeping the field notes descriptive minimized misunderstanding on my part. Holliday (2007) emphasized that it was not the data that made thick description, but rather what the researcher did with the data at the time of analysis. This made taking detailed notes critical, because at the time of the field notes I did not have a complete picture, so could not separate the important from the unimportant. Recording the interviews and lesson reviews for transcription helped ensure that I captured accurately the language of the participants as they described their thinking.

Since it was important to understand how the participants were thinking about their teaching, getting their responses to what I was seeing and hearing was an important component for validity. Stake suggested returning a summary of interview responses for validation to the participants. “Interviewees often are dismayed with transcripts not only because of the inelegance of their own sentences but because they did not convey what they intended” (p. 66). After I had transcribed the initial interviews I created a summary of the responses for each participant and returned it to them for feedback. Most agreed with what I had written as their responses, but a few took the time to enhance an answer after further thought, or make comments regarding their responses before returning the summaries to me. The lesson reviews were a form of allowing for participant feedback about their lessons. The protocol was designed in a way that first allowed the participants to reflect on the lesson before I raised any questions regarding what I had observed. These conversations expanded my understanding of the observations with insight from the participant’s viewpoints about the lessons as they had occurred. Stake made the suggestion that a rough draft of a participant’s case could be given for feedback. “…the actor is requested to examine rough drafts of writing where the actions or words of the actor are featured, sometimes when first written up but usually when no further data will be collected from him or her” (p. 115). He went on to say that the feedback should be taken into account, but should not control the reporting of the case, since it is ultimately a narrative of the researcher’s analysis. The four participants included in the final paper were given copies of their individual cases for feedback, and any comments were considered during the cross-case analysis.

Because of the nature of qualitative research, the person collecting the data is always a factor in the research.

> No matter how extensive the research, different researchers will always pursues and see very different things in the same setting. They will collect different data; and even if they did not, they would interpret the same data in different ways. (Holliday, 2007, p.73)

This warning is particularly true in relation to the manner in which I interacted with participants. Although I had a protocol to follow each time, because each participant's different setting, as well as understanding of standards-based instruction, the substance of the interactions varied greatly. For example, Flossie and Paul chose general Biology classes, while Dot and Jessica chose accelerated Biology classes. Students in accelerated classes tend to be more oriented toward science and therefore more willing to do research without strong teacher guidance. This meant that conversations with each participant about the observations were often different because of their willingness to allow the students to do the more open research in accelerated classes. I was a major factor in the discussion, determining which standards-based instruction issues needed to be raised and discussed with each participant. Since each observation was unique, both because of the participant and the setting, I chose the issues based on the strategies employed during the classroom observation. I used the protocols as a basis of all interactions with the participants in order to minimize the difference of the data collection process between participants.

Triangulating the methods so that the data collected during the process added to the validity of the research. Stake recommended planning from the start of the research the inclusion of different methods of data collection into the protocols. "With multiple approaches within a single study, we are likely to illuminate or nullify some extraneous influences" (p. 114). As can be seen in Table 3.6 each research question was answered through analysis of multiple data sources generated through the variety of methods (observation, member checks, interviews, documents) used in the plan for research.

Table 3.6

Data Sources for Each Question

Question	Data Sources
Which set of goals more strongly influence these Biology teachers' planning and instruction?	Setting Interview ICQ
How much does the final test and system requirements for implementation influence their classroom practice?	Setting Interview Lesson sample System curriculum guide
How much of their understanding of standards–based (inquiry) teaching including characteristics and nature of science do they implement in the classroom?	ICQ Setting Interview Lesson sample
What changes occur in teacher thinking about standards-based instruction during the course of the professional development?	Initial Interview Lesson Reviews Log reviews Reflective Interview
In what ways are teacher practices altered through sequences of practice and reflection?	Lesson handouts Classroom observations

	Lesson reviews Log reviews Reflective Interview
How do contextualizing reform expectations support teacher willingness to practice standards-based instruction?	Lesson logs Log reviews Classroom observations Lesson Reviews Reflective Interview
How does a professional development model employing cycles of practice and reflection within the classroom context support the enactment of standards-based instruction in high school Biology?	Analysis of case studies Lesson logs Log reviews Lesson reviews Reflective interview

Ayers et al. (2006) recommended triangulating the methods when the research was as complicated as case studies. "..methods can be triangulated to reveal the different dimensions of a phenomenon and to enrich understanding of the multi-faceted, complex nature of the social world" (p. 48). They considered the process of triangulating the information a means of integrating multiple facets of the phenomena being studied. "We describe the greatest level of integration as *integrated methods*, in which the inter-meshing occurs from conceptualization onwards to the final reporting of the research" (p. 51). True to this thinking, I began considering how the methods and data would give insight into different facets of the professional development. This was done as I decided during the planning of the professional development model how each component would not only support the experience of professional development, but also how it could give insight into the various components of the model if used as data. Although analysis often examined each component of the data, it was the integration of the various pieces that gave a more complete picture. As Ayres et al. (2003) recommended, finding the themes in the analysis is important, but even more important is finding the relationship between them. "Until these themes are reintegrated in a manner that shows how they work together in an actual (or constructed) case, the analysis is incomplete" (p. 881). Without a variety of data, it would have been difficult to develop multiple themes, and the research assertions would have been based on less complex information.

The professional development model had been based on current recommended best practices not only for professional development, but for success in assisting teachers in implementing standards-based instructions. This set up an expectation of a positive response to the activities and sequencing of the research. As I analyzed the data I had to be careful to listen to the data for supporting, as well as refuting evidence of change in the participant's teaching practices and thinking. Ambert et al. (1995) point out that reliability in qualitative research can be difficult to assess because "qualitative research often relies primarily on the informants' own formulations and constructions of reality checked against those of other similarly situated informants or the observations of an informed observer" (p.885). For this reason it was necessary to make sure that the terms used by the teacher's in their interviews were well defined. It was important to listen during the lesson and log reviews to be certain of how the terms were being used. The literature definitions I had did not necessarily match the participants' use of the term. I was always careful to follow up with them as they used the language of the standards.

Because I carried a dual role of researcher and professional developer, my intervention in the process was extensive. The lesson review protocol is an example of one way I tried to access the participants' responses prior to my intervention. Each facet of the lesson began with their response before I gave a response. My response was intended as a professional development prod, whereas their responses were meant to be reflective. I was always very careful throughout the research to keep the interactions I had with participants focused on the events in their thinking and classroom. I did not integrate discussion by mentioning what others in the study had responded to the same protocols. Several times I was asked about how others were responding, and I always assured the participant that their response was the one I was interested in at that moment. This appeared to have been effective, since at the end they all were curious to know who else was involved in the research.

CHAPTER 4

Participant Definition of Their Setting

> *The message of the many-layered, district-created assessments, the science chair concludes, is that teachers lack the skill or objectivity to evaluate their own students' learning, effectively discounting teachers' judgments. (Tobias & Baffert, 2010, p. 51)*

How students experience the Biology curriculum is guided by the teacher. It is the teacher's responsibility to interpret the Biology curriculum and guide students to an understanding of it. The setting for the study was not a school, a district, or a state it was the Biology classroom. The day-to-day work of learning Biology happened within the classrooms of the teachers who chose to participate in this study. Phase I was conducted so that the definition of the setting in which Biology instruction took place would be done by the teachers. Participants described their work through defining their inquiry orientation using a questionnaire, describing their classroom practices during a recorded interview, and through a sample of an assignment they had used with their students. Participants were given the opportunity to select a pseudonym for the study, so the names used in this study to identify them were self-selected.

Making sense of the data

Initial coding of the transcriptions of the recorded interviews generated one hundred thirty-two codes. It became clear early in the process of coding that these Biology teachers could not discuss their practice without the use of content specific terms. Thus content specific terms became a separate category containing one hundred eleven unique codes. I grouped the codes conceptually as shown in Table 4.1. There are twenty-five elements in the Biology GPS content co-requisite that define specific concepts to be taught in the course. When the one hundred eleven terms were grouped conceptually, they defined twenty-two of these elements.

Table 4.1

Conceptual Grouping of Biological Terms by Instructional Units

Reproduction	Cellular Basis of Life	Cell Division	Chemistry of Life
Genetics	Cells	Mitosis	Organic molecules
Traits	Organelle	Meiosis	Amino acid
Mendel	Homeostasis	DNA	Photosynthesis
Punnet square	Mitochondria	Replication	Respiration
Mendelian genetics	Chloroplast	Transmission	Carbon dioxide
Homozygous	Hydrophilic	Translation	Pigment
Heterozygous	Hydrophobic	Transcription	Chemistry of life
Monohybrid	Cell membrane	RNA	Protein
Co-dominance	Cheek cell	Protein synthesis	Acidity
Dihybrid	Nucleus	Spermatogenesis	Solutions
Genotype	Cell wall	Sperm	Neutralize
Generation	Transport	Egg	Isotonic
Gene		Reproduction	Hypotonic
Gene sequence		Chromosomes	Hypertonic
Test cross		Deoxiribose	Energy transformation
Allele		Adenine	Calvin cycle
Karyotyping			Krebs cycle
			Carbohydrate
			Macromolecule
			Osmosis/Diffusion

Ecology	Classification	Evolution	General Terms
Environment	Organism	Evolve	Stomach
Succession	Protist	Evolution	Bones
Water cycle	KPCFGS	Lamarck	Wing
Ecology	Paramecium	Darwin	Microscope
Producer	Microorganism	Organic evolution	Chromatography
Global warming	Viruses	Astrobiology	Scientific method
Energy flow	Elodea	Macroevolution	
System	Prokaryote	Change over time	
Abiotic	Eukaryote		
Carbon cycle	Plant		
Food chain	Leaf		
Autotroph	Stomata		
Heterotroph	Midvein		
Nutrient cycling	Blade		
Biome			

Two of the elements not defined dealt with human impact on the natural biological system and one dealt with animal adaptations to conditions. As a group, the seven participants managed to define most of the vocabulary of the course in the process of describing their teaching practices. Many of the terms went beyond the requirements of the standards and indicated a higher level of expectation for student understanding of Biology than those defined by the GPS.

The complete set of codes with tallies for participants can be seen in Appendix L. These codes were grouped into naturally occurring themes. These were systemic issues, student issues, instructional strategies, and ideals/goals.

Table 4-2

Grouping of Commonly Occurring Codes into Themes

Themes	Systemic Issues	Student Issues	Instructional Strategies	Ideals/Goals
Sample codes	Pacing charts Grading patterns State testing	Motivation Reading Maturity Gifted/General level	Technology Laboratory Lecture/discussion Projects	Excited about science Students asked to think Students making connections
Total number of codes	16	30	25	15

Thirty six of these codes were repeated on the interview analysis of four or more participants.

The seven participants described twenty-five different instructional strategies used in the course of their teaching. The three strategies mentioned by almost all participants were labs, projects, and vocabulary building activities. Many other strategies were mentioned by two or three, or even individuals. A large variety of strategies were described during the interviews. An analysis of the portion of the interview that asked participants to describe a unit indicated an inability to describe the sequencing of instruction within a unit. The ten codes that did not fall clearly within the four themes aligned with the participants' inability to articulate the planning and sequencing of a unit of instruction. These four broad themes along with the inability to clearly explain unit planning and implementation were strong elements in each participant's interview. These similarities were true across the levels of instruction, general or advanced, as well as the multiple school settings.

The scores on the Inquiry Conceptions Questionnaire (ICQ) summarized in Table 4.3, indicated a strong understanding of inquiry as described in the third category defined by Koballa et al. (2008). This indicated that in their classrooms participants had an orientation toward students being engaged in doing science.

Table 4-3

ICQ Scores by Teacher

Teacher	Score for I	Score for II	Score for III
Anna	8.3	33.2	58.1
Dot	16.6	33.2	49.8
Flossie	41.5	16.6	41.5
Jessica	16.6	24.9	58.1
Jimmy	16.6	41.5	41.5
Paul	8.3	24.9	68.4
Sarah	8.3	49.8	41.5
Mean	16.6	32	51.3

Overall it appeared that the group's understanding of inquiry teaching was well developed. When combining the orientation toward inclusion of lab experiences in instruction, it became clear that in thinking about science instruction these teachers thought that inclusion of the processes and nature of science was necessary.

The sample assignments selected by the participants were as varied as the inventory of strategies found during the analysis of the interviews as illustrated in Table 4.4. A sample illustration of Paul's assignment can be seen in Appendix M.

Table 4.4

Sample Assignments Comparison

Participant	Type of Assignment	Teacher or student guided	Vocabulary terms
Anna	***Reading*** – included guided questions photosynthesis and respiration	Teacher	17
Dot	***Project***- compare/contrast mitochondria and chloroplasts	Teacher with student choice of 2 options	17
Flossie	***Poster***-Analogies of cell parts Define and draw	Teacher	24
Jessica	***Computer simulation***- genetic crosses, extended to evolution	Teacher with some student manipulation	18
Jimmy	***Paper lab***-translation-transcription Included follow up mutations	Teacher	21
Paul	***Lab***- examining surface tension with follow-up reading on mosquitoes	Teacher	11
Sarah	***Web quest***- sites defined with questions to answer on DNA and RNA	Teacher	27

Examining the assignments it was clear that very little in the assignments was open to student choice. Even the Web quest and lab activities contained teacher directed questions that looked for right and wrong answers, with little need on the part of the students to compare or use data. For example, the project Dot gave her students required the same information; they merely had a choice of the format for the project. Paul's lesson (Appendix M) is in what he described as a lab format. Every step is defined by the teacher in the directions, and students are told what they will learn during the lab, and the meaning of the data. Flossie's analogy of cell parts contained three pages of directions, an analogy worksheet organized for students to define the organelle, it's function and an analogy. The scoring rubric definition required a full page, and finally there was a two page grading sheet for the posters with twenty four organelles listed examining each for the drawing or description and analogy. In all there were seven pages needed to define the poster project, including the scoring sheets. All the samples focused on a large number of vocabulary terms which reflected the strong emphasis on vocabulary development seen during the interview analysis.

Describing the context

When discussing instruction in their classrooms, all teachers focused on negative factors that impeded their ability to work with students. Many indicated that the students arrived in their classes lacking skills and prior understandings needed for success in Biology. They often mentioned their students' inability to read material with different attributions for the cause. For example, Anna described her need to find books with a lower reading level than the current textbook for use with students enrolled in General Biology classes. She had students reading out loud in class "Because that's something that's basic enough…In fact sometimes what I'll do is everyone has to read one sentence, we'll go around the room" (Setting Interview, p. 4, lines 159-

162). Flossie referred to the difficulty ESL students had with reading English because of their lack of experience with the language. “ But it’s difficult for them because of all the vocabulary in English. That’s not their vocabulary”(Setting Interview, p. 3, lines 101-102). Jimmy even stated “I wish I did not have a lot of reading” (Setting Interview, p. 3, line 129). The focus on vocabulary was not only evident in their continuous use of terms in describing their teaching but also as all teachers emphasized the need to teach the students the vocabulary of Biology in their interviews. As Jimmy stated: ”A lot of what is the difficulty with Biology, ninth grade, is just the vocabulary. It’s just so many terms” (Setting Interview, p. 3, lines 109-119).

There appeared to be a general agreement across participants that the students were immature and difficult to motivate to attend to class-work. Jimmy said “their attention span is very short…they’re not very good listeners” (Setting Interview p. 5, lin3s 206-207). Sarah mentioned the need to entertain the students. “…make it fun, because you have to entertain and give them different ways to go about learning it.”(Setting Interview, p. 1, lines 18-19). Jessica also mentioned the challenge with gaining attention: “Most of the time I only get maybe half the class to really focus” (Setting Interview, p. 6, line 228). Six of the seven participants expressed concern about students who did not participate in class, refused to complete assignments, or even take advantages of opportunities to retake or make up work. Some saw the refusal to complete work a problem arising from the culture of the feeder middle school which they considered too supportive. They found themselves as ninth grade teachers, especially in the fall semester, as the ones who needed to get students to understand the rigor of high school and beyond.

Student misbehavior was an issue mentioned by all the participants and indicated that it diverted them from what they considered their focus as instructors. Participants stated that off task students found other ways to behave and many mentioned separating the off task students from those on task so that they could work with the motivated students better. Jessica had regrouped the seating in her room so that the students who were going to be off task were grouped in one part of the room.

> And the way I have the classroom set up I would have to step over these people who are working and there would be this little group who was, this little group who wasn't and this little group who was. Now I have the room set up, I got all the people who work in one area and then I can just focus on the non-workers. (Setting Interview, p. 6, lines 228-233)

Dot described her dilemma this way when talking about students who are off task. "Who come to class without anything, hands dragging, no pen, no paper. That's tough, and that destroys the whole atmosphere even for those who want to learn" (Setting Interview, p. 9, lines 390-391).

An examination of the instructional strategies described in the interviews indicated teacher centered work occurring in most classrooms. Because of the frustration described above, many discussed their teaching as simplified, basic Biology. Dot said "I find that I've given up those grandiose ideas of them understanding. Let's just understand this little piece right here, and understand it really well" (Setting Interview, p. 2, lines 51-52). Paul talked about giving small, short reading assignments with a few directed questions. All teachers provided guiding work for videos, reading, technology use and activities in class that ensured that the students didn't miss important concepts. Many of the activities described by the participants involved worksheets. Students were involved in doing a great deal of paper and pencil manipulation of ideas. Lectures were described as discussion, however interactive notes were often provided to ensure that students focused on the content the participants considered to be the most important.

Analysis of the data indicates that labs, an instructional strategy considered the mainstay of high school science, were used in several ways. The first was to illustrate the concept being discussed. Sarah described a lab this way "I do diffusion, osmosis. The bag, the dye moving in and out of the cell. Hypotonic, hypertonic" (Setting Interview, p. 3, lines 128-129). Labs also were used as motivators for student engagement in topics. When asked about working on student interest Dot described a Protist lab this way "Like with the Protists. Who the heck cares? But when you look into pond water! Oh, we got a worm! We got a…so at least you know they're interested" (Setting Interview, p. 11, lines 474-476). Finally, Flossie used labs to provide illustrations so her ELL students would have a link to vocabulary.

The participants also indicated that labs were often optional, done only when time allowed. When asked what labs she ran in her genetics unit, Jessica replied: "If I weren't pressed I have some ears of corn that we do. I have a Carolina simulation with some little flippy things that I do, but I'm running out of time. So I do mostly pen and paper activities" (Setting Interview, p. 4, lines 137-139).

Six of the participants mentioned projects as an important instructional strategy. As they described the projects, most descriptions consisted of models, posters, flipbooks, or interactive notebooks that covered extended time periods in the classroom. Dot described a project that involved some research on human impact in relation to a content topic in the course. For the most part the term project was not associated with any kind of research on the part of students either individually or in groups. Data analysis shows that students were usually creating graphic organizers for the unit of instruction, making analogies or writing creative stories that included the vocabulary of the unit. Little library or Internet research was required for the completion of projects, and no data collection was involved.

Throughout all interviews the participants returned to systemic issues that affected their classroom. The conditions set by the school, the system, or the setting in which they found themselves entered into their thinking about every part of their classroom work. The school system curriculum, with its associated benchmark tests showed up in direct references to the curriculum and pacing chart or in indirect references to time constraints. When asked about her inability to have ideal days in the classroom Sarah said “Having too much material to cover. The requirements by the system are insane” (Setting Interview, p. 7, lines 281-282). Several were uncomfortable with the sequencing of the topics especially with the need to start with evolution. Jimmy found evolution a difficult topic to teach because of its place in the sequence. Anna stated “… unfortunately we start with evolution…” (Setting Interview, p. 3, line 118). Just as Jimmy did, Anna found it a difficult topic to connect students with at the start of a course. The pacing chart set out specific time periods within which the units were to be taught. Participants referred constantly to time as an issue that affected instruction. Jimmy stated “Yes, time is the evil thing that jumps in and gets in the way” (Setting Interview, p. 6, line 244). The mandated window for administering the benchmark tests did not allow for full development of conceptual understanding.. Jessica stated “I’m behind the pacing chart and the test is coming up. So I haven’t finished everything (Setting Interview, p. 3, lines 102-103).” When asked if this meant she would omit a topic she responded “I’m not leaving it out, I’m not giving it as much time as I would like” (Setting Interview, p. 3, line 107). The instructional time was perceived as diminished since some class time was set aside to administer the benchmark tests for the system during the course. The participants were unable to go over these tests as follow- up for learning. As Flossie stated, “they want to keep the integrity of it. Can’t let the kids see it and go back and talk about what was right and what was wrong (Setting Interview, p. 5, lines 199-201).” In addition to their inability to use the benchmark tests as a learning tool, the participants reported they were not to use the scores as part of students' course grades. In effect, the time devoted to administering the benchmark tests was time taken from instruction of the Biology course.

The state mandated tests, End of Course Test (EOCT) and Graduation Test, came up repeatedly in the discussions. All participants described one of their major responsibilities was to prepare students for these tests. Dot, Anna and Flossie mentioned success on the tests as one of their major goals for their students. Anna added the reference to test success to her original goal that students learn to love science. "Obviously another goal is to get them the material that they need, the understanding that they need to be successful because like it or not we have the end of course test in Biology that the students must be successful on in order for them to move on to the next level" (Setting Interview, p. 1, lines 11-14). Jessica referred to the importance of taking tests in her room "So therefore I have to try to get them to value tests. Because the [EOCT] test costs 15% of your grade" (Setting Interview, p. 9, lines 388-389). In describing his planning for instruction Paul discussed the needs of the students who were in his class and then went on to add "And then I also look at the EOCT requirements. It's unfair not to look at them. You've got to accept that the kids are going to take a standardized test" (Setting Interview, p. 2, lines 77-79). Many explained their focus on vocabulary as preparation for the state tests. Sarah discussed her heavy emphasis on vocabulary year long as a means to prepare students for testing. "All year long, if you don't, second semester you're not going to get it and you're not going to keep it….that makes it into long term memory or you're dead in the water" (Setting Interview, p. 9, lines 373-375). Anna described being out one day for jury duty and leaving an EOCT review book assignment for her students. "Well what I had them do is, cause they knew I was going to be out, they just had to read a paragraph, answer questions, read another paragraph, answer the question"(Setting Interview, p. 4, lines 144-146).

Within the school day, participants stated that they had difficulty finding ways to support their students. Several mentioned the problem of providing extra support with tutoring and retaking of tests because of bus schedules that brought students to school at the start of the day and took them home immediately after school ended. Three described interactions with parents that were not supportive of achievement in their classrooms. Except for Paul's proactive communication with parents regarding assignments, the usual contact with parents was regarding poor performance in class, or misbehavior problems. Participants stated that those parental contacts have little lasting effect on the students' performance in their classroom. Students did not come for extra help even when parents had been notified of the need. Anna described an AP student who dropped the course after her meeting with student's the parent. "She pulled him out. She didn't want AP Biology to hurt his GPA. The kid was so embarrassed…. " (Setting Interview, p. 8, lines 351-355). Anna and Flossie described difficulties with ELL parents who did not value education highly, but who valued being employed as more important. "You have parents who say, he's not doing well. I'll just pull him out and let him work with me"(Setting Interview, p.. 10, lines 432-433).

When asked to describe an ideal class, all seven participants had the same vision. The classroom would be characterized by students working on their own, enjoying what they were doing and the teacher would be simply guiding them as students took ownership of learning. Flossie's first answer to the ideal classroom was "I hope they'll be laughing" (Setting Interview, p. 6, line 238). All described students in conversation with each other. Paul described these conversations as "Oh this is cool! Let me show you this!" (Setting Interview, p. 7, lines 282-

283). Many others described this kind of interaction between the students. When asked how often they achieved the ideal in their classroom Flossie said twice a semester, Jessica and Sarah said most of the time only half the class achieves this, Jimmy said forty percent of the time and Anna stated “I don’t”. Dot described a classroom where meaningful student interaction was not always possible, so she settled for what she could get while managing the disruptions. These statements indicated that the participants maintained the goals of inquiry teaching, as the ICQ had shown, but were finding it difficult to implement inquiry instruction on a regular basis in their classroom.

All described a desire for students to think, and to make connections between the content topics of the course. Many described beginning units with activities that referenced previously taught topics in order to help students connect the information. Most referred to the inability to teach stand alone units without referring to previous topics. Dot stated “I’m talking about ecology while we’re talking about cells” (Setting Interview, p. 2, lines 66-67). Most described the spiral nature of their instruction. Anna said “I’m trying constantly to try to get them to link. Don’t learn in isolation. Try to go back and think about what we learned before” (Setting Interview, p. 3, lines 109-111). Yet in these descriptions there was a sense of frustration that students did not see the connections. Jessica stated “ If you just memorize what the organelles were and see what they do. Every time I spiral back to it, it’s amazing that they don’t remember” (Setting Interview, p. 10, lines 426-428).

During the interviews each participant was asked to identify a specific unit taught and describe how it was planned and implemented. Although each one could name the unit and describe their first activity, none was able to describe a sequencing plan. Each described many labs, projects, computer work, paper and pencil activities, vocabulary activities, reading and lecture/discussion, but in no particular sequence or relationship to each other. Many did not discuss their student assessment process until asked specifically about it. Many described selecting from previously used instructional strategies, indicating a repertoire of materials from previous years. Jessica, Dot, Sarah and Flossie discussed changes in their teaching from previous years, and were aware of the difference in their selections of strategies for use. Although Sarah wanted to be more student focused, she was finding it difficult. "…but if it's a hard unit, it's going to more me than them. Not that I'm lecturing too much, it's not about that It's the work I'm having to provide for them"(Setting Interview, p, 6, lines 244-246).. Often the difference was related to simplifying the work and getting at the core concepts only, with little enhancement. At one point or another in the description of their teaching all expressed frustration at their incomplete success as teachers. Their standard for success was based on the passing rate of students on the EOCT. Dot stated "I am competitive and score driven, what's the core that they need to understand to understand the concepts that they may see on the End of Course Test (Setting Interview, p. 3, lines 118-120)."

The participants indicated an understanding of an inquiry model that placed the student as the center of classroom activities, with strong tendencies toward creating a hierarchy of instructional strategies. Only Flossie who taught at a majority ELL school showed a strong tendency toward focusing on the content as much as focusing on the students. When asked about her learning goals she indicated an awareness of this divergence of thought.

> …deep in my heart they come away feeling like science is all around us, it's interesting, it's a way of knowing about the world that is infinite and fascinating…Then the really cynical part of me…pass the benchmarks, pass the EOCT, pass the Biology portion of the graduation test. (Setting Interview, p. 1, lines 9-15)

This dilemma was reflected in the scoring of the ICQ. When completing the ICQ, each time the teacher selected an answer from column I (Appendix B) it was related to the need to focus their instruction on ensuring that the students understood the content standards well. Examining the choices from column III indicated that the group did not see lab only as inquiry work, they chose options that viewed inquiry as inclusive of many different strategies. Participants appeared to have an understanding of inquiry, however they were pulled back toward ensuring acquisition of content, as the choices for column I on the ICQ indicated.

The sample assignments provided indicated the focus on content acquisition. An examination of the assignments given to me as exemplars by the participants, regardless of type, was teacher directed with explicit directions and except for Dot's, students had no choices in how to approach the work. Only the diary or museum assignment, had choices for students. However, the content questions for each choice were the same,; the choice was whether to make a museum exhibit or describe a day in the life of a mitochondrion and chloroplast. Only one assignment provided correlated the content focus with previous knowledge from other areas of Biology. The focus of the assignments was on content acquisition, with very little integration of concepts, or applications of the information. True to the teacher focus on vocabulary, most classrooms had word walls with terms associated with the course. These were part of what administrators expected to see when they visited the classrooms for teacher observations.

Discussion

The ICQ data analysis and goals for the classroom expressed in the Setting Interview, indicated that all participants had an understanding of inquiry teaching that included teaching the characteristics and nature of science with content. They did not consider inquiry a method or strategy rather they tended to view it as a means of helping students gain a broad understanding of science. This tendency to want to teach in this manner was reflected in the interviews as they often addressed the need to make the content more relevant to students beyond simply viewing them as topics in science. All teachers referred to using examples and real life application of the content. For example, as Paul discussed the introduction to his unit on the chemistry of life he described eating in front of his students. “We talked about acidity in the stomach (Setting Interview, p. 2, lines 132-133)” The participants also demonstrated this understanding when they integrated technology into their instruction. A highly guided computer simulation on genetics that Jessica used with her students was followed by a more open section of the lesson that allowed students to apply the genetic concepts explained in the guided section to genetic variability and its impact on evolution.

The goals expressed by the participants for their students included understanding the processes of science, application of science in future daily lives, and considering careers in science because of excitement about science. These goals reflected their views of inquiry. The teachers amended these goal statements with references to success on the EOCT. Without exception these goals were referred to first in response to the question about learning goals for their student before any reference was made to test success. This is exemplified in Jimmy’s reflection. Jimmy reflected “I want them to have certain, a greater appreciation for science. That science is a part of our everyday life. It’s just a lot of it is what we do” (Setting Interview, p. 1, lines 24-26).

The ideal classroom described by the participants lined up well with the description of what learners were doing in an inquiry setting as described by the National Research Council (2000). They clearly had a vision of a student centered classroom with themselves as the facilitator of learning. However, two of the participants believed this would be only possible with their gifted classes. They did not see this ideal classroom as one that would be likely to occur with general students. Overall, the participants did not believe their students were capable of working on their own, and thus they approached learning in a teacher-centered classroom. This was reflected in several of the participant's descriptions of students. For example, Anna described a perfect lab situation in which students would examine cheek and plant cells under the microscope and anticipate with questions the difference between plant and animal cells, she regretfully stated "They wouldn't want to poke each other, try to put the onion in someone else's eye, all that kind of nonsense they try to do" (Setting Interview, p. 8, lines 320-321).

The participants did not believe the students were mature enough to have the learning behaviors that would be needed if they were to turn learning over to them. Those who tried were frustrated by the lack of student engagement and misbehavior that arose, diverting the intent of their activity. Some others did not even try student-centered activities because they saw the students' inability to read as an obstacle to their working independently. All teachers focused on the primary task of developing vocabulary, not conceptual understanding.

Although the list of strategies described in the interviews was extensive, many of which lent themselves easily to inquiry-oriented activities, the description of how these strategies were implemented did not indicate a student-centered approach to learning. Response to the interview questions indicates that labs were not used as learning opportunities. Instead they were used to confirm concepts already taught, motivate students to pay attention or give a concrete example of vocabulary terms. The description of labs did not include opportunities for students to use data as a basis for discussion or in creating an understanding of the topic of the unit. Projects, which were required as part of grading in the school system, were seen as simply an alternate means of assessment. The description of the projects involved students showing teachers that they had learned the appropriate content through models, posters and notebooks of various kinds. There was no description of projects as opportunities for students to make connections between topics or life outside the school, consider alternative explanations, or even argue claims based on evidence. There were no descriptions during the interviews of any kind of independent, or group research in either lab or project work.

All participants described connecting concepts so that students could understand the relationship between them. It was clear from their descriptions of how they went about integrating topics for the bigger picture of Biology as a whole that these teachers understood the nature of science. The participants did not want to teach the topics in isolation as they knew often happened in a Biology course. They often expressed frustration that the students did not see the connected nature of the Biology topics, even when clearly pointed out. However, when participants described the activities, labs, or projects, separate topics were the focus of these examples. There was little if any discussion of expecting or helping students with a conceptual understanding of Biology through instructional activities. The relationship between concepts was very clear in the participants' minds as they discussed the spiraling or connecting of concepts for students. However descriptions of how this was done were always through the teacher identifying these relationships for students. They described few activities that encouraged or even helped students make the connections on their own.

It appeared from analyzing the data that the participants assumed responsibility for their students' test results. In many ways they were holding themselves accountable for the scores their students would receive on the EOCT. Even if the original goals for students were oriented to the full set of co-requisite standards, as the interviews continued, the goal that became dominant in the description of their practice was that of student success on the content standards of the EOCT. The state testing appeared to have driven their actual decision making about teaching. Because of this, the participants focused heavily on teacher directed activities, to ensure that they had gone over all the topics that would be on the test, using the language that they considered important for success on the test.

The focus on test success was reflected in participant grading practices. Participants structured their grading around quizzes and tests. Many mentioned the need to get students familiar with tests, since so much of their grade in the course was dependent on test success. The participants often expressed frustration that the students did not understand the goal related to testing in the way that they did. In addition, this goal described by the participants did not seem to help the students focus on their assignments and learning. The school system generated pacing guide and benchmark testing compounded the participants' sense of accountability. They focused on teaching in the blocks delineated by the pacing guide working toward the benchmark tests distributed throughout the year. Analysis of data indicates that the participants had internalized the responsibility for these five tests and were working in the unit segments of instruction to prepare students for them.

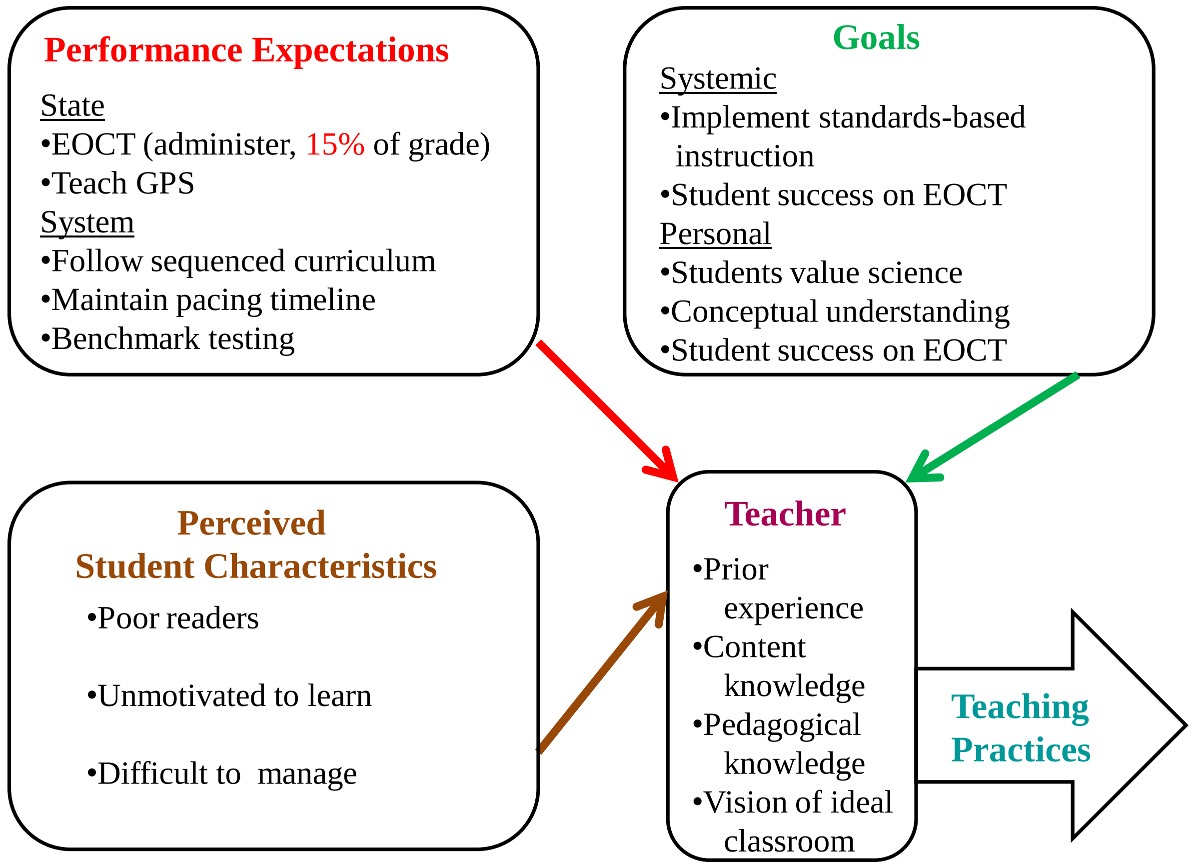
The descriptions of units of instruction focused clearly on the content topic defined. There appeared to be an understanding that students needed to be brought into a unit of instruction, and all could define and explain the first activity. However, after that the discussion became generic, with a listing of strategies used, with no sequencing or relationship between the activities. The larger goals of understanding science processes, thinking, getting students interested in science as a career were lost in the focus on making sure there had been enough activities to bring the content to students' attention during the time allotted. There was not even a description of how to sequence understanding of concepts developmentally within units.

Model of the teaching context

The participants expressed a sense of being caught in a system that expected from them far more than they could provide. The participants indicated that the system provided them deficient students, and they found themselves unable to teach in a student-centered manner because they had to make up for these deficiencies with their instruction. The participants also indicated that they felt locked into teaching a curriculum determined by others, in a timeframe not of their choosing. The accountability measurements emphasized in their minds their lack of control over how they would go about teaching. Their ideal of what a good science classroom would look like aligned well with inquiry in theory. However in practice, they found themselves unable to figure out how to reach these ideals in the midst of their current setting.

Four factors appeared to interact together leading to the kinds of teaching practices described by the participants in this research. Participants were very aware of the performance expectations that the state and the school system had for their work. They were also very aware of goals the system had for them to achieve as well as their own personal goals. Participants examined their students as they interacted with them daily and had come to develop a description of these students as deficient in many ways. This view of students impacted how they approached their teaching. The final factor was the individual experience each brought to the teaching from prior years of work, pedagogical and content preparation, mediated through their vision of an ideal classroom. When all these factors interacted the participant selected teaching practices that they thought would lead to as much success with students as possible as measured on the EOCT. The model in depicted in Figure 4 contains the broad categories as well as the components identified through the interviews and ICQ analysis for this specific group of participants.

Figure 4 Contextual factor interactions



All teachers have performance expectations set by others. In their study, Tobias and Baffert (2010) also found this to be true.

> What we learned is that secondary science teachers have little or no say over their own teaching assignments, over budgeting for lab materials, or-when and if science is added to No Child Left Behind-over the content and pacing of their lesson plans (p. 6).

These factors come as a part of the job description, and must be met as part of retaining the job. In the case of these specific participants, the expectations within their school from local leadership did not appear to be a factor in their work environment. The state's expectation that they would follow the Biology GPS in their instruction and administer the EOCT making it worth fifteen percent of the course grade guided instruction. They school system had also made this a part of the expectation for job performance and was reinforcing it through issuing a sequenced, paced curriculum. In order to ensure that students were on proper pace to be prepared for the EOCT at the end of the course, benchmark tests, centrally distributed and collected, had to be given within the time window of the pacing chart. Although the system was highly diverse demographically, and academically, all classes of ninth grade Biology were required to follow this timeline. Because these benchmark scores were reported and examined by the school system, the participants described their efforts to maintain these expectations, often to their frustration at an inability to meet student needs.

Part of the reason for the paced sequence, tied to benchmark testing was related to the school system's goals for students in Biology. The system wanted students to experience standards-based instruction. The paced curriculum contained a content sequence fit to the timeline. However, it also contained the requirement that the Biology teachers follow the co-requisite characteristic and nature standards as they implemented the content sequence. Pacing the curriculum helped ensure that the students in all classrooms would have the opportunity to learn the entire set of content standards. This appeared to be important to the system since they also expected student success on the EOCT. These scores were public information, and the system wanted to ensure that students had an opportunity to be successful. The participants also had a goal of student success on the EOCT. Since the grade for the course was partially based on the EOCT score, it affected student success in their individual classrooms. The participants spoke of other goals for their students that were more abstract than success on a test. They spoke of a desire to help students gain a conceptual understanding of science so that they might come to value the role of science in their personal lives. While these were additional goals, testing success for students appeared to be a primary motivator and guide for the participants.

As the participants tried to implement the expectations of the job with the school system and personal goals, they examined the needs of their students. It was important that the instructional design of their class take into account the needs of the students. In this case, what the participants described were students who were not prepared to reach the high level of success that both they and the school system wanted on the EOCT. They were faced with a dilemma of how to teach in a standards-based manner, which would help their students learn not only the content but the characteristics and nature of science, and also have the students be successful on the EOCT. The participants had formed a mindset that the EOCT was a content focused test. This was reinforced by the school system curriculum sequence with detailed descriptors and sequencing of the content co-requisite standards. The characteristics of science co-requisites were described in the curriculum in one sentence encouraging the inclusion of these. Standards-based instruction required that participants allow their students time to develop the conceptual understanding of science the participants valued, yet the ability of the students to work independently and the time frame of the system curriculum were issues they were finding hard to resolve.

As experienced teachers, the participants brought backgrounds of having problem solved instructional issues with multiple sets of students in previous years. Most had spent their entire career teaching within the same system, so they understood well the nature of the students in the school system. All had graduate degrees which helped develop a depth of content and pedagogical expertise. Because they had been teaching for several years, all had also experienced a great deal of professional development intended to enhance their pedagogical skills. The participants retained a vision of a student centered, teacher guided classroom. They all had the preparation to manage the expectations, goals and students.

Despite all the experience and expertise, participants described an inability to achieve their vision of an ideal classroom on a regular basis. Was this sense of helplessness and inability to carry out their inquiry orientation brought on by their own redefinition of success based on the institutional goal of test success, or were they simply unable to control their circumstances to the point that creativity as a teacher had been lost? Creating professional development for Biology teachers in this setting required offering opportunities for them to bring their creativity to problem solve using their personal resources. It might be possible that if Biology teachers were given the opportunity to reflect and alter their practices through a personalized, reflective professional development model they would solve the dilemma they had created of ideal versus reality of practice.

CHAPTER 5

Individual Professional Development Case Studies

The advantage of the case study is that it can 'close in' on real-life situations and test views directly in relationship to phenomena as they unfold in practice (Flyvbjerg, 2006, p. 235)

Examining Individual Growth

This chapter describes the experiences of four participants in Phase II of the study. Each participant, Jessica, Paul, Dot and Flossie, was unique in many ways. The response each exhibited to the opportunity to grow as a professional is best described through the use of case study narratives. The cases were written in a manner that allows the reader an opportunity to bring their own personal understanding to the stories. Flyvbjerg (2006) stated that one of the strengths of case study research was its ability to relate the understanding to the personal experiences of the reader. "The goal is to allow the study to be different things to different people" (p. 238). Keeping this advice in mind, each case starts with a description of the specific context of the participant, followed by a description of the individual response to the implementation of the professional development model. At the end of each case is a short analysis of the professional growth exhibited during the time of the research, as well as a recommendation for further professional development that would allow the participant to teach Biology in a standards-based manner, as described in the literature and mandated by the Georgia Performance Standards.

Jessica- From Test Prep to Student Prep

Context. Jessica discovered teaching as a career thirty years ago when the major professor in her Ph. D genetics program died. A career as a geneticist was gone with no one to guide her research. Jessica realized how much she had enjoyed teaching as a graduate assistant, and became alternatively certified to teach. At the time of the research this African-American teacher worked at a mixed income school with mostly African-American students that had not made appropriate Adequate Yearly Progress (AYP) in the preceding years, and was under mandated support from the State Department of Education. Jessica had an undergraduate and a Master's degree in Zoology. She stayed current with her content through summer experiences in research and AP Biology seminars. Her pedagogical growth was through sporadic general professional development with the school system, and conversations with fellow teachers.

Jessica expressed a frustration at teaching Biology to ninth graders due to her perception of the student's immaturity. Her inability to teach as she would prefer was complicated by the lack of time available to her as she tried to teach a full year Biology course on a one semester block schedule. The curriculum sequence and its pace mandated by the school system, previously enforced with benchmark testing, made Jessica feel that others controlled how Biology was to be taught to her students. Although the benchmark testing did not count on student grades, she still felt accountable for student success on each test.

> I got to get these benchmarks in. It doesn't matter what the data is. But you know in the back of your head, well my kids are off, and it's showing up. So it does count….It's documented some place, yes it is. It does count. So I'm always adjusting, trying to get it to look better. It can't look better unless they are better. (Jessica, Initial Interview, p. 7, lines 301-308)

Jessica continued to refer to this thinking even after the unit benchmarks had been replaced by one end of semester test. This thinking was related to the pressure she was feeling to meet annual yearly progress for the school. There was serious talk at the time that Jessica's student scores on the state end of course test would soon become a part of her annual evaluation.

As the department chair, Jessica was often juggling these responsibilities with her teaching. "I found Jessica as she was running around because she had three teachers out in her department and as department chair she had to get the materials to the substitutes" (Field Notes Observation #2, p. 1, lines 3-4). The school system required that the day's focus and plan be written on the board. If Jessica were visited by an administrator, part of her evaluation would be based on the information on the board. On the day I observed, this added to the things she had to get done before the students arrived.

> Jessica then went to the whiteboard where the pre-made arrows pointed to the day's sequence and started writing: Next to *sponge/warm up*: USA Test prep questions. Next to *work period*: Period 10 Predator/prey lab, Periods 30, 70 Kesab wetlands energy flow. Next to *closing*: Quick write about activity. (Field Notes Observation #2, p. 1, lines20-26)

Jessica's commitment to lab work in science could not be questioned. If she were not an organized person who valued structure, it is possible that she could have become overwhelmed by all she was expected to do on a daily basis.

Professional Journey. Jessica had developed a manner of teaching that depended on a great deal of structured work on the part of the students. She had participated during the school year in professional development about thinking maps, a form of concept mapping. Students spent nine of the twenty days in her log creating thinking maps during class time. Students maintained a structured Interactive Notebook that required six pages of directions to explain its components. A great deal of the grade in the course was dependent on constructing the thinking maps, often with peer review included, and maintaining the interactive notebooks. Her description of these notebooks emphasized the importance she placed on them as a study guide for the EOCT.

> That's on the right hand side. On the left hand side I do all of by GIZMOS [computer simulations] and we do the circle maps, and we do the concept maps, the vocabulary, all that's on the left side. So they have everything in their notebooks. (Starting Interview, page 6, lines 235-238)

As she explained her understanding of the curriculum, Jessica focused on the need to get through the content topics. She had indicated during the Phase I interview the she was uncomfortable with the previous year's mandated school system sequence, and during the fall semester the new system sequence had not worked well with her students. "I'm biology sequenced, I can understand the topics. I can make it fit. But see, I understand it. Getting them to understand is another… So I found that we use...I teach the topic. I teach these topics" (Starting Interview, page 4, lines 144-146). Because test scores were not up to her expectations she was changing the curriculum sequence during spring semester.

Jessica's major resource for students to use was a commercial set of test review books. These were on the tables at all times, and were used during class when students worked on creating thinking maps. Jessica had a substitute in her class five days during the four weeks she kept the log because she had been pulled from teaching Biology to ninth graders to spend time leading graduation test review sessions for the juniors and seniors at her school. During her absence the ninth graders in her assigned classes used these test prep books four days and on the fifth there was a general review sheet with vocabulary and questions identified as the EOCT Domain Cell to complete. During the course of the four weeks her log indicated that the ninth grade students worked through sections 31-35 of the test review book.

As we discussed Jessica's understanding of integrating the co-requisites Characteristics of Science into her teaching during the starting interview, she mentioned labs, demonstrations and employing the scientific method. She found teaching a full year of Biology in a one semester block an impediment to doing projects and reading articles."Well my kids have to cover so much material in a short period of time, …" (Initial Interview, p. 7, line 280). Jessica perceived that taking time to do long term projects interfered with her ability to get the topics taught.

Over the course of the four weeks Jessica's students participated in three labs. These labs took multiple days to complete filling six of the twenty days recorded in her lesson log. Two were on days I observed the class. The first one had been especially adapted to accommodate use of the materials available, as well as the occasion. When I asked her if thinking about the co-requisites made the lesson richer, Jessica responded "I always think of the scientific method" (Lesson Review #1, p. 4, line 143). The second lab was developed commercially and came with a kit. The directions for running the activity as well as processing the data on the handout were highly prescriptive. Jessica had used the lab often in the past and thought it helped students understand the ecological concepts. But it also helped them prepare for the EOCT. " …and it sets them up for when they take the test being able to understand tables" (Lesson Review #2, p.4, line 136).

The second Log Interview appeared to indicate a change in thinking on Jessica's part. Up to that point the Content standards had been identified very specifically by element in her log. Each standard has four to six elements that described it. However, the Characteristics of Science co-requisite standards were identified in the log only by number. As we compared the standards and elements I had noted in the lesson I had observed to those she had noted in the log for that day, Jessica was amazed to see how many more content standards she had taught than noted in her log. We had a long discussion about the elements of the Characteristics of Science standards and the possibility of focusing on these as she thought about her lessons. From that point on, her log listed the elements for both co-requisite standards. When asked during the first lesson review how she would elaborate on the lab with her students, Jessica's response was "They were supposed to read the entire lab and then decide how they would. They did not do that….If they had planned they might have been able to figure out what they were going to count" (Lesson Review #1, p.2, lines 62-65). When asked the same question about the second observation that followed our discussion about noting co-requisite standards in the second log review, she responded "So I'm going to let them think about what they did and then we'll do a follow up" (Lesson Review #2, p.2, lines 85-86). Her thinking about the lab throughout the first review was focused on procedural issues, and during the second it was on student thinking and enhancing the lab itself to create better data for discussion. After the second Log Interview, Jessica no longer used the term scientific method even though we had not had any dialogue about that term. The discussion became far more specific as she used the characteristics of science terms in the elements of the standards.

During the Reflective Interview at the end of the study Jessica revealed the insights she had gained through the professional development. According to Jessica, one of the biggest was 'Well, what I realized was that I was using them [Characteristics of Science standards]. I hadn't paid real attention to it. I'd been so busy with the content and I always realized that the scientific process is necessary" (Reflective Interview, p. 1, lines 6-8). She had plans for modifying the work in her classroom so that she could use these scientific processes to her advantage for teaching content. She did not plan to add new activities, rather "I would like to expand on them to get into the research or the reading activities that I don't do…To incorporate that into it without too much time" (Reflective Interview, p. 1, lines 35-38). She explained that she was getting at most of the first six Characteristics of Science co-requisite standards, but not the last two listed which are related to the nature of science. It is these that she hoped the changes would help her address. "Right now I don't think I ever put seven and eight in there" (Reflective Interview, p.2, lines 58-59).

Jessica indicated that she wanted to eliminate the use of the review books in her classroom. The thinking maps would be used for the students to "…visually demonstrate the concepts that we are talking about, the textbook, the lab" (Reflective Interview, p. 5, lines 188-189). She reflected on a change in her thinking that would be needed to use more class time for students to process information, rather than for direct instruction. "I guess if I would not worry about the end, and focus on the process, maybe I could accomplish that" (Reflective Interview, p. 6, lines 245-256). She admitted that she is struggling with the idea of being less directed in her instruction.

Jessica chose three labs to discuss as lessons that blended the co-requisite standards well; her focus was on the understandings the students gained from the lessons. Jessica described the content learning in the labs, the process learning, and the manner in which the labs helped sequence the learning of future topics. She thought the process of students thinking about the data collected enhanced their content understanding, visualization of concepts, and processing skills. One of Jessica's biggest surprises during this time was the realization that her students liked the structure of her class and really enjoyed the work. "I hear them sitting here making comments that they can't stand me. But then 'this class didn't last that long'. 'Ooh, we did this!'" (Reflective Interview, p. 7, lines 281-283). Instead of focusing on her student deficits, she was talking about the positive events of her class.

Overall, Jessica did not stop referring to the EOCT in our conversations. However, as the six weeks progressed, the prominence of the testing preparation became secondary to her focus on student learning. As she discussed reorganizing her teaching to allow more time in class for data analysis and discussion, Jessica described it as creating "more quality time" (Reflective Interview, p. 6, line 231). Jessica was beginning to focus on her ability to manage her class and less on the management restrictions imposed through time, curriculum, testing and students.

Analysis. Giving Jessica opportunities to reflect on her teaching as she worked within her school brought about quite a bit of change. At the start she spoke often about the negative work habits of her students, the limitations of the time available, and her inability to achieve the success she wanted with student scores on the EOCT. She was a participant in this professional development experience because her responses during previous research had revealed these very issues described in Phase I of the research as constraining her teaching. Jessica taught in ways that focused on the content and specific lab skills needed for test success. Her focus was on the group success as described by Hilliard (2000) and Seashore, et al. (2005). Jessica began the process teaching with the limited scope described by Valli and Buese (2007) as she was focusing on the making sure that the information was taught before deadlines, without flexibility based on student needs. Jessica stated in her Starting Interview: " So I just, I try to get as much information as I can and I move on. Simply because there's no point in spending too much time on it." (p. 5, lines 199-200).

As Jessica reflected on student work in the observed classes, she noticed the thinking the students displayed as they figured out ways of collecting data. She was surprised by their ability to work collaboratively and creatively. Some of the insights they gained from processing the data caused her to rethink the possibilities of how to use the labs as instructional activities for content. Jessica was beginning to see the potential rather than the limitations of her students. As she considered adding more time for data processing and discussion in her classroom, Jessica began to consider relinquishing control of learning to her students.

Jessica's focus on the Characteristics of Science standards was probably the most influential factor in her rethinking of her instruction. She went from talking about the scientific method, to discussing scientific processes. She began to differentiate science skills from the nature of science as described in the standards. Some of Jessica's most creative thinking came from her desire to find ways to expand her teaching activities so that she included more opportunities for students to experience the nature of science.

Overall, the data analysis indicates that Jessica was beginning to retake control of the factors in the classes that she previously seen as limiting her work. Test success was still important in her mind, but the way to it was no longer through the structured review and notebook path she had previously followed. She began to discuss eliminating the use of test review books as resources and using the textbook more. She wanted to restructure class time so that instead of spending so much time building thinking maps, she would work on data processing, reports, presentations, and discussion. The thinking maps were discussed as homework that would help students relate concepts throughout the course.

The lack of success with the system's curriculum had already started Jessica's thinking about change. She was implementing a sequence this semester that aligned better with her approach to Biology conceptual understanding. The elimination of benchmark tests at the end of the system units had allowed her this flexibility. In some ways, before the professional development began she had already begun to rethink some of her practice.

Jessica did not have an opportunity to implement the changes she considered during the professional development time. Although six weeks of reflection brought about changes in thinking, more time and interactions with further professional development experiences would be necessary to implement these. As a researcher I was left with a big question: can she alter her practice once the professional development has ended and the opportunity to reflect with me no longer exists? Additional time and data collection would be needed to answer this question.

Paul-Telling stories and creating experiences

Context. Paul had been a teacher for thirty years when this study was conducted. He majored in Biology with education as part of his undergraduate degree. He minored in Chemistry and Psychology. After earning an M. Ed in science education, he described maintenance of his content knowledge as self taught. He read things like Scientific American, and science-related web sites. He had continued to develop his pedagogical understanding by earning both special education and gifted certifications. Paul placed great value on learning from fellow teachers. “I think I just got older and figured it out…I think the truth is, I learned from people that have taught longer than I” (Initial Interview, p. 2, lines 51-54). However, he did have a sense of where he was in his career when he stated “Unfortunately I’m on the other side now and people look and say ‘How are you doing?’ So I get less of that because I’m older” (Initial Interview, p. 2, lines 56-56).

After teaching in a private school for some time, Paul returned to public school teaching. The school where he taught at the time of the research was located in an upper-middle class, mostly White neighborhood where as a White teacher indicated that he fit in to the community. Because of the school system openness to movement between schools, students from various areas of the highly diverse system were bused to fill open slots. This made Paul's various certifications an asset to his teaching since he taught inclusion and gifted classes. The class I observed during the research was an inclusion special education class that Paul taught with the support of a special education teacher. It was a diverse class and included ELL students, as well as the special education group. Demographically it reflected the diversity of the school system with African American, White, and Hispanic students all represented..

The school ran on a year-long schedule. Paul never mentioned concerns about the amount of time allotted for the course. As a student-focused teacher he saw himself as the "Papa Bear" of the children in his class, as the poster in the classroom proclaimed. His greatest concern was the number of students assigned to him on a daily basis. When describing how he tested his students Paul felt his testing practice was altered in response to the numbers in the class. "I have 150 kids just no way for me. I try to do two or three grades a week. Just can't do it. Tests are usually one hundred questions, mine are about twenty" (Initial Interview, p. 6, lines 248-251). He was in some ways overwhelmed by the extensive amount of diversity among his students, and his need to support each.

> I can't tell you how many Title IVb plans, how many SST plans, how many special ed, how many ESOL, how many gifted, how many that don't fit into those categories that probably should. It's an almost impossible task. (Reflective Interview, p. 4, lines 177-180)

Despite the assessment of an almost impossible task, the numbers did not stop him from running labs with his students at the rate of about forty a year by his estimation.

The school was in the process of renovating its facilities, so about twenty teachers had been moved to a "learning cottage" park next to the parking lot. Paul was one of these. In an effort to make it attractive he had scattered seeds throughout the area and planted bulbs outside his classroom. There were planters with pansies growing at each trailer and a poured concrete sidewalk. However, when it rained water backed up throughout the area and students and teachers had to dodge the puddles to move between classes. Paul was the only science teacher in the trailers. The mid-year move was a factor in Paul's thinking about his teaching. He had been in the long, narrow trailer, packed with desks for thirty-two students for about two months when the research began. I noticed the girls were seated on one side and the boys on the other. Paul admitted he had seated them that way for classroom management and compared the situation in the trailer to his classroom.

> In the classroom it's not an issue because it's a large space. But in the trailer there's really not much room for. I'm doing everything I can do to minimize the interactions that are negative in the smaller space. (Lesson Review #1, p. 1, lines 27-29)

Compounding the lack of space and resources was his less than optimal interactions with the inclusion teacher assigned to work with his class. She was new to his classroom this school year, and he was having difficulty working smoothly with her. Paul explained that he expected her to teach something each day. Paul indicated that his previous experience with an inclusion teacher had been highly cooperative and this was making his adjustment to the newly assigned teacher more difficult. "She's a new co-teacher for me this year. I had one that I had for…we worked hand-in-glove. I think we could read each other's minds. It's been a much harder struggle" (Lesson Review #1, p. 3, lines 99-101). Paul was still in the process of figuring out how to work under the new conditions in terms of both space and co-teaching he had been assigned that year.

Professional journey. Paul saw himself as the interface between science content and his students.

Paul: I like the written and spoken word. The foil between two moving parts. I like being the person that brings the understanding scientists

Marion: Like both sides?

Paul: I do. I like being right smack in the middle. (Initial Interview, p. 1, lines 32-26)

Because of this he spoke often of telling stories in his classroom as a strategy for teaching. “I tell stories. Stories are the way to go” (Initial Interview, p.4, lines139-140. His log reflects this approach since he included eight days in which videos were shown and two with a movie. He used ten out of the twenty five days in his log to bring stories of science visually to his students. He specifically discussed linking viral infection and protozoan labs to videos that helped the students complete their understanding of the two lab experiences. Paul used his own story telling, movies, and science videos in his classroom as a means to develop concepts through images and stories.

The data analysis indicates that Paul’s major focus was on the needs of the students in his classroom. He indicated that he did not necessarily follow the school system curriculum sequence because he thought “It stands kids off. They don’t have the background to understand it” (Initial Interview, p. 3, line 96). He went on to say that this had always been his approach to the standard school system curriculum. Student needs were always primary in his classroom. “You need to do what the kids need to do, and not what the county tells you to do. You don’t feel like you’re doing right by your children…”(Initial Interview, p. 4, lines 161-163). Paul was more focused on student success on the EOCT, and thought his principal was in agreement since he had received no concerns from him when during the previous year his students’ system benchmark scores had been low. This had happened because the curriculum in the classroom did not align with the system's sequence.

The general success of his students on the EOCT encouraged Paul to continue teaching the sequence he preferred. "And my scores are pretty high. So I think of all the things, my way is how successful people do it" (Initial Interview, p. 3, lines 105-107). His way was to begin with foundational concepts, working toward the larger concepts, such as evolution. Although the school system curriculum divided the units into equal time portions, Paul thought it was important to take his time as he built the foundation for understanding the larger concepts. "The first semester is slower. So the things that I would call the building steps, these have greater weight" (Initial Interview, p. 3, lines 112-113).

The sequence for the Biology course that Paul organized followed the small to large described in his ideal course. Yet, even though this was the overall general plan, he referred to integrating various concepts throughout the course. "I go to the five big GPS and I weave something about it into everything" (Initial Interview, p. 5, lines 190-191). Yet, when he described his testing, it was limited to the current chapter. An examination of the log indicated that Paul's content focus for the five weeks had been mostly on the third GPS which related to classification of organisms. There had been some reference to the fourth GPS about relationships between organisms. On the last two days before the spring break the movie shown by Paul to his students had focused some on DNA, RNA and DNA technology. There was very little weaving of topics evidenced in the log and handouts he included. Paul appeared to have the big picture in his planning; however it did not seem to be conveyed during his practice. The classroom activities were focused on the content of the unit, and with the exception of the movie, little linking to other areas of Biology was seen.

Paul had a plan for building competence for the EOCT throughout the year. During the first semester he focused the start of class around the word of the day, building vocabulary competence. Once the second semester started, he had developed fifty questions of the day as review for the EOCT. His approach was "I'm a squirrel. I put a little bit away, every day" (Initial Interview, p. 6, line 227). The questions were given in a random order so that it simulated the EOCT. "You don't know the order of the questions you're going to be asked on the EOCT" (Initial Interview, p. 5, lines 221-222). Students maintained the collection of these fifty questions and turned them in for a grade at the end of the sequence. Paul returned the questions once graded because he considered them to constitute a great review packet for the test.

These fifty questions were an essential component of Paul's second semester instructional plan. True to his explanation, the twenty-three questions in the log related to all five Biology GPS in a random sequence. On both days I observed, he began the class with a question projected to the whiteboard as the students arrived. The first day the discussion of the question took fifteen minutes of the fifty five minute class, and the second day it took ten minutes. On both days Paul had labs for the students to do with the remaining time. When asked to consider using the time for lab and postponing the review question, Paul had difficulty considering this. "I always contemplate whether I should move the questions around the next day I do that thing, it's always 'Oh, we do a question today?' Then you got the other side, you've now broken the routine" (Lesson Review #1, p. 4-5, lines 180-183). Although Paul indicated that he considered the lab experience important, the review for the test took precedence in his allotment of instructional time.

Paul's estimate that he ran about forty labs a year aligned with the sequence in the log. Each of the five weeks of the study he devoted one day to a lab activity. If there was follow-up work to the lab, it was done through a video. Students did not spend much time processing lab data. He described the process of collecting data and thinking about as more important than the actual knowledge acquired.

> Why do you say that? What would lead you to that conclusion? What scientific knowledge do you know that leads you to that? A lot of it is…the questions the experiments that I do. I think these are critical. I actually think this is sometimes more important than the shared knowledge. In order to look at problems, very important. I don't include them on my lesson plans, but I never forget these. (Initial Interview, p. 7, lines 285-290)

An examination of the five labs done during the course of the professional development indicated Paul's strong focus on content and the language of Biology. There was some openness to varied responses in the lab calling for students to create a dichotomous key and grow bread mold. For the most part, all labs were very directed in their instructions, with little need for students to process the data to arrive at any answers to the lab questions. My analysis of the two observed labs indicated that neither met any criteria for inquiry on the rubric from Essential Features of Classroom Inquiry (Appendix A).

My first observation in Paul's classroom was of a viral transmission simulation lab. Three exchanges of liquid were needed and Paul controlled the process of exchange, step by step, verbally directing the students. The data from this activity could have been used as a statistical study of viral transmission; however the students did not collect enough data for the process to happen. A critical step was left out of each exchange for sufficient data to be collected. During the first lesson review we discussed how Paul had processed the data with his students.

Paul: Saw a video the next day. They got it. They understood the significance of the viral pool. It was heartwarming.

Marion; Kind of pulled it together for them? Did you ever go back and try to get them to figure out?

Paul: We tried a little bit. It didn't, it wasn't going to work. (Lesson Review #1, p. 2, lines 57-61)

Although Paul seemed to value the process skills of science, his lab was far more focused on developing content understanding than data analysis skills. Students did not get the opportunity to analyze the data and develop an understanding from that process. Paul described to them the meaning of the data in terms of speed of transmission of a viral infection.

Maintaining the log required Paul to describe what was in his head. This was not easy for him to do, as evidenced by the progress of the notes in the log. Before the first log review he had not marked any co-requisite Characteristics of Science standards. He had been totally focused on the content standards. Some co-requisite standards were added after the visit, as seen by the use of a different ink color. At the second log visit, when we discussed the differences between the standards I had seen addressed in his lesson, and the ones he had marked in the log, Paul was surprised. He had not included the Content standards of his EOCT review question, or the review at the end of class. His focus had been on the main lab activity. We agreed for the most part on which Characteristic of Science standards he had addressed, however mine had been more specific to the element, rather than the broad standard. Following our discussion that day, Paul's log changed so that both Content and Characteristics of Science standards were noted at the element level, rather than broad standard numbers. During the second observation we were still not marking similar elements in the standards. After I described the standards I had observed Paul was surprised. “I didn’t realize I was doing those” (Lesson Review #2, p. 1, line 11). Overall, he marked few of the Characteristics of Science co-requisite standards. The ones marked the most were exhibiting curiosity, investigating problems, and communication. He did not identify either of the ones related to the Nature of Science, number seven and eight of the co-requisites. He saw them as behavioral standards, difficult to define. “I don’t think they’re well written at all from my perspective. I don’t, they’re trying to take a behavior and quantify it. And I don’t know if that’s doable with human behavior that they want us to do” (Reflective Interview, p. 2, lines 77-79). Despite his concerns, on eleven occasions he marked the standard that called for curiosity, honesty, openness, and skepticism.

As Paul reflected during the final interview about what he might have learned during the process, he came to realize that his focus on diversifying instruction needed to include the science co-requisites.

> I don’t think in those co-requisite things. I think more in terms of diversity of presentation to students. The concrete students especially, I think it’s important to vary instruction. So, I don’t think in term of the co-requisites. I think more in terms of content. How can I teach this in a different way? (Reflective Interview, p. 1, lines 25-29)

His special education and gifted certification had given him many skills on diversifying instruction. However, Paul was beginning to understand that the co-requisites called for more than diversification; they called for developing specific skills. He admitted that he had been forced to look at the co-requisites through logging them. Paul had not previously examined them for specific guidelines; they had been in the background of the content standards. He was beginning to include them as part of his teaching focus. “How can I not only vary my mode of presentation, how can I make sure that I’m getting those particular co-requisites?” (Reflective

Interview, p. 1, lines 35-37). He admitted that keeping the log had been "doing something unsavory" (Reflective Interview, p. 2, line 46) , but had been well worth the effort.

Paul found it difficult to assign a grade for student competence of the Characteristics of Science co-requisite standards. He saw them as something he kept in his head, and therefore hard to define for grading students. Yet at the final interview he was beginning to consider the possibility of creating a rubric for evaluating some of these standards. "You could have a standard set put them up there and say, a, b, c" (Reflective Interview, p. 4, line 142). He was starting to envision a set of criteria for the co-requisite standards. His students would be aware of all of them, and be directed to the applicable ones during a given lesson. Getting a way to make the standards visible to his students was still in a formative stage in Paul's mind.

Analysis. Paul's view of himself as the "Papa Bear" of the classroom indicated his need to take care of his students, who he always referred to as children. Based on the analysis of data, it appears that Paul's ability to reach Southerland and Evans' (2008) description of an inquiry teacher who could give students ownership of their learning would be a long journey for him. Paul indicated he had two-way conversations with his students. "It's a dialogue, a dialogue back and forth" (Initial Interview, p. 6, line 241). Despite his stated perspective, during both classroom observations his questions to the students were directed at verifying their understanding, not probing or open questions. Although the class I observed was orderly and friendly, Paul indicated he did not have full confidence in his student's ability to work independently. Before starting both labs he had students read the directions aloud, and then he went over them verbally. Throughout the lab activities, Paul continuously reminded them of the procedures. When we reviewed his second lesson his response about modifications he had made indicated a lack of trust that the students could understand even the directions. "I brought my level of language down, actually. My language, my word questions. (Lesson Review #2, p. 1, lines 16-17). The feedback given students during both observations related to finding the correct answers to the questions. During my second classroom observation, a mushroom dissection lab, all the questions for the lab write-up pertained to content verification. Students were instructed to use their textbooks for help. At one point it was clear they were having difficulty finding the answers so he made a general announcement of how to use the book to find answers to a specific question. "Paul reminded the students to use the index in the back of the book to help them with their questions" (Field Notes of Observation #2, p. 3, lines 92-93).

When discussing the co-requisite standards related to characteristics and nature of science, Paul continued to use the term scientific method throughout all our interviews. It was clear that as Diamond (2007) found in his research, Paul focused on the content of the test rather than the broader scope of learning associated with a Biology course. When I asked about assigning value to these co-requisite standards, Paul explained why this did not happen much in his classroom. "The reason I think that's true because the test is always content based" (Reflective Interview, p. 4, line 148). His priority for instruction was still related to the need to prepare students for the EOCT. He understood that students could be prepared to pass the test without labs, but valued them enough to always include them as a part of his instruction. It costs him out of pocket about $20.00 per week, yet he includes them. As he described the reason for doing labs, Paul focused on creating interest for students. "They like the idea no matter how goofy my labs are, they like touching stuff and looking at stuff. They know the difference between a computer lab, a paper lab, and a real lab" (Reflective Interview, p. 7, lines 285-287). It is clear Paul still viewed science labs as the way to include the co-requisite standards. Yet when describing the lessons that best integrated the standards he chose a movie because of his favorite co-requisite, curiosity. Paul had an innate sense of the importance of the co-requisite standards, but still needed more guidance on how to fully implement lessons that focus on student acquisition of those understandings and skills.

The analysis of data indicates that changing the way Paul approached the class was clearly difficult for him. Paul indicated that our conversations helped him rethink what he was doing.

> First it made me frustrated. Because I know that this is not exactly the way I would do it given a different situation than what I have. But it reminded me that I need to go to that standard in my head as much as I can. In terms of, and not just stick in my head. (Reflective Interview, p. 2, lines 66-69)

He was starting to reconsider his practice, yet when he discussed how successful placing the protozoan video after a lab had been, Paul was still slow to consider changing the order next time. The arrival of the protozoans early had brought about the change. Paul found it difficult to rethink resenquencing of instructional activities in such a way that students could begin the learning prior to his direct instruction. He had a system that worked well. “It fits well with my vocabulary, lab, video kind of scenario. That’s the typical pattern” (Reflective Interview, p. 12, lines 491-492). Paul would be willing to change, it was beginning, but further conversation would be needed. Keeping the log helped, but it was clear Paul needed further feedback and dialogue to be able to process his thinking and enact change

Dot-Making biology understanding accurate and relevant

Context. Dot had spent eighteen years teaching Biology when this study was conducted. This was her specialty having earned an undergraduate degree in Biology followed by an M. Ed, and a Ph. D in Secondary Science Education. By the time she had been in the classroom eleven years, she had already taken over twenty two hours of graduate Biology courses, and earned her PhD. Maintaining her content knowledge afterwards was through summer research internships with scientists, and preparing herself to teach college level courses in the evenings. Dot thought that her work revising the AP Biology content for the College Board had also added to her professional growth. "So that made me have to go and look up something when we have a debate over it, or somebody else says something" (Initial Interview, p. 1, lines 41-42).

Her pedagogical preparation had come from her graduate degrees. She found little in the professional development taken over the years that had added to her pedagogical understandings and skills. She thinks that being reflective over what happens in her classroom was her main way of developing her understandings and skills.

> I'm always looking to do better because my students do not have 100% A's. So there's always better. Sometimes I find I revisit old ideas that for whatever reason I dropped it. Now I feel more invigorated, or this time I can make it work. So I pick up old things and try it again. (Initial Interview, p. 2, lines 75-78)

This sense of herself as having a good pedagogical repertoire was reinforced through her great success presenting to overflowing rooms at the state science teacher's conference.

Dot, an African-American teacher, had been at her current school location for over fifteen years. Although the school began grouping ninth graders into an academy with specialized teachers and space, she continued to teach AP Biology in addition to her ninth grade Biology classes. During the year long school schedule she taught two levels of introductory Biology and AP Biology. The school located in an upper middle class White community had few concerns regarding test results. Dot's unique style of teaching was accepted because of her students' success on the EOCT and AP tests.

The classroom contained multiple aquaria and terrariums with creatures from toads to cockroaches occupying her side counter and space in the back of the room. Very little space was left on the side counter to set up materials for lab activities. She made only one sink available for student use during lab. "They were to drain the cold water over the back sink. Some students used the wrong sink, and were redirected" (Field Notes Observation #2, p. 3, lines 128-129). The demonstration desk at the front of the room had an interactive whiteboard system and a whiteboard behind it. The demonstration desk was flanked by a small computer to the left, and to the right, at the front door entrance, a large computer monitor on the teacher desk. Student constructed DNA models and posters were scattered across the sides of the room and on the walls. The student black top tables were fixed to the floor in rows so it made rearranging the space impossible. The room appeared cluttered. Because of renovation at the school, all space available was being used. This meant that during her planning period, Dot had a large class of social studies students in the room. Dot was clearly concerned about someone being in her room and on more than one occasion made sure she was back at the ending bell or in the area during the class time in order to monitor the use of her space.

Although Dot indicated in her interview that she did not agree with the system curriculum sequencing, she did her best to follow it and maintain the time intervals allotted. She would have preferred to start with ecology rather than evolution. "It's very conceptual. It's difficult to understand and starting there is hard for students" (Initial Interview, p 3, lines 99-100). She found ways to make it work in her classroom, giving an introduction to evolution as the schedule called for, and returning to the concept throughout the year to reinforce it when students had further knowledge. “I’m trying to give the hook that we can hang things on later. Because this is, evolution is one of those unifying themes” (Initial Interview, p. 3, lines 126-127. Her concern for student success gave her reasons for following the system schedule “…because the kids, especially the general level kids they get shuffled around. I would like to believe that my colleagues’ doing the same thing. When they come to me they’re not completely screwed up” (Initial Interview, p. 5, lines 220-223). Making sure her students could do well on the EOCT or the AP tests was a high priority for Dot.

Professional journey. A general description of the research requirements was part of the invitation given to research participants. Dot’s only concern had been maintaining the log. Her concerns had been a factor in my design, trying to keep it simple for her sake. Dot kept an orderly and complete log marking her standards at the element level from the beginning. Her first log visit to check logistics indicated that she found it reasonable work. “She finds having the GPS in the back helpful in completing the log” (Field Notes from Log Review #1, p. 1, lines 3-4). At this early stage, less than two weeks into the time, maintaining the log had enabled her to reflect on the scope of the standards. “Examining the co-requisites made her aware of the breadth of the content she must cover in Biology, not the depth” (Field Notes from Log Review #1, p. 1, lines 16-17). Dot indicated in our discussion of the log that she had already found many of the co-requisite Characteristics and Nature standards overlapping and difficult to distinguish from each other.

Dot invited me to come to an earthworm lab for the first observation. Students were going to be observing live earthworms and she asked the students to treat the worms with respect. The lab directions consisted of a series of questions the students had to answer based on their observations. For example "7. Can you distinguish between male and female worms?" (Acknowledging Annelids, Handout for lab). She was using the experience to generate interest in animals, since this was the first day of her animal unit. Dot was expecting the students to use observational data to answer questions. In an addition to the written portion of the lab acetone was provided so that students who wished could see if worms reacted to smells. Dot had added that portion based on her examination of the standards. "The acetone, I sort of added because I had the lab printed out….But after you came in and I was looking…(Lesson Review #1, p. 1, lines 42-44). She made room for student generated investigation, but did not feel it had gone well. "They need directions. And I know I'm supposed to do the open-ended, and let them come up with their own thing" (Lesson Review #1, p. 2, lines 98-51). Yet, she had already made the change in her handout to include the acetone in next year's lab.

When we met for the second Log Review and compared the standards she had identified for the lesson to the ones I identified, we were closely aligned. The Content standards were identical. Our differences came because of Dot's deep thinking about the meaning of the Characteristics of Science co-requisite standards. For example, I had credited the students with writing lab reports. Dot indicated at that time that in her thinking answering lab questions was not writing a full lab report. Part of this she admitted was her own fault since she had not asked her students to create full lab reports as a part of completing lab write-ups in her class. During the second lesson review when I asked her about students processing the data, Dot said they did not find value in doing that. She went on to admit that it might be because of the way she taught. "But that's partly my fault. Just think of the time constraints. You don't have time to delve into these things. And I really do well with the schedule" (Lesson Review #2, p. 6, lines 261-262).

Dot created lab experiences that called for student to collect and examine data, but included little follow-up work with the data.

The second lesson I was invited to observe was a live fish respiration lab. Students worked in groups of three counting the respiration of two fish, one under controlled conditions, and one with a temperature decrease over time. This was a complicated lab to carry out. Students had to collect the fish into containers from the aquarium, observe and count fish respiration cycles, lower temperature in one container, noting the change, and count respiration cycles at the lowered temperatures. Students took fifteen second counts and had to multiply to get the data into one minute values. When done with the respiration portion of the lab, they removed the fish from their containers and measured their length. At the end, the fish were returned to the aquarium without "waterfall" fish happening, as Dot expressed it. The students carried this lab out smoothly within a fifty five minute time period. This lab had specific directions for the students, but the write-up questions were open ended and required examining data.

Dot and I differed on the Characteristics of Science standards that we marked. This time the difference was related to Dot's inattention to the manner in which the lab groups worked. Just as during the first observation, my field notes indicated that she sat at her desk while the students were conducting the lab, only looking up to scan periodically. She did not monitor their conversations or the quality of their work. Dot was unaware that the students had to collaborate to create a good technique for counting the respirations of their fish. She did not note in her standards that the one related to controlling the conditions of the experiment to get good data had been important. She had undervalued the work of the students in ensuring this as they developed a respiration counting technique. When we discussed the elaboration she might need for the lab, Dot expressed concern about how well students could define the variables. I pointed out that of even more concern to me was the fact that the students had not collected data on the control fish in the container that did not vary in temperature. Dot responded “Every time they were supposed to measure both, I said that, I know I said that. It was in the directions” (Lesson Review # 2, p. 3, lines 121-122). Some of the data needed for comparison, and graphing had not been collected, partly because Dot had not closely monitored the student’s work. It appears that she assumed that if the directions were in writing, the students could understand and follow them.

Having students follow directions, once given was important to Dot. It was clear that she had spent a great deal of time developing her students’ ability to work on their own. She would not have been able to sit at her desk doing other tasks during a lab period if the students were disorderly. One factor that helped this happen was the amount of work Dot put into preparing her lessons. She mapped out her lessons far in advance. “I have my handouts printed out a month in advance” (Lesson Review #1, p. 1, lines 42-43). That had led to the verbal modification for the addition of acetone in the earthworm lab. Both lab activities required preparation of materials on her part. Dot not only had to collect the paper towels, rulers, magnifiers, containers and such for her classroom, she had to purchase earthworms and two aquaria of small goldfish. When I observed that her students seemed well aware of the need to read and follow the directions, Dot agreed.

> From the beginning when they ask a question I say ‘what do the directions say’? If they can’t tell me that, go back and read the directions. If they can say the directions say this, but I don’t understand this, then we can talk. (Lesson Review #2, p.6, lines 236-239)

Her log included three visits to the computer lab to use a science simulation program. All three visits were related to environmental topics, even though she had been in the midst of teaching animal classification. Since getting access to the computer lab called for advance planning and scheduling, Dot placed those visits when she could get into the room and adjusted her instruction around them.

Interviews, handouts and log analysis indicated that assessing student learning came in multiple forms in her classroom. Dot gave cumulative tests at the end of units. During the time of the research the tests covered plant adaptations and animal classification. Although the main focus of the test was that unit, anything taught that year could be tested. The EOCT covered the entire year, and she used the unit tests as a way to help her students prepare for it. Yet Dot used a variety of assessments in her classroom.

> I'm very much into alternative authentic assessments. Although I have to give a test, and now we're required to have certain categories, I believe that assessment happens in lab, in homework, in projects more than in the test. I think the projects show more of what they know that the tests. (Initial Interview, p. 6, lines 255-259)

Dot's log reflected this approach, with the use of a variety of assessments documented. As an example, the three trips to the computer lab had differing assessments. The project for the animal unit spanned the entire time of the unit, and required students to creatively pull the classification information together.

When Dot showed videos, as she did for over ten days of the twenty eight in her log, they were used to help students make comparisons between animal groups. Although she called the graphic organizers worksheets, they were far from the ordinary worksheet. They were designed to guide students into comparing and contrasting the various phyla studied. Each day Dot held a question and answer session at the end of the video. She tied multiple content areas together through this compare and contrast activity, such as advantages of sexual and asexual reproduction, comparison of structure and function of the various classification groups, the evolutionary basis of modern classification, and animal adaptations and behaviors. "She has a sheet that students complete as she goes through the phyla, adding components of the organisms which is designed for them to see the development of complexity in the organisms. This leads to a natural discussion of evolution" (Field Notes from Log Review #3, p. 1, lines 33-37). Dot's intention was that through the analysis of the data given in the videos, as well as the three lab experiences during the animal unit that students would come to not only learn characteristics of the various phyla, but apply that understanding as they considered evolution one more time at the end of the course. She had followed the same approach to the study of plants, having students create comparison charts of this area of study as well.

When thinking about what she might have learned through the activities of the research, Dot realized that a great deal of the Characteristics of Science standards were in her head, yet not made overt to her students.

> It reminded me that I needed to debrief my students more because some of the things that may be in my head about what I could do, or was doing, or the activity would have done it needs to be brought to their attention. (Reflective Interview, p. 1, lines 13-16)

Dot's thinking about how students learn reflected in the planning and activities throughout the unit indicated that she valued students developing the understanding and skills in the co-requisite Characteristics of Science standards, however, it was so deeply embedded in her lessons that she became concerned that her students might not realize what they were doing. She became aware of the need to make these standards as relevant in her students' minds as the content standards. "So bringing it back to the discussion using maybe the terminology and the vocabulary that was in the standards" (Reflective Interview, p. 1, lines 25-26). As focused as Dot had been on having her students learn the content vocabulary, she had begun to realize the importance of developing understandings, skills and language in both sets of co-requisite standards.

Examining the log made it clear that Dot had little trouble noting the Characteristics of Science co-requisites. From the start not only had she marked them at the element level, and multiple co-requisites were marked on lab and computer lab days, all were from the Characteristics of Science section that focused on understandings and skills of doing science. However, she had over ten days with only content co-requisites marked during the video lessons, and this seemed to bother Dot. Since she saw herself as a teacher who practiced standards-based instruction, having so many empty slots in the log concerned her. Looking at the color of ink used, it is clear that she went back three weeks after starting the videos to add a Characteristics of Science standards element. “Somewhere in there under videos they were all blank and then looking at something else, oh this will work for the videos!” (Reflective Interview, p. 3, lines 106-108). The co-requisite chosen was from the Nature of Science standards, and was a broad element relating to the universe working on the same basic principles. Dot had begun to think beyond immediate skills, and true to her earlier discussion about making standards overt, had come to realize this was a standard that she intended to convey to her students through the sequence of lessons. The only other time she had noted a Nature of Science co-requisite was when she had given students freedom to try music or acetone experiments with the earthworms. That day she noted that hypothesis led to different experiments and that testing could lead to the revision of students’ previously held theories about animal behavior.

Dot was still not very open to extending the lab experience. She admitted that early in the school year when she was teaching the introduction to science unit she ran several fairly open labs. However, she found it difficult to do with content. “But when you’re doing the labs, when you're doing the characteristics of science with the biology standards, then it's harder to learn the biology standards that way. So that's why I don't" (Reflective Interview, p. 5, lines 198-201). Dot indicated that she had engaged her students through lab, and that had led to content learning. During the interview she considered rethinking her choice of activities for the coming year because she realized that having students engaged had helped with learning. "I do a lot of labs and activities. I could probably trade out some of the ones I have for other ones that are more engaging" (Reflective Interview, p. 10, lines 413-414). The need to teach content explicitly still influenced her unwillingness to use more time for students to process the lab information. "Yes I made changes, but the nagging behind me was, yes it would be great to teach this way, but I'm on a time schedule. The exploratory inquiry type learning it really requires time" (Reflective Interview, p 1, lines 42-44). Dot admitted in the end, that whether or not she would include more time to work on the co-requisite Characteristics and Nature standards would always be dependent on the nature of the students she had each year. If they were willing to become engaged she would do more, if not she would do more directed instruction.

Analysis. During both observations Dot chose to teach labs as examples of lessons that integrated the Content and Characteristics of Science standards. Analysis of both lessons using the essential features of classroom inquiry (Appendix G) indicated that she understood and emphasized most of the five features at a high level of student self direction. Both called for students to answer the questions posed by the teacher, except for the later addition of acetone and music to the earthworm lab. The feature that Dot emphasized the least, and retained control of, was the need for the learners to communicate and justify their explanations. Somehow exploring, examining evidence and beginning to propose explanations was good enough for her lab experiences. Dot appeared to be unable to consider having students spend time with the data. Instead, she went to the video sequence to ensure that students were exposed to the content she felt they needed. The project assigned could have been done with more student control over finding the information needed to compare the phyla; however Dot retained control through distributing information by way of video and class discussion. When I asked her about possibly preparing the students a day in advance for the complicated fish lab, Dot indicated that her students were not capable of retaining that information and arriving prepared. “They forget overnight” (Lesson Review #2, p.6, line 226). Throughout the interviews and lesson reviews Dot indicated that she found it difficult to completely trust her students to learn without her strong guidance. This was reflected in her log references that focused on the Characteristics of Science standards. Her references emphasized the process and collection of data, with very few notes on the two standards that emphasized the use of the data for analysis and communication.

Although Dot indicated that she would like to do more inquiry instruction, she was still concerned about ensuring that the content standards had been carefully taught because of the EOCT. “Very rarely are there topics that I don’t get [to with my instruction]. I know that my colleagues don’t teach certain areas of the curriculum, period” (Lesson Review #2, p. 6, lines 263-264). Dot continued to view the Characteristics and Nature standards as separate from the Content standards. Even after careful consideration of all standards displayed in her log and our conversations, Dot was reluctant to change toward a manner of teaching that allowed more student control of the learning. As she summarized the three best lessons in her log for me, she kept returning to the content that the students had learned. “They cannot walk out and say they did not learn something at any level, whether they were gifted or general. They left knowing more than they came in” (Reflective Interview, p. 9, lines 385-388).

In addition to a focus on learning the content, Dot indicated that she hoped that the experiences would also alter her students' view of the world. When reflecting on the difference between doing a flower dissection and simply labeling a diagram, Dot emphasized the importance of experiencing Biology. "And when they walked by the next flower they would not have equated that paper drawing with the thing in the florist, or the thing on the street" (Reflective Interview, p. 9, lines 394-396). The distribution of labs throughout the time of her log reflected the idea of experience over student use of data. Although seven days were noted as lab activities during the twenty eight days of the log, four were in the first week, two weeks had one, and one week had none. The lab experiences were not distributed in a way that allowed for integration of these into her overall instruction. There also appeared to be little integration of the computer lab experiences with the development of learning, since they were on topics unrelated to the animal characteristics and classification focus of the unit that made up the majority of the log. Dot explained that scheduling time in the computer lab was difficult, so she had to fit in visits when she could, and they did not always fit her learning sequence of topics.

The process of maintaining the log helped Dot return to considering the language of the standards. "I think some of the language is ambiguous enough that you can put it almost whenever you want if you're creative enough" (Reflective Interview, p. 3, lines 108-109). Yet she had gaps in noting standards. Even with three days of computer generated labs she did not note the element that related to using technology for developing and testing models. Although Dot had a strong background in Biology, and practicing science, she also found it difficult to note the more theoretical Nature of Science standards. The references to these in the log were few, and Dot only added one because she had found herself with too many empty slots for

Characteristics and Nature of Science standards for the large number of video presentations of the animal kingdom. It was only on reflection that she found one element to match those days.

Overall Dot's thinking about her teaching appears to be very pragmatic. She wanted student success on tests, she wanted to collaborate with peers to help students learn appropriately, and followed the curriculum the system suggested. She was beginning to reconsider how to blend the Characteristics of Science and Content co-requisite standards, but further observations with reflective conversations would be needed to facilitate her rethinking about how to make her desire to teach in a more inquiry manner feasible in her classroom.

Flossie – Using evidence and having fun

Context . Flossie was a product of the school system in which she taught. She grew up and graduated from a high school located in a White, affluent community that made up one part of the diverse school system. As an undergraduate in college she had a double major in Biology and Psychology. Only after graduating did she get certified to teach, by earning an MAT. For twenty one years she had been a high school teacher in two different schools within the system.

At the time of the research she taught at a high school in the mostly Hispanic section of the school system, with eighty five percent of her students speaking Spanish as their first language. Flossie spoke little Spanish, so often depended on her students to translate for each other in her classroom. In the classroom I observed during the research, a student had just arrived from another country two days before the research began. When she divided the class into three groups, she was not sure the new student understood so Flossie depended on students to help. "A student let the new student know in Spanish that he was in group 1" (Field notes from observation #1, p. 1, lines 33-34). By the end of the research time, Flossie was beginning to think that this new student might be gifted, but his lack of English skills would make it difficult to move him from the ELL class. Several times she emphasized in our conversations that when a student was ELL it did not indicate a cognitive label, but that merely indicated a language issue that needed to be taken into account in her teaching. In many ways she thought that the move from a middle class White high school to the current one had been great for her. As we discussed the yeast respiration lab she elaborated on why. "She no longer assumed that the students understood what she was saying. For example, she did not assume that they knew that it was carbon dioxide that was filling the balloon" (Field Notes from Log Review #2, p. 2, lines 25-27). She was now much more focused on checking for understanding as she taught.

In addition to first year Biology, Flossie also taught AP Biology. After graduate school, where she had taken eight or nine graduate Biology courses, she felt that the summer workshops for AP Biology helped maintain her content expertise. She read science magazines such as *Nature* and *Scientific American*. Flossie enjoyed using Internet resources not only for content updates, but also for help with her pedagogy. She particularly appreciated sites where teaching ideas included background information. Flossie had taken the coursework to add the endorsement to her certificate that allowed her to teach both gifted and ELL students and thought they added to her repertoire of strategies, but knew they were just a start. because ".. then you modify it for science" (Initial Interview, p. 2, line 48).

Flossie had just moved back into her classroom after some renovations at the school. The long hall where she taught was painted white, and when I first arrived it was a bare place to walk. As time went on, student posters, first from her class, and later from the Chemistry class across the hall began to cover the walls outside the science classrooms adding some interest to the space. There were signs of renovation inside the classroom with a large blank area in the center of two small whiteboards awaiting the interactive whiteboard that did not arrive for almost two months. The aquarium was set up and running, with the word wall behind it. The counters around the room with separate tables always had materials for labs being set up or taken down. Slowly, over the time of the research, student work began to be posted on the walls and cabinets, and mobile student projects dangled from the ceiling. It looked like an active science room, yet on the last day I was there Flossie began to scurry around preparing for an administrator "five minute walkthrough" coming the next day. She found her content standards and posted them in a prominent location and altered the sponge activity for the next day to a language that matched the current research-based focus of the school. She knew that the three essentials that would determine her score as a teacher the next day were: a word wall, the language of the work on the board, and having content standards posted.

Flossie was sharing leadership of the science department with another teacher. This meant that when her Biology co-teacher had to be out, it became her responsibility to help with those classes when substitute teachers were present. Flossie did this willingly because she was proud of the fact that her school was able to pass Adequate Yearly Progress each year. It appeared to be a collaborative effort among the faculty since Flossie missed three days of instruction with her students to help review juniors for the high school graduation test. Throughout the semester, she was mentoring a student teacher, whose responsibilities indicated that Flossie viewed her very much as a co-teacher reflecting Flossie's inclusive approach to working with other professionals.

Professional Journey. Flossie was much attuned to the needs of her students. She was aware of the fact that language was not the only hurdle her students needed to overcome during the Biology course. Biology content was also an issue for her students. She described her ELL students as recent immigrants without the middle school science experiences that other students brought with them to high school. "…the vast majority of them, non speakers, very recent immigrants and not from educated or privileged backgrounds. So when we start Biology you are really starting biology" (Initial Interview, p 2, lines 71-73). Although there were ELL students in her gifted class, she knew they were students who had been in the country for some time and had the opportunity to develop some background and vocabulary in life science content. For this reason she felt that the integrated school system curriculum was not a match for her students. She thought integrating evolution for example throughout the curriculum was a worthy goal, but without a background to discuss it, she struggled. "…you're talking about things evolving and you're trying to use examples and the kids are going, 'I don't know what that is'" (Initial Interview, p. 2, lines 85-86). She had thought about how to approach the course for the ELL students since they took the EOCT along with the students in her gifted class.

> ESOL is not a cognitive ability level. It's just really a language ability level, that often leads to days, or years, or weeks or months in the country exposure. You get an ESOL class it's like 'cell what?'. And right next period you have, both taking the same Biology class, same EOCT, same everything. (Initial Interview, p.3, lines 102-106)

Her thinking led to a philosophy she expressed as being a school philosophy of how to approach her class. "You have to meet the children where they are, that's our number one phrase" (Initial Interview,, p. 2, lines 78-79).

Flossie felt it was critical to sequence the lessons so that students could build concepts. As she was creating her ideal sequence during the Initial Interview she verbalized some of this thinking. "You teach this to teach this to teach that to come back and teach this" (p. 3, line 114). As we began the discussion reviewing the first lesson I observed, a lab that used yeast, this thinking was clear in her description of what she thought had led to the success of the lab activity. "We'd taken some notes on it; we'd done some activities with manipulatives. Cut out mitochondria and little CO_2 coming out. We had seen yeast previously in the kingdom chapter. The idea of making those connections, sometimes happen, which you're hoping for…"(Lesson Review #1, p. 1, lines 6-9). Her focus on the success had not been due to the way in which she created the lab lesson, rather on the preparation and sequencing that led to that day. Flossie saw her teaching as holistic with all parts working together. She emphasized this in the Reflective Interview when I asked her to describe a good lesson.

> You say the lab went really well. In the case of my kids that means the day before had to go really well. They had to understand something to do the lab. So lab went really well, the next day when we wrote summaries for that to go well means they had to have gotten something out of the lab. (p.5, lines 204-208)

This broad view could be seen in the selection of strategies she used for instruction. They were sequenced intentionally to build concepts for her students.

Flossie used a wide variety of activities for instruction. Her log included three kinds of activities, a lab, videos, drawings, discussions with note taking, and three projects. She wove these together in such a way that there was no pattern to when a strategy was used based on the day of the week or point in the unit of instruction. The unit she taught during the time of the log was the fourth one in her ideal sequence. She felt free to change her course sequence since the system no longer was giving unit benchmarks and her dislike of the new sequence the system had sent the previous fall semester. When asked about the school system sequence she felt it did not fit her students. “We dropped back and punted to this one in our building” (Initial Interview, p. 2, line 63). The organization of the strategies was such that it built concepts with two weeks emphasis on energy use in living organisms through photosynthesis and respiration, followed by food chains and webs, and concluding with biomes. Both observations of her class confirmed her pattern for building conceptual understanding with her students. The log reflected this focus on content with every day except one having a reference to the content standards, but only half the days referencing the characteristics and nature standards.

The first lesson Flossie invited me to observe was a yeast respiration lab. One of the gaps in student understanding she had to close was the lack of familiarity with yeast. She said since her students came from homes where baking did not often include yeast, she went out of her way to make them aware of the common use of yeast in baking. Before she began the lab she spent time doing a sponge activity that focused on writing the equation for respiration, and emphasizing the chemical components of the reaction. Growing the yeast in Erlenmeyer flasks, with balloons on top was a new experience for the students. Flossie did not let them know in advance what to expect and the student surprise at the balloons increasing in size was clear.

> Flossie: I thought the kids did seem to be terribly intrigued when the balloon started to blow up. I thought that seemed, if you happened to be hear some of the kids before that they looked kind of blasé.
>
> Marion: That was the only time I heard the noise level go up was when they balloons started to blow up.
>
> Flossie: You could see, I felt, that they were literally surprised at that. It was like 'Woa, hey!' (Lesson Review #1, p. 1, lines 41-47

One of the things she and the student teacher did was move between the groups during the yeast experiment to ensure that the students knew that the gas was the carbon dioxide described in the respiration equation. The lab had two other flasks that either did not contain yeast in one, or in the other sugar. Flossie spent a good deal of time talking to the groups about why three flasks were needed for this experiment. She valued the process and results of the lab being used as evidence for explanation. "I just want more people to go off into the world and get the idea that scientists, the real scientists say 'well there's a preponderance of evidence that this is really happening" (Lesson Review #1, p. 3, lines 123-125). An examination of the standards identified in her log, however, did not match this understanding of the importance of using evidence for explanation.

As we met for the second log review, we compared the co-requisite standards she identified to those I had identified following my observation. I had identified nine content standard elements, where Flossie had identified one. Her entire focus had been on respiration as a concept, even though she had tied it to eight other content elements that supported the discussion and understanding of respiration. She had identified four characteristics and nature standards broadly, without element identification, while mine had six standards with eleven elements within them identified. During the conversation Flossie realized she had not considered the full scope of the lesson that day. She had completely ignored the work during the sponge activity. "Flossie said she had taken an old familiar classic lab and rewritten it for this class. She thought that some of the familiarity with the lab had been the reason she had not considered all the factors I had seen" (Field Notes from Lesson Review #2, p. 2, lines 20-22). When we discussed the possibility of looking more carefully at the elements when she planned, Flossie thought it was a good idea, and said she was going to do that from then on. However, an examination of the log indicates that after this point in time she marked few Characteristics of Science standards, and those she did were marked mostly at the standard level without element designation.

The second lesson I observed was a project assignment, rather than a lab. Students were guided in the creation of a food web that included themselves through an analysis of the meals they had eaten the previous few days. This was intended as a culminating activity for the study of food webs. Early in the lesson it became clear that the students were not ready for the project assignment. The sponge activity had a sample food web on the board and the students were asked to identify the role of the various organisms in the web. As Flossie started to go over it in a class discussion it soon became evident that the students were confused. As we discussed this in the lesson review she realized that having letters instead of organisms in the web may have caused some confusion. Her intent was to keep the web simple so that the students would not have been confused by the name of the organism. "My thought process going into it was to keep it really simple. Not to having to say 'what is a?'" (Lesson Review #2, p. 1, lines 26-27). This was in line with her approach to teaching described in the Initial Interview, which as to keep the concepts simple so the students would not be confused by too detailed a language. Flossie's solution to the problem was to add a component to her lesson before moving on. She went and collected a set of cards from the back of the room.

> She had her student teacher start handing out chalk to the students at the tables while she went into the back of the room to collect some cards. These cards were laminated with pictures or organisms on the front and the name of the organism on the back. (Field Notes Observation #2, p. 2, lines 60-63)

As she grouped several cards and distributed them to each table, the students were directed to form food chains, drawing the arrows with chalk on the table. Flossie was well aware of her students' lack of understanding. "I saw them struggling, and went and got the cards" (Lesson Review #2, p. 1, line 33). Although her main lesson plan had been to work on the personal food web assignment, she knew her students were not ready, and took time to make sure they were prepared to do the work. Flossie's focus on sequencing instruction for conceptual understanding meant that she would not move on to the next activity until she was certain that her students were prepared to learn the next concept in her planning.

Although creating a food web appeared at first to be a simple exercise, Flossie had added components to the assignment that expanded its use of the characteristics and nature co-requisites. A honeybee had to be a part of the web. She took the time to show a video on the honeybee to the students. This was followed by an article, rewritten to an appropriate reading level, titled "Mystery Disease is Threat to Bee Colonies." It described the death of honeybees from an unknown cause, and included a list or crops dependent on honeybees for fertilization. After noting the critical role of honeybees in agriculture, Flossie emphasized what scientists would be doing to help solve the problem of their loss. "Flossie asked them what was the problem? A student answered 'sickness.' Flossie said they weren't sure yet, so they needed scientists to find out. This is what biologists do" (Field Notes Observation #2, p. 4, lines 142-144). The students then worked on their personal food webs that now included in some way honeybees. The students were encouraged to add their own photo to the project, and illustrate the various components of the web with pictures. This multi-day project was one of three listed in the log both as activity and assessment, which was consistent with her philosophy on assessment.

Flossie thought that multiple choice questions did not fully capture her students' understanding. "I think bubble in tests are really good for, I know what this word means" (Initial Interview, p.4, line 163). She thought that if she wanted to understand whether her students understood the concepts, it was necessary to use more open ended assignments. "For that I would rather have them write paragraphs, essays or articles, abstract articles" (Initial Interview, p. 4, lines 159-160). This could be seen in her log since only one test was listed as an assessment over the course of the month she maintained it. During that time she listed four guided notes, four general activities, one lab, one poster, two projects, and four sponge questions as her means of assessment beyond the one test.

The focus on active student learning made Flossie open to discussion about ways of making her lessons stronger. During the first lesson review we discussed a theoretical question about acid-base indicators she had added to the yeast lab. When I suggested running a demonstration on the side so students could examine an indicator change, rather than making it completely theoretical, she thought it was a great idea. “As soon as we finish here I’m going to type that in so I can have it for next year” (Lesson Review #1, p. 5, lines 183-184). As she reflected on some things she had learned over the time of the research, she came to realize that just having an activity planned was not enough. She already had activities that taught the content, but she realized they also needed to do more. “Which one of these is more interesting, the wonderment? Which one of these does a little better at independent, dependent variable?” (Reflective Interview, p. 1, lines 22-24). She had added criteria related to the Characteristics of Science standards to her thinking about which lessons would be best to use with her students. Flossie thought it had begun to alter the way she worked with her other classes as well. She was starting to look for quality in the lab work, rather than just checking to see if the answers had been completed. “Is that graph good? Properly done? If not let’s address that making your graph” (Reflective Interview, p. 2, lines 50-51). Although she had not recorded many of the co-requisite standards in the log, it was clear Flossie had been reflecting on their meaning. When I mentioned a possible way to reconfigure her unit Flossie thought about it carefully. We discussed her understanding that including the characteristics and nature co-requisites in her planning for instruction was an advantage. She agreed that thinking of them in advance as she worked on her lessons was going to help because then she would be “Using them to your advantage as opposed to one more thing you have to do” (Reflective Interview, p. 3, lines 127-128).

One of Flossie’s highest goals was that students should have a good time in her class. During the interview she pointed out it would help them value science and encouraged curiosity with her lessons. As she discussed the success of the yeast lab I observed in lesson one, Flossie indicated that student curiosity was an important factor. She described the group as a “curious little bunch in general” (Lesson Review #1, p. 2, line 64). Flossie appeared to believe that nurturing curiosity led to wonderment, and then the students could have fun in class. When she selected her top three lessons during the reflective interview, being able to allow for curiosity on the part of the students was an important criterion. Describing the yeast lab she pointed out that the fact that the students were intrigued and curious had added to the success. Another lesson she chose was one in which students had to create travel brochures for a biome they selected. “This went well because it was fun. There was actual giggling. I like giggling” (Reflective Interview, p. 7, lines 296-297). In a school with such high language needs and poor content background, Flossie managed to remember that science was more than test preparation, it included curiosity and fun. She took preparing her students for the EOCT seriously, but also looked for ways to improve the inclusion of characteristics and nature of science in her classroom.

Analysis. The two observed lessons were very different from each other, yet fundamentally called for students to be engaged in collecting and using it as evidence for explaining the phenomena being studied. When summarized on the Essential Features of Classroom Inquiry (Appendix G) the yeast lab collected data during lab, and the personal food web project required generating a list and analyzing the kinds of food students had consumed. Both tended to be more teacher guided, rather than directed, however Flossie provided the question each time. Students were expected to create their explanations by using the evidence, and in the case of the food web, it connected to a larger scientific issue of honeybee disease.

Flossie did not consider language differences a barrier to learning and trusted her students to work together in both English and Spanish as they collected and processed the data.

It was clear from analyzing the data that Flossie did not consider doing lab activities as the only way to address Characteristics of Science standards in her classroom. Her log contained only one lab, yet data analysis shows she understood the expectations of the school system for her inclusion of these standards in her instruction. "I'm gathering that we're trying to show them actual science. The methods and the habits of the mind I think they call it. The critical thinking" (Initial Interview, p. 5, lines 194-195). She indicated that having her students understand the history of scientific discoveries, and current issues in science also met the criteria of helping her students learn the Characteristics of Science co-requisite standards. She discussed this understanding of the co-requisites in her early interviews. What changed in her thinking over the course of the research was the realization that she had not been expecting her students to display as high a quality of understanding of the characteristics and nature standards as she had the content. Part of what was going to help with her enhanced focus on these was her realization that these kinds of activities, especially labs served as a foundation for her students' understanding and skill development. "So you use these as anchors. Things they remember" (Reflective Interview, p. 1, lines 32-33). Flossie had an unstated understanding of standards-based instruction, and further reflective conversations would facilitate her ability to consciously incorporate her understanding into her teaching.

Examining the difference in Flossie's initial and reflective interviews indicated a growth in thinking about how to bring about standards-based instruction in her classroom had begun. Her emphasis in the conversation had shifted from a strong focus on assessment to one that included instruction and assessment. During the initial interview she mentioned three strategies for instruction as she described her teaching, yet in the reflective she mentioned eleven different strategies, many of them multiple times. Her initial interview had a good deal of discussion regarding assessment, but in the reflective interview she mentioned assessment only in passing, and that was the EOCT. By then the data analysis showed she assumed that the content was not an issue, and had begun to focus on strengthening her instruction. Flossie had spoken of the need to build concepts and to tie the learning to real-life experiences from the first interview. By the reflective interview she was repeatedly discussing the need to blend the content and the process skills, and the importance of curiosity in her students' learning. It appears from analyzing the data she was beginning to think more about her instructional practice and worry less about the assessments.

The data analysis indicates that Flossie was a student centered teacher, who was able to look beyond superficial issues and see the potential for learning in her students. She also was able to see beyond the content and had a sense of the importance of the processes and nature of science as part of her instructional practice. She had already found many ways of blending the co-requisite standards with her students, and was close to becoming a standards-based teacher. Her ability to be reflective about her practice through dialogue, if not through the log, meant that she was ready to complete the process of change given a little more time for interaction together with the professional development experience.

CHAPTER 6

Cross Case Comparisons of the Professional Development Model

In a multiple-case study, one goal is to build a general explanation that fits each individual case, even though the cases will vary in their details. (Yin, 2009, p. 142)

Using the individual experiences and re-examining the data allowed an evaluation of the model design as a whole. Although as seen in the previous chapter, each participant responded to the professional development in a slightly different manner due to the specifics of their settings and experiences, there were common themes to these experiences. These commonalities allowed a closer look at the professional development model. Participants responded in two broad ways: (1) they became more aware of their practice, and increased professional reflection on their practice; and (2) they also made changes in their practice, and envisioned future changes in the coming school years that would alter their practice. This chapter will examine these themes starting with the increased awareness of their practice participants displayed, followed by a discussion of the specific ways in which they had altered or planned to alter their instruction to include both sets of standards.

Increased professional thinking

Scope of teaching. The participants in this study brought many years of experience to their classroom practice. Over the years they had not only refined their interactions with students, they had also accumulated resources for use in instruction. This was exemplified during lesson reviews when they were asked how the lesson might be modified before being taught again. The focus of the discussion was on tweaking the procedures so that the activity might be run more efficiently in the time available, or on intended changes never carried out. Paul's response during the second lesson review was typical of this thinking.

> Yeah, if I rewrite, this is one of three labs during the year that are not mine. Perhaps, two or three other teachers use it during the year. I would rewrite it. I find the font structure too much text. I think I would simplify the text. Each year I tell myself I'm going to rewrite it. (Lesson Review #2, p. 4, lines 173-177)

In many ways their practice had been to select from a collection of activities, videos, readings and other strategies collected over the years as the topic came up in the curriculum. From analyzing the data collected during Phase I, it was clear that when planning units of instruction, the participants had gone to their tool box of strategies and selected the ones that fit the topic without much planning about the sequencing of these activities throughout the unit.

During the second log review, we compared the standards I had seen taught during the first observation of their class to those noted in the lesson log for that day. Without exception more standards were addressed in the class than were noted in the logs. As we discussed the differences one area that was overlooked regularly was the opening activity of the day. Three participants had the practice of using what they called sponge questions at the start of class. Often these were setting the stage for the lesson I had been invited to observe. The participants did not include standards taught during this portion of the lesson in their logs. They focused on the main portion of the lesson. Where I had identified four to eight elements of content being taught, they had noted one. Dot had noted the content standards in the same way as I had, but differed in the characteristics of science co-requisite notation. Following this review the logs began to include many more elements both in content and characteristics of science. When I compared my list of standards for the second lesson observed to the log notes, we were much more closely aligned than during the first. In many ways the content was more aligned to the actual observation, and the characteristics of science noted were greatly increased.

Analysis of the data indicates that much of the teaching had been done unconsciously. It was second nature to the participants and much of what they did was in their heads, without being overt. By the end of the professional development, this was no longer the routine. As they examined their teaching on a daily basis, and interacted with me in discussions, the participants became more focused on intentionally examining the standards as they taught their students. Dot indicated that her lack of focus on the standards had kept her from helping students be as proficient in characteristics of science as they were on content. “You know, this is the standard it’s not just enough that in my mind I understand it. They [students] need to understand it. This is the reason we did this. Yes we did it. But do you know why we did it” (Final Interview, p. 1, lines 20-23)? Jessica became aware that in many ways she was teaching the characteristics of science standards, but had not thought about how she went about it. “Well, what I realized was that I was using them. I hadn’t paid real attention to it. I’d been so busy with the content” (Final Interview, p. 1, lines 6-7). Throughout the professional development participants gradually increased the specificity of the references to standards through log notations, lesson reviews and on reflection of their growth during the final interview.

Conceptualizing the Nature of Science. There are eight co-requisite Characteristics of Science standards divided into six designated as habits of mind, which focus on science procedural skills for the most part that can be made measurable. An example of this set of GPS would be 3c “Collect, organize, and record appropriate data” (Georgia Department of Education, 2008). The seventh and eighth standards are designated as nature of science and are far broader, calling for students to be able to describe how scientific knowledge is generated and how scientific inquiry is conducted. For example GPS co-requisite standard 8d states "the merit of a new theory is judged by how well scientific data are explained by the new theory" (Georgia Department of Education, 2008). As participants were examining the set of eight, the discussion gradually began to center on the differences between the first six and the last two.

During the Initial Interview participants were asked to give an example of how they taught a specific element (1b and 8c). The first dealt with different explanations for the same evidence, and each could give an example of how this was incorporated into a lesson, usually a lab. When asked about the second, researchers assessing the quality of data for bias, most had difficulty describing an example, and often reverted to a lab descriptor focused more on a procedural skill. When Flossie responded to this element of standard 8, I repeatedly refocused her answer back to how she taught it. She was unable to give an example. "I wish I knew. We talk about it, we tell them about it" (Initial Interview, p. 6, line 242). All discussed the need to help students value examining evidence as important, but could not directly explain how they went about embedding this in their practice.

An examination of the lesson logs supports this difficulty with teaching the nature of science standards. One participant never indicated standards 7 or 8; one had a few references at the standard level with no elements; one identified 7a only; and one 8 a, b, c in selected places. Yet throughout all logs, the content standards and habits of mind were identified repeatedly and in detail. The lesson log indicated that the participants were examining the co-requisites and making note of them daily, but were simply unable to identify little in their teaching that related to helping students understand the nature of science. The only reference Dot made was to 7a which asks students to understand that the universe functions on the same basic principles throughout. She used this on days in which her students were watching videos of each phylum of organisms. The ink color in her log is different, and she had clearly gone back and added it at a later time. Until that was added, the column in her lesson log for that co-requisite had been blank for many days, since she showed videos on nine days.

Of the eight lesson reviews after observations, only one incorporated a discussion about the importance of students understanding how science uses data to inform its knowledge acquisition and decisions. All other discussions about the inclusion of the co-requisite standards were focused on the procedural standards to some degree, and always included the importance of the content. The primary purpose of most lessons, even those that involved some data collection, was to enhance the understanding of the content. Participants had included more content and characteristics of science standards in their lessons without being conscious of it as indicated in the analysis of the previous section. However, there was not an incorporation of the nature of science standards, even at an unconscious level.

During the final interview participants expressed the difficulty they had found teaching the nature of science portion of the standards. Dot stated, " I don't know, I think some of the language is ambiguous enough that you can put it almost whenever you want it if you're creative enough" (Reflective Interview, p. 3, lines108-110). As Jessica had examined her practice she realized that she taught the procedural standards well, but was not including the nature of science ones. She made plans to include them in future lessons. "Right now I don't think I ever put seven and eight in there" (Reflective Interview, p 2, lines 58-59). Paul realized the need to be more explicit in teaching the characteristics of science, but expressed frustration because he could not find ways to include the nature of science ones. "I don't know how you turn those into student behaviors" (Reflective Interview, p. 2, line 88). Flossie referred often to the importance of curiosity and using data for decision making. But at one point she decided a lesson had not been good because in her language there was "Straight content, no nature, no curiosity" (Reflective Interview, p.9, line 411). Participants were able to express an understanding of the difference between the two sets of characteristics of science co-requisites. Yet each was still struggling with how to incorporate the nature of science standards into their teaching.

Focusing on content as well as characteristics of science co-requisites. As the study began it was clear that the participants were aware of the content standards. The reference to the content standards in the lesson logs were at the element level daily from the beginning. The participants were very aware of which content element they were focusing on with their students each day. Some participants did not add the characteristics of science reference until after the first log visit, where I checked to confirm that they had understood the logistics of maintaining the lesson log. Up to that time they had merely listed the content. Prior to the second log review where we compared their log reference to standards in the observed lessons and mine, most had maintained the characteristics of science in the lesson log simply at the standard level. After that point the logs began to describe the characteristics of science standard at the element level. Even with this increased focus on characteristics of science notation, the notations in the log did not match those I had identified through my observation. For the most part, the participants underestimated the number of characteristics of science standards they had emphasized in the lesson. Our notations on the content standards of the observed lessons were more closely aligned. The participants gradually increased the detail of their characteristics of science references over the time of the professional development, however, they still were not completely aware of how these standards matched the activities conducted in class.

Each observed lesson had both sets of standards designated in the lesson logs. However, during the lesson reviews the participants emphasized the importance of the content acquisition over the opportunity to learn and employ the characteristics of science. For example, Dot had conducted a lab with live fish, and students had collected a great deal of data on respiration in various conditions. When I asked how long she would take in her teaching to use the data collected as a part of her lesson, Dot indicated she did not have time for that and would be collecting the lab write-ups the next day. "Just think of the time constraints. You don't have time to really delve into these things. Very rarely are there topics that I don't get" (Lesson Review #2, p.6, lines 261-163). In the log Dot had identified that her students would not only be following procedures, collecting and analyzing appropriate data but that they would also be evaluating the process and comparing data and using the data to support claims. Her students learned a great deal about running labs safely, collecting data and graphing the information, but had no opportunity to interact with other students or Dot in the analysis of the information since the lab write-up was due overnight, thus was done individually at home. From the notes it was clear that Dot valued the complete set of characteristics of science standards, but needed to move on in content.

As the participants began to examine both sets of standards over the course of the study, some made modifications to lessons because of the increased awareness of the characteristics of science standards. Both Dot and Jessica modified the first lesson because they were examining both sets of standards. They were using lessons they had taught previously, but the increased awareness led them to make some modifications. Flossie added a discussion about controlling the variables during her lesson because she was more aware that this part of the lab was as important as the content she was emphasizing through the yeast growing activity.

During the reflective interview all participants indicated that they were aware that they had been focusing on the content standards, and in many ways had ignored the characteristics of science standards. Dot described her change in thinking “It reminded me that I needed to debrief my students more because some of the things that may be in my head about what I could do, or was doing, or the activity would have done, it needs to be brought to their attention” (Reflective Interview, p. 1, lines 13-16). Dot was well aware that she had placed the characteristics of science standards in the background of the content. She was sure her students understood the content standards because she had emphasized them, but was aware now that she had not emphasized the characteristics of science standards enough for her students to understand them. Flossie realized that the characteristics of science standards were not foremost in her thinking, even though she had provided students opportunities for learning these as well. “I hadn’t paid real attention to it. I’d been so busy with the content and I always realized that the scientific process is necessary” (Reflective Interview, p. 1, lines 6-8). Flossie felt she had skewed the direction of her teaching toward content, and needed to be more intentional about emphasizing the characteristics of science as well. Paul realized he had focused more on the mode of presentation of content and had not even examined the characteristics of science standards. The professional development had raised his awareness. “I had to think about them, period. Be honest with you, I just couldn’t blow them off” (Reflective Interview, p. 1, lines 33-34). He was now considering how to embed the characteristics of science into his teaching, and understanding they are more than just modifying his modes of presentation. Flossie described a manner of teaching that included a large number of lab experiences, yet she felt she had lost sight of the reason for these. Through the process of the professional development she had a new awareness of the purpose of these experiences for her students. “I try to do a lot of labs with my kids. I slide things in and mention and mention it. It brought back to the forefront. We’ve been so focused on you need this information, that information. Maybe losing sight of the best way to get that information, nature of science" (Reflective Interview, p. 1, lines 6-10). Jessica realized she was teaching the characteristics of science, but not the nature of science and looked for ways of adding this to her teaching in the coming year. "As I thought, I feel really bad that I was not doing the interdisciplinary things. I have not done long-term research and that kind of stuff" (Reflective Interview, p. 1, lines 16-18). All participants described and increased awareness of the importance of the characteristics of science standards which they felt they had neglected because of their stronger emphasis on the content standards.

Changes of Practice Enacted and Envisioned

Linking and sequencing topics. In the interviews during Phase I of the research all participants had difficulty describing their sequencing of a unit of instruction. They had been teaching Biology for many years, and had accumulated a large repertoire of lessons related to every topic they taught. Pilot interviews prior to the research had indicated a need to ask participants to get specific regarding a unit of instruction if I wanted to get a sense of their thinking regarding the sequencing of instruction. For the Setting Interview, I specifically asked participants to name a unit and describe how they taught it. Most had been able to define their initial activity but went into a general listing of activities and lessons, with no sequencing or system for planning a sequence. For this reason, I added the component to the professional development model that asked participants to sequence an ideal Biology course.

At the Initial Interview I gave the school system curriculum sequence to participants and they were asked to number the topics in the order they would prefer to teach the course. One participant checked to be sure that a pseudonym would be used before continuing with this activity. All expressed their dismay at the current sequence they were being asked to teach because it did not fit their students, or their way of teaching. They felt that their background in biology made it possible for them to understand the sequence; however, their students did not have enough understanding of biological topics as they entered the course to be able to make the connections required by the curriculum. Some who were on the semester block schedule indicated that during the fall semester they had not been satisfied with their success following the current school system sequence, that they were reverting to a sequence of their own.

As participants numbered the preferred sequence during the Initial Interview many were verbalizing the reasoning for their choices. Dot mumbled her way through the numbering process explaining in short bursts her sequencing. "So we come back to classification but now looking at the characteristics of the different…more in depth. (Initial Interview, p. 5, lines 196-197)" As Flossie was describing the needs of her ESL population she pointed to various topics describing why she sequenced the topics as she had done. "You teach this to teach this to teach that to come back and teach this" (Initial Interview, p. 3, lines 114-115). She saw the connections between the topics, and felt a need to build a sequence that would help her students also see them. No participant's sequence matched that of the school system.

When asked about the amount of time allotted for teaching in the school system sequence, most felt it was not suitable for the topics. Many wanted more flexibility both for the topics, or the needs of their students. Paul and Flossie indicated that some topics were foundational, and if sufficient time were spent on those, the others could be taught in less time. The participants had found ways of coping with the rigid schedule. Jessica, who was teaching on the semester block, allowed herself some flexibility as indicated in the Initial Interview.

Jessica: I think this is just a guide. I don't think that I am held to this.

Marion: So you don't think you have to do this exactly in that little block of time?

Jessica: No I don't.

Marion: Do you find some topics take longer?

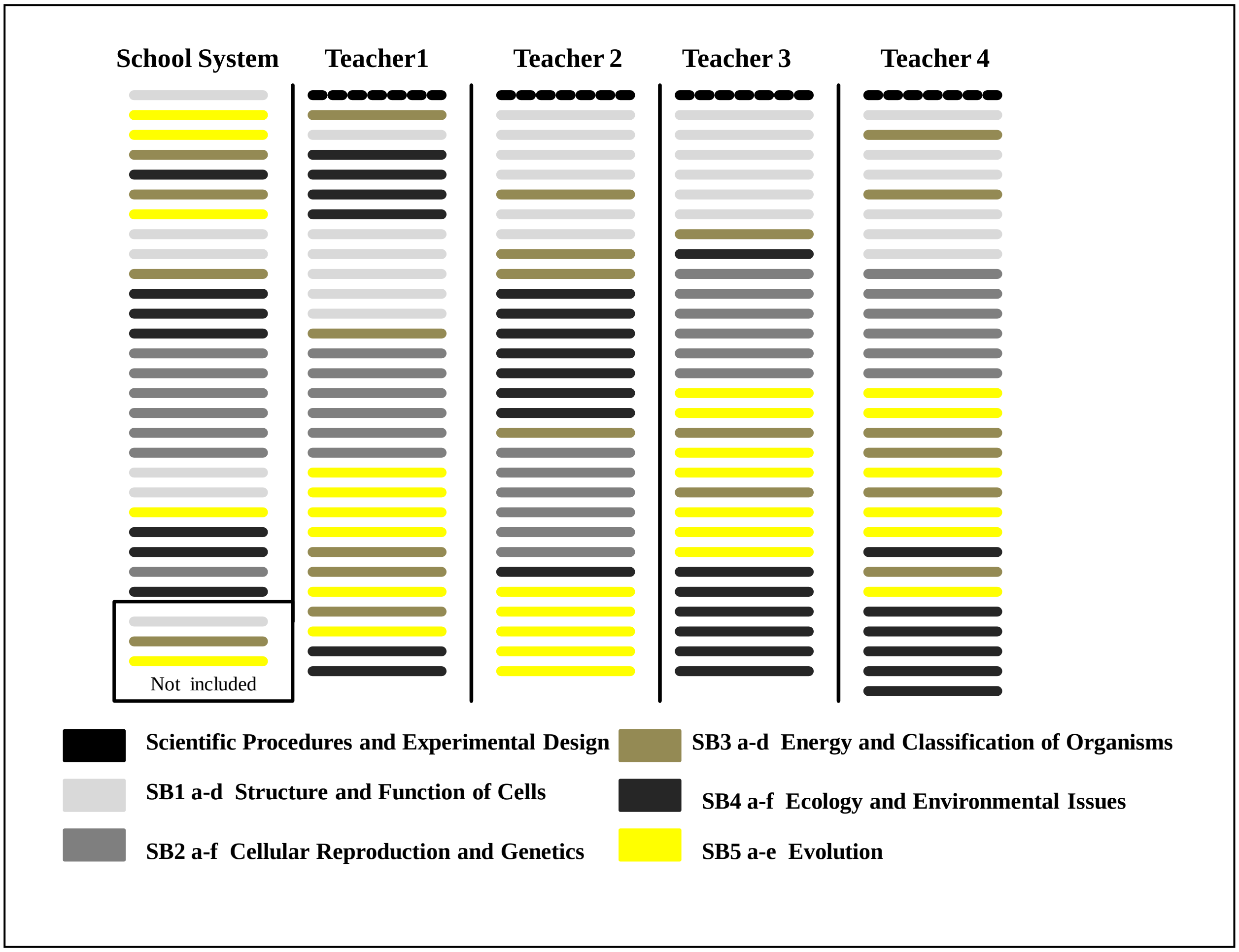
Jessica: Oh yes!

(Initial Interview, p. 5, lines 192-196)

Dot and Flossie also wanted some flexibility within the school system schedule so that they could meet the needs of their students each year. All saw a purpose in the time sequencing and tried to stay within the school system plan as much as possible. Two main reasons were given: (1) the need to be fair to students who might change classes, and (2) the need to avoid personal favorite topics, while avoiding others students might need to learn.

I created a list of topics from the Biology GPS each participant developed at the Initial Interview and returned it to them for confirmation. All rearranged the sequencing at that response time as they looked over the list. Several had omitted content standard elements, which I added at the bottom and they integrated into the sequence. As we made these exchanges throughout the study, participants explained why they were altering the sequences, and why they were integrating the omitted topics. As can be seen in Figure 5, there was general agreement among the participants about the sequencing of content topics. Although the school system did not include an introduction to scientific procedures and experimental design all participants began their course with this topic. Participants were in agreement on the placement of the structure and function of cells at the start of the course, cellular reproduction and genetics about the middle, and evolution as a concluding topic. All placed evolution following cellular reproduction and genetics. This was virtually the opposite of the school system sequence, which placed most of the evolution elements at the beginning of the sequence. The energy and classification and the ecology and environmental standards were distributed differently based on the connections each participant made to other topics. Overall, there was little correlation between the school system sequence of topics and the participants' preferred sequencing.

Figure 5 Biology content topic sequencing



At the third log visit I presented participants with their final sequence and asked them to group the topics into units. The two participants who were teaching on a semester block schedule divided their sequence into fewer units than the two who were teaching a year long course. With the shorter time available for the Biology course, the block schedule teachers appeared to be creating instructional units that included more topics. Participants then were asked to select the unit they had taught during the majority of the time they had maintained the lesson log. It was at that time that it became clear that participants were not teaching the school system sequence but their own. An analysis of their logs in light of the timeframe of the course confirmed this. The participants were using their professional experience as Biology teachers and expertise to provide a sequence that would, in their opinions, help the students learn.

During the Reflective Interview, I asked participants to examine their log and describe the sequencing of their unit and the reasoning they had used. This time, with the log in front of them, they were all able to verbalize the reasoning and the sequencing. Many described their transition from the previous unit and how they had set the stage for the unit with their initial lessons. For example, Flossie linked a unit on energy to the previous cell unit:.

> She starts with photosynthesis and respiration because the unit previous to this one was on the cell. She finds the transition through photo/resp a chance to deepen the cellular unit with the discussion of the mitochondria and chloroplasts. This also reinforces the idea of autotrophs and heterotrophs. (Field Notes Log Review #3, p. 1, lines 16-20)

Many described how the sequencing allowed integration of previously taught concepts or preparation for future units. Dot described her sequencing of diversity of life of animals as a way of revisiting evolution. "She likes this sequence of instruction because it allows her to tie in evolution as she compares the anatomy of the animals" (Field Notes Log Review #3, p. 1, lines 31-32). All participants were able to a greater degree than they had previously; to describe not only the sequencing, but the rationale that supported this unit. They were more aware of their thinking about the sequencing of lessons, as well as the purposes each lesson served in advancing the student understanding of the topic.

Alteration of lessons. Throughout the study participants began to make a few changes to their lessons as they reflected on the Characteristics of Science co-requisite standards on a daily basis. I had asked to be invited in to observe a lesson the participant thought integrated to two sets of standards well. It was their decision which class would be involved in the study, as well as which lessons were observed. Two participants selected gifted classes, one selected a class that included special education students with a co-teacher, and one selected a general level class that was entirely composed of ELL students. As I observed the lessons, it was clear that the composition of the classes did not influence the participants' willingness to present lessons that called for active student participation and development of both sets of co-requisite standards. Although the lesson logs indicated that thirty seven percent of the total lessons had been student focused employing both sets of standards, all eight observations were of this kind. It appeared that the participants had considered the blending of the co-requisite standards well enough to understand the type of lesson they knew would meet my request.

Three participants made modifications to their first lessons because I was coming to observe them. Dot, who ran all materials for class off well in advance, admitted that she had added the exploration of a worm's response to acetone because she had been examining the co-requisite standards. "The acetone, I sort of added because I had the lab printed out. I have my handouts printed out a month in advance. But after you came in and I was looking because there is another part to the lab" (Lesson Review #1, p. 1, lines 42-44). She had made a note and already added it to the instructions for use in the coming year's lesson. Both Flossie and Jessica had completely rewritten their first lessons, which were labs. Jessica, with a gifted class, had made the observation of a pond ecosystem more student guided than she had previously done. Examining her simple, one page lab directions (Appendix O) it was clear she had given broad directions, with some hints, but not specific instructions. She had encouraged students to identify the organisms, without specific directions, and included a section that called for students to compare their data, since each group had a unique composition of their pond water that she had manipulated. She was concerned during the lesson review that some groups had not taken complete data. Our discussion on modification to the lesson was built around how to structure the activity so that the students would be more likely to take that data the next time, not how to write better directions to instruct the collection of data.

> Marion: I'm wondering if it might trigger them sooner to take the measurements if the thermometers and pH paper was sitting at the counter with the microscopes.
>
> Jessica: Yeah, I wanted them to figure out to use the pH paper. Yeah, you're right.
>
> (Lesson Review #1, p. 5, lines 178-182)

Jessica indicated that this lesson would also be used with her general level class, using a slightly more structured set of directions. Flossie's lesson included three flasks with varying mixtures of water, sugar and yeast. During the lessons she began to emphasize the importance of the two control flasks with her students, which had not been included even in her rewritten directions.

After the second observation the discussion of the lesson review had changed in focus from procedural or content follow-up with students to a greater focus on conceptual understanding of both content and characteristics of science. Jessica, who had been concerned about students not collecting the right data during the first lesson, discussed her plans to follow up the second lesson with plenty of time for students to examine and develop an understanding of the data collected. Dot had been concerned after the first lesson with the need to clear up student misunderstandings regarding the relationship of worms and snakes, however at the second lesson review she was more concerned with their ability to work with dependent and independent variables. At that point Paul was working to continuing to run lab activities in the trailer setting. He had made modifications to the lab because of having fewer microscopes available, but was determined to continue to provide his students lab experiences. "When I'm in the classroom it's done differently. The students have twelve scopes. I have at least one dissecting scope out. I got a place to walk between tables. The space here" (Lesson Review #2, p. 3, lines 129-131)!

During the Reflective Interview several participants discussed some of their changes in practice over the course of the study. Jessica indicated that she had made her second observed lesson, which she only used to teach to gifted students, available to her general level students. She had modified the procedures so that the added structure could allow her to manage the data collection process. Flossie indicated that although she was logging the lessons for the ESL class, she had found herself more closely examining the work of her students in her gifted classes in light of her reflections. A page from this log can be seen in Appendix P. She had begun to focus more on developing procedural skills such as graphing with the other class as well, and became more concerned about the quality of the Characteristics of Science skills displayed in the student work as indicated in the Reflective Interview: .

> Focus on some other elements of it too. If you do a graph, that basically says carrying capacity say, did you do the graph well? Did you title the graph? Did you label your x and y axes? Things that are a part of science. Things that they should be learning in addition to being able to identify carrying capacity graph. (Reflective Interview, p.2, lines 53-57)

The data analysis indicates that participants were beginning to make modifications of practice that gave greater emphasis to the Characteristics of Science standards in their lessons.

Greater value for the Characteristics of Science standards. During the final interview all participants described not only their increased awareness of the Characteristics of Science standards, but also their increased valuing of these standards as being important to teach. The focus all had shown throughout the process on the importance of the Content standards was evidenced in many ways. All lesson logs, on a daily basis described the Content standards in detail, even when Characteristics of Science standards were not present. In the Setting Interview, as well as the Initial Interview, the participants had discussed clearly the specifics of the Content standards, but the language describing the details of the Characteristics of Science standards was rather vague. Every lesson review had strong descriptions of how the lesson supported student content understanding. An analysis of the twelve lessons selected during the final interviews found participants identifying ten of them as strong because the students were able to learn to content through experience. Five of the lessons were considered good lessons because they allowed incorporation of multiple content topics.

When asked about how their thinking might have changed regarding the Characteristics of Science standards during the final interview participants appeared surprised by their changes. Dot, who valued inquiry teaching greatly, realized that she had not been teaching the Characteristics of Science standards overtly, even though she thought they were important. She went on to emphasize that she now considered them equal to the Content standards. “So bringing it back to the discussion using maybe the terminology and the vocabulary that was in the standards” (Reflective Interview, p.1, lines 25-26). This is a strong statement since throughout the study the student’s ability to use the vocabulary of the Content standards was always a high priority in her mind. Flossie thought that using the Characteristics of Science standards in her teaching made her lessons more student centered and active. This would create what she called “anchors for remembering content” and would make it more memorable. She was struck by the thought that these were not check off standards, but rather means of improving her instruction. Jessica who always valued the Characteristics of Science standards realized she had moved them to the “back burner” and needed to bring them forward. And Paul, who struggled the most with these standards, realized he had been using multiple instructional strategies for student diversity, but needed to focus more modifying his instruction to include the standards. In all cases the participants had come to develop an increased focus on the Characteristics of Science standards, and their value for their students as well as for their instructional practices.

Considering how to better include both standards. Although the participants had signed the consent form for research that described the study as a professional development, they chose to be involved because it was for research purposes. They focused more on the research aspect of the study, and seem to have forgotten that the study was about professional development. This factor made the conversations we had throughout the study more meaningful because they thought we were simply talking about what I had seen and their reflections on using both sets of standards. The participants’ willingness to project possible change in their practice into the future, as well as to be open to changes in lessons observed was evidence of their professionalism as they reflected on their practice.

The lesson reviews following observations were structured in such a way that each question was first answered by the participant as they reflected, followed by my reflection on what I had experienced during the lesson. The participants were always interested in my observations, especially since I often was able to observe students employing the Characteristics of Science standards in greater detail than they had since they also been involved in managing the class. On one occasion a student was placed in Jessica’s class to isolate her from a room where she had been a disruption. Before the lab activity was done, she had joined a group through two rotations of the lab, and was actively engaged in the process, including helping to clean up at the end. Jessica had been unaware of this student's engagement in the lesson and was delighted to hear of it. During the respiration of fish lab in Dot's room she had not realized the amount of negotiating and collaboration that her students had to practice to successfully collect data during the small time allotted for such a complex lab. Our conversations during the lesson reviews helped participants refine their view of how students were seeing and employing the Characteristics of Science standards at a deeper level than they had estimated. Through this they began to consider and look for ways of improving student engagement with these standards.

A second portion of the lesson review was a reflection on how to modify the lesson for the future. The participants explained their proposed changes, and during the first review they were often related to management of the lesson. However, by the second review they were considering how to enrich the lesson with more Characteristics of Science standards. My suggestions always related to adding the use of these standards into the lesson observed. The participants responded to these suggestions with a positive attitude. Flossie could not wait for our discussion to end after the first lesson review to get to a computer to add it to her lesson so that she would have it for the next time she taught it. Jessica and I entered into a discussion of how a complex lab she used with her gifted students might be made more manageable for her to be able to use with the general students. One suggestion I had made was that the data collection be distributed to the groups, with later sharing of data for the complete view of the lab. Jessica seemed open to this change as illustrated in the second Lesson Review.

> Marion: General would need two set ups. One third of the class could do the water, one third of the class would do the sand, one third would do the open. Their two sets of

numbers would be averaged and then you would then share class data across the class. The time going around collecting wouldn't be as chaotic.

Jessica: I see that. But they wouldn't get the experience of doing. They wouldn't get the experience of doing the three things.

Marion: Feeling the difference.

Jessica: Right there is a difference.

Marion: I knew that was important but I'm thinking in terms of maybe they don't get the experience, but it gives you an opportunity to model trusting each other's data, shared data. It gives you an opportunity to talk about the difference. Particularly if you have two groups and you have to average their scores.

Jessica: Oh I see, so you have two groups.

(Lesson Review #2, p. 5, lines 188-203)

This was a typical dialogue, with the participants willing to enter into rethinking how to alter their lessons in ways that would include more of the Characteristics of Science standards.

During the Reflective Interviews, the participants described various ways they were thinking about modifying their teaching so that Characteristics of Science standards could be included in a better manner than they had done previously. These considerations were becoming quite specific to their personal practice and setting. All participants were struggling with how to rearrange their instructional time to accommodate these changes. Dot thought that if she lessened the content depth it would allow her to focus some more of her time on developing the Characteristics of Science standards. Jessica began to discuss moving some of the review activities that used up her class time to homework, and free up more time to use in class for lessons that required practicing more these standards.

Participants began to discuss specific changes to their sequencing and selection of lessons to better include the Characteristics of Science standards. Flossie planned to be more selective as she chose her lessons, looking for ones that included strong components of characteristics of science in them. Paul wanted to increase the number of labs he ran because of the opportunities it gave his students to experience with doing science. Jessica was considering using journal articles to enrich her lessons and allow her students to consider how scientists go about their practice. She hoped this would help address the Nature of Science portion of the standards she realized she was not teaching. Participants described ways of including the Characteristics of Science standards in their grading system through making a list of standards and selecting some each lab to emphasize or through creating a rubric that graded these standards for quality of work.

The changes described in their future plans were specific. I returned their individual case study for feedback at the start of the next school year several participants thanked me for the reminder at that point in time of the ideas they wanted to implement. They planned to make some of the changes they had considered during the study as they began the new school year.

CHAPTER 7

Placing the Research in Current Context

> *Because intelligent people adapt to the situations in which they find themselves, if students are in contexts where scientific thinking is neither needed nor valued, it is highly unlikely to appear. (Schauble, 2008, p. 56)*

Science education standards are currently undergoing the first major revision since the 1996 edition of the *National Science Education Standards*. *A Framework for K-12 Science Education: Frequently Asked Questions* (2011) described this process of revision. The revision process was begun by a committee of eighteen experts convened by the National Research Council, who developed a proposed framework for national standards in science education. The committee based its work on the previously developed documents in use, however, committee members refocused their efforts because “much has been learned over the past decade about how students learn science most effectively, and the new Framework incorporates those findings and approaches” (National Academy of Science, n.d.). In July of 2010 a draft was opened for public comment. Following this, the committee issued *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (2011).

Unlike the previous standards that were suggestions for best practice, the Framework bodes the development of standards that have the potential of being immediately adopted for use as written by the states. This is because the process of framework development leading to standards is linked to the federally funded Common Core standards. Georgia adopted the English Language Arts and Mathematics Common Core Standards on July 8, 2010 (Common

Core State Standards Initiative, 2011). This adoption was part of the plan that brought four hundred million dollars for education into the state in the form of a Race To The Top grant (Georgia Department of Education, 2010). Georgia is one of the states that have volunteered to work on building science standards from the Framework, in collaboration with Achieve (Next Generation Science Standards, 2011). As a part of this process the state has made a commitment to seriously consider adopting these science standards once they are completed in 2012.

The new standards will continue to include expectations that students learn more than content knowledge in all areas of science, including Biology. Just as the GPS has included co-requisite standards relating to the processes and nature of science, the new national standards will add to the content expectations, science and engineering practices. The new standards are also expected to include an additional area not currently seen in the GPS, which are cross-cutting concepts that will be threaded through all content areas of science.

This study has revealed some issues that should be considered as implementation of new standards are considered. Standards that are implemented without curriculum expansion to local settings have led to uneven, individual teacher interpretations of their meaning for practice. Teaching science practices do not always lead to teaching the nature of science to students. Even when spelled out clearly in a standard, teaching the nature of science has not happened easily in Biology classrooms in this study. Should the nature of science no longer be stated, but implied it could decrease student understanding of it. Multiple choice format tests are viewed as content focused tests by teachers. This viewpoint has a tendency to skew classroom practice away from including characteristics of science in instruction, with emphasis on content. General professional development to orient teachers about standards has not brought about changes of practice that emphasize standards-based instruction. When provided with opportunities to reflect about the implementation of standards within their contextualized practice, teachers are able to change to a more standards-based form of instruction. Given the issues to be considered I will describe the implications they raise in several areas: standards, assessment and professional development. I will conclude the chapter with some implications for future research.

Implications for Standards

The currently adopted Georgia Performance Standards that were part of this study (Appendix Q) consist of two set of co-requisite standards. As the study has revealed, it was the process of examining the co-requisite standards that helped the participants develop their own thinking about implementing standards-based instruction in their Biology classes. The study further revealed that prior to the professional development participants had guided their teaching using a thorough examination of the Content co-requisite, with little attention to the Characteristics of Science co-requisite standards. Once they added both sets of standards daily to the lesson logs, planned lessons that incorporated both sets of standards, and reflected on this process through lesson and log reviews, participants began to modify their instruction, and expand their understanding of standards-based science teaching.

The newly developed science Framework divides the standards into three dimensions: (1) scientific and engineering practices, (2) crosscutting concepts, and (3) disciplinary core ideas. The disciplinary core ideas align well with the content standards that have appeared previous national and state standards. As the study showed, these experienced Biology teachers did not appear to have difficulty interpreting and operationalizing these standards as they planned instruction for their students. When examining the dimension of scientific and engineering practices it is not difficult to align them with current characteristics of science standards. The first six of eight Characteristics of Science standards that the participants found they could easily incorporate in their lessons line up well with this dimension of the Framework as can be seen in Table 7.1. Refer to Appendix Q for the full description of the GPS references.

Table 7.1

Alignment of Current GPS with Proposed Framework Dimension-scientific and Engineering Practices

Framework K-12 practices	GPS Characteristics of Science
Asking questions (science) and defining problems (engineering)	SCSh3a SCSh1a, b, c
Developing and using models	
Planning and carrying out investigations	SCSh3b, c SCSh2a, b, c
Analyzing and interpreting data	SCSh3d
Using mathematics, information and computer technology, and computational thinking	SCSh4a,b,c SCSh5a,b,c
Constructing explanations (for science) Designing solutions (for engineering)	SCSh1b, c SCSh6c
Engaging in argument from evidence	SCSh6c,d
Obtaining, evaluating and communicating information	SCSh5f SCSh6a,b

The Framework document describes an expectation that through the teaching of these practices students will develop an epistemic knowledge of the "…constructs and values that are intrinsic to science" (p. 3-22). The document then defines what some of these are such as "…through collaborative efforts of groups of scientists whose critiques and arguments are fundamental to establishing which ideas are worthy of pursuing further" (p. 3-22). This appears to place some of the more explicitly stated nature of science standards in the GPS in the background of understanding without being explicitly stated. For example the nature of science standard 8 c and d would line up with the thinking above. " c. Scientists use practices such as peer review in publications to reinforce the integrity of scientific activity and reporting. d. The merit of a new theory is judged by how well scientific data are explained by the new theory" (GPS). The study found that the last two standards in the Characteristics of Science, numbers seven and eight describing nature of science rather than practices, were more difficult for the participants to envision ways of implementing and actually implement as evidenced by the few references to GPS standards seven and eight in the lesson logs. This was true even when they were spelled out for the participants in standards seven and eight of the GPS and examined by participants as they recorded their lesson logs throughout the study. The direction of the new standards based on the Framework appear to embed an expectation that teachers who follow the classroom practices above will be able to help their students achieve and understanding of the epistemic (or nature of science) knowledge of how science is practiced in the scientific community. However, the study data analysis has indicated this thinking about science is not easily communicated to students through teaching the processes. The participants openly discussed their difficulty in ensuring this happened such as Jessica described in her Reflective Interview. She had come to realize that she had been teaching the first six Characteristics of Science standards that aligned with the practices, but felt she was not addressing the nature of science ones in her work. "Right now I don't think I ever put seven and eight in there"(Reflective Interview, p. 2, lines 58-59). Seeing these concepts in writing had led to her realization that there was a difference in teaching the practices and teaching the nature of science.

The Framework document proposes that many of the nature of science concepts would be better addressed at the curriculum implementation level. In describing why the Framework did not include these nature of science concepts, the writers emphasized their importance however they stated that they "decided would be better treated at the level of curriculum design than at the level of framework and standards" (p. 10-5). The authors of the Framework stated that these remaining nature of science concepts were "historical, social, cultural, and ethical aspects of science…"(p. 10-5). These they thought, were better dealt with at the descriptive level of how to implement instruction. It appears that the standards that will be generated from the proposed Framework will not provide any better guidance to teachers about how to implement nature of science standards than the current ones do.

The Framework will not be the guiding document for creation of curriculum, the standards which are being developed to align with the Framework will. This will place these explicit statements regarding the dimensions for science teaching in the Framework two steps away from the curriculum teachers will use for instruction. If the current practice used by most school systems in Georgia continues, the teachers will not be provided with a developed curriculum, but rather with the standards document as the guide for instruction. The goal of the Framework developers that nature of science concepts be developed for curriculum implementation will not happen. This will, in effect, move these concepts out of science instruction expectations. The participants in the study were teaching from a set of school system curriculum that grouped and sequenced content standards listed by Biology GPS number. This document grouped the Biology topics into units that listed the content referenced to the GPS numbering system. Each grouped content unit of instruction had a recommended time allotted for instruction. All the Characteristics of Science standards were summarized in this curriculum provided by the school system with a statement below the grouped units of content: “Each unit integrated laboratory experiences and field work using the process of inquiry” (School system internal document). This pattern of curriculum development indicates that nature of science concepts have the potential of being overlooked in the formal documents guiding instruction. The current practice of using standards without elaborating into the deeper curriculum descriptions serve to counteract the process envisioned by the Framework. States will need to ensure that school systems understand that the adopted new standards are to be the starting point for developing a teaching curriculum matched to local needs.

Although the Framework consists of three dimensions, the current plan is that the standards will be written as a single document, with statements in the standards that blend these dimensions. “The committee suggests that this integration should occur in the standards statements themselves and in performance expectations that link to the standards” (p. 9-1). Reading this statement leads the reader to understand that there will be a blend of the dimensions in the standards, with no separation of practices, crosscutting, and disciplinary core ideas. When I put this question to Dr. Stephen Pruitt, head of development for the science core standards at Achieve, he replied:

> You are correct. The NCR’s *Framework for K-12 Science Education,* focused on three dimensions, Science and Engineering Practice, Crosscutting Concepts, and Disciplinary Core Ideas. The vision laid out in the Framework is the integration of these dimensions in classrooms and the standards. Our job is to develop the *Next Generation Science Standards* with the Framework as the foundation. So, the new standards will contain all

> three dimensions in integrated statements. In essence the integration will describe the performance expectations for students. (Personal communication, September 16, 2011)

The committee provided an example within the Framework document of how they envisioned this integration process. The sample for Life Sciences was from the first life science Core Concept. A table was provided with five components: Tasks, Criteria, Disciplinary Ideas, Practices, Cross Cutting Concepts. Each component was divided by grade level bands with four bands being identified: end of grade 2, end of grade 5, end of grade 8 and end of grade 12. Table 7.2 provides the general outline of this model for integration of the Framework into standards.

Table 7.2

Suggested Integration Model for Standards from the Framework (p. 9-12)

Broad statement of concept to be taught				
	By the end of Grade 2	By the End of Grade 5	By the end of Grade 8	By the end of Grade 12
Tasks				
Criteria				
Disciplinary Ideas				
Practices				
Crosscutting Concepts				

This model does not appear to integrate the three dimensions in a manner easily operationalized by teachers. The largest area of the table is the line for Disciplinary Ideas, which continues the spelling out of detailed topics to be taught, in the same manner as the current Georgia Performance Standards for Biology. Should this be the model adopted by those creating the *Next Generation Science Standards* the potential remains for teachers to focus on the content portion of the standards?

Implications for Assessment

Participants in the study indicated during the Setting Interviews that one of their major goals for the students in their classes was success on the EOCT. At the time of the study the EOCT counted fifteen percent of the course grade. Students would also have taken the High School Graduation Test (GHSGT) in science which included both Biology and Physical Science concepts, to meet graduation requirements. Current rules passed since the Race to To The Top grant have altered these requirements for students in Georgia. Students entering high school in 2011-12 school year, will have the EOCT grade in Biology count as twenty percent of the course grade. Students, who pass the EOCT in Biology, will now be exempt from having to take the GHSGT to meet graduation requirements. The GHSGT will gradually be phased out as the EOCT rule becomes implemented with future classes.

The study results indicate that one of the primary reasons participants focused so heavily on the content portion of the standards was because they perceived the content portion as being the core of the EOCT. Ensuring that students had an opportunity to experience all Content standards, even if they were not taught in the student-centered manner called for by the complete set of standards, had become essential to the participants. The Setting Interviews indicated that participants reverted to teacher-centered practices, especially when the they perceived that student-centered instruction could prevent them from teaching all Content standards because of lack of time. Analysis of data indicated that participants were heavily focused on teaching the vocabulary of Biology rather than helping students develop a conceptual understanding of the topics in the course.

Since the EOCT will not change until new standards are implemented, the data analysis suggests that the increased accountability of the test will move teachers of Biology in Georgia even further from teaching conceptually in a student-centered classroom. Although the developers of the current test have indicated that it is designed to include both sets of co-requisite standards, the multiple choice format has guided teachers toward a content focus. If future tests developed to align with the release and implementation of new standards does not reflect the focus on learning tasks envisioned in the Framework, teacher practice is unlikely to change.

Classrooms that are student-centered require multiple assessments. The data analysis in the study indicated that participants used multiple assessments with their students, but as the lesson logs indicated, units of instruction ended with tests, not performance assessments. Participants indicated in the Setting and Initial interviews that part of the reason for this test focus, was the need to prepare students for the EOCT. The school system benchmark test format, that used a set of multiple choice questions, reinforced this teacher practice.

The model for standards in the proposed Framework seen in Table 7.2 includes tasks and criteria for those tasks as a part of the format. This appears to be intended to guide assessment format for the standards. The writers of the Framework addressed this concern. "…a glaring and frequent mistake is to assume that current standardized tests of the type used by most states to assess academic achievement for accountability purposes can also suffice to fill the other purposes of assessment" (National Research Council, 2011, p. 10-13 – 10-14). The Framework went on to describe the problem they saw with the multiple choice assessments being used for the new standards.

> …they do not adequately measure other kinds of achievements,, such as the formulation of scientific explanations or communication of scientific understanding. They also cannot assess students' ability to design and execute all of the steps involved in carrying out a scientific investigation or engaging in scientific argumentation. (p. 10-14)

The call is for new formats for accountability testing that better capture the understandings presented in the standards. However, these formats cost a great deal more to create and implement than the current multiple choice formats. Because they contain more open-ended questions they also take longer to grade and return scores to those who took them. If EOCT test scores must be included as a part of the course grade, the delay in return of the scores to students creates a logistical problem in terms of turn-around time. The increased costs for the more open-ended form of assessment were cited by the Georgia Department of Education as a reason for continuing with the multiple-choice format at the time of the implementation of the GPS.

If the practice of providing accountability assessments such as the EOCT is going to continue to be to use multiple-choice formats, the possibility of aligning teacher practice with the student-centered, inquiry instruction called for in current as well as proposed standards, will be reduced. Analysis of data from this study indicates that a set of standards with extensive content focus tied to the multiple-choice format has caused teachers to attend to the content rather than the processes of science in their teaching practices. This was reflected in the detail references to the Content standards in the lesson logs of the participants. The detail of references to the Characteristics of Science standards for most participants began with vague references, and gradually became more specific as the professional development progressed. During the Reflective Interviews, the participants recognized this tendency on their part to focus on content and neglect the characteristics of science as one of the practices they become aware of during the professional development. Unless the accountability assessments support the change in classroom practice envisioned by the Framework not only does the current study, but other research supports the implication that there will continue to be a more teacher-centered practice implemented in Biology classrooms.

Implications for Professional Development

The results from this study show that although participants had taught using the Biology GPS for six years, and indicated an understanding of the basic principles of standards-based inquiry teaching on the ICQ, they had not achieved a student-centered classroom. When asked during the Setting Interview how often they attained the goals they expressed for inquiry teaching, all participants indicated that they found their lessons matching these goals on rare occasions. The interviews with participants during Phase I of the study indicated that there was an awareness of this lack of success, and participants expressed their frustration at this. At that time, several reasons were described as impeding success such as student maturity, teaching a paced curriculum, poor sequencing of curriculum and the need to focus on skills for the EOCT. None expressed concern that they had not been provided with adequate professional development to develop the appropriate skills needed to teach the GPS and have students be successful on the EOCT. Participants indicated that when they had to choose between what they indicated was a time-consuming student-centered instruction and a teacher-centered, efficient content delivery instruction; they chose what they perceived as more efficient due to time constraints. The participants' priority for student success on the EOCT led to an emphasis on the content. Jessica expressed this inability to embed more student-centered activities due to the need to complete instruction on content during her Setting Interview. "…but I'm running out of time. So I do mostly pen and paper activities" (Setting Interview, p. 4, lines 138-139). She appeared to be well aware that this was not the preferred way to teach Biology, but had not found a solution to incorporating both sets of expectations.

When the GPS was implemented in Georgia, the professional development provided by the Georgia Department of Education focused on a train-the-trainer model in large group format throughout the state. Participants in this professional development were provided the resources to return to local systems and provide large group format instruction on the standards. Testing data on Biology EOCT scores reflect lack of student success (Governor's Office of Student Achievement, 2009-2010). Table 7.3 summarizes the statewide student achievement scores as well as those for the system involved in this study.

Table 7.3

Biology EOCT Passing Rate Percentages 2009-2010

	Total	Asian	African-American	Hispanic	White
State	66	82	50	60	80
School System	55	57	51	50	89

Analysis of these test results indicates that teachers both statewide, and within this system included in this study were experiencing limited success implementing the standards-based instruction as measured by student success on the end of course test for Biology.

For the most part, it became the responsibility of the classroom teacher to decide how to implement the standards within the classroom. The data analyzed indicated that participants in this study had chosen to focus on the Content co-requisite standards with little attention to the Characteristics of Science co-requisite standards. Analyzing the testing data as well as data from this study, indicates that the manner in which the Biology teachers have chosen to implement the GPS for Biology has not led to a high level of student success. When participants in this study examined the standards more closely, and reflected on their practice, they indicated an understanding of the need to change instructional practices if they were to be aligned with the expectations of the Biology GPS. Participating in the general professional development did not appear to have enabled these teachers to conceptualize the importance of teaching both sets of standards. When analyzed, the data in this study indicate that through experiencing the reflective, a contextualized model of professional development the participants had made the connection of the standards to their practice.

Developers of the new Framework have made suggestions regarding the kind of professional development model that would best support implementation of the new standards. "This professional development should not only be rich in scientific and engineering practices, crosscutting concepts and disciplinary core ideas but also be closely linked to teachers' classroom practice and needs" (National Academy of Sciences, p. 10-12). The committee realized that models of professional development used in previous implementation of standards would not be sufficient. "It should be understood that effective implementation of the new standards may require ongoing professional development support and that this support may look different from earlier versions" (National Academy of Sciences, p. 10-12). One of the reasons given for this need was to take into account the varying teacher and contextual needs for professional development. The results of this study indicate that moving in this direction with professional development for the new standards could lead to implementation in the classroom that is more closely aligned with the standards. It will mean, however that school systems, and schools will need to be involved in personalizing the state professional development on new standards not only at the time of implementation, but in an ongoing, continuous manner within their individual contexts.

The recommendations of the National Academy of Sciences' committee align with the National Council for Accreditation of Teacher Education's (NCATE) blue ribbon panel's report (2010) for future direction of teacher preparation. This report encourages a more clinically-based approach to teacher preparation. This model proposes a great deal of embedded experiences in classrooms, with opportunities for reflection. If professional development is intended to continue teacher growth, then this model would seem appropriate for use. As the research in implementing standards has indicated, even experienced teachers feel de-skilled when faced with new performance expectations, such as during times of changing standards. A professional development model that is aligned to recommended best practice in preparing novice teachers would have the potential for success, since in effect, experienced teachers become novices when implementing the new practices expected in standards.

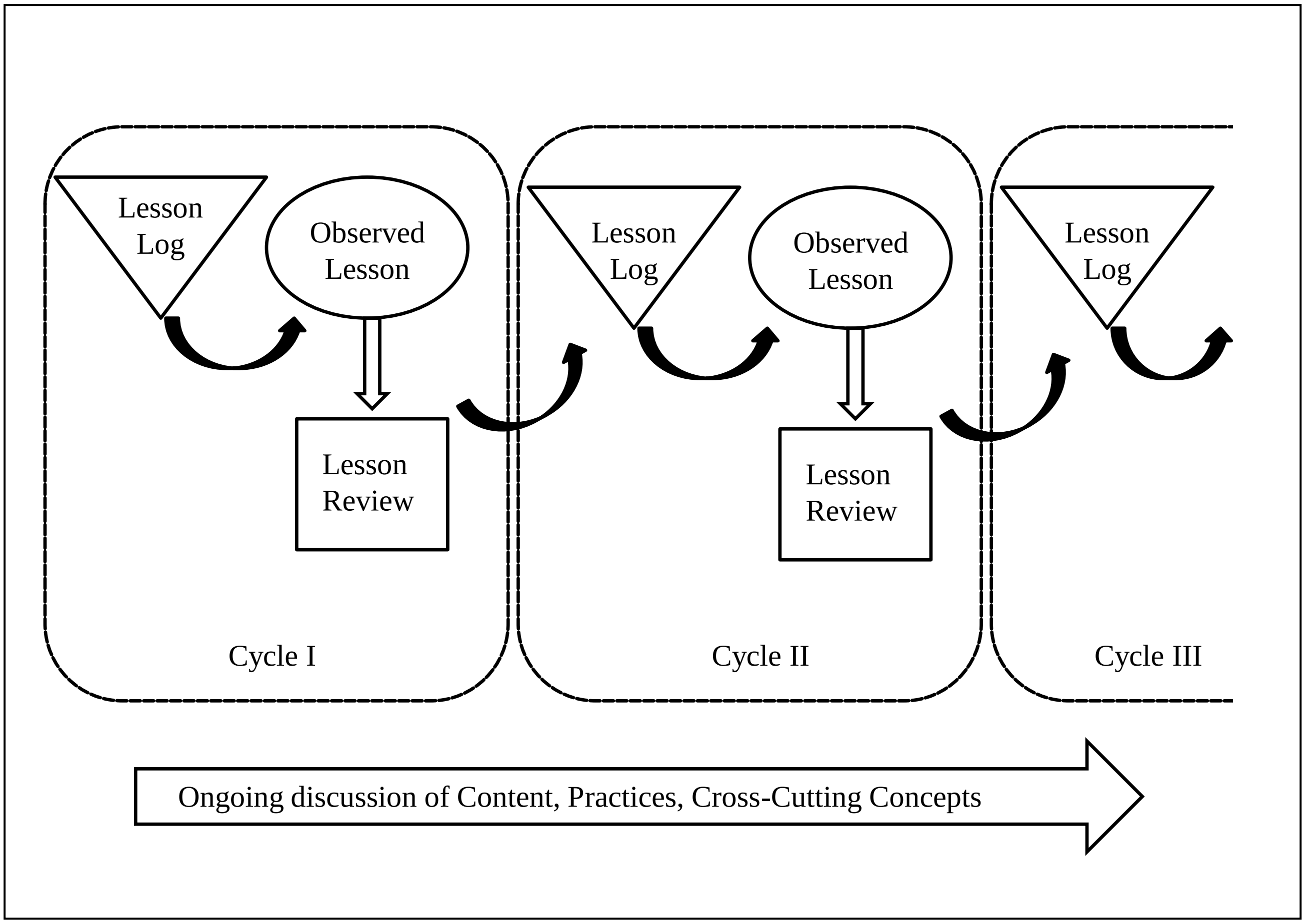
This form of preparation of pre-service teachers brings expectations that there will be expert teachers who can serve as support for students as they participate in the increased clinical work. These experienced teachers should be able to model for the students in teacher preparation their own reflective practice, and continued learning. Professional development opportunities that allow reflective practice within the context of school instruction will need to be included regularly as part of learning opportunities for experienced teachers. Unless there are more of these reflective, contextualized professional development opportunities the goal of changing teacher preparation to a more clinical model could be hampered due to lack of support within the schools in which the clinical experiences are expected to take place.

Three of the design principals proposed in the blue ribbon panel's report align with the professional development needs foreseen by the NRC framework committee. First there should be a focus on helping pre-service teachers focus on developing student proficiency in standards. "Candidates need to develop practice that advances student knowledge as defined by, for example the Common Core State Standards, for those subjects for which they have been developed" (NCATE, 2010, p. 5). The clinical learning focus means that participants in pre-service programs will need a great deal of "school-embedded practice" (NCATE, 2010, p. 5). A third recommendation is that pre-service programs should create teachers who are experts not only in the content, but in how to deliver it. "Further, effective teachers are innovators and problem solvers, working with colleagues constantly seeking new and different ways of teaching students who are struggling" (NCATE, 2010, p. 5). The blue ribbon panel did realize that teaching pre-service candidates in this manner would bring with it greater costs.

The model of professional development used in this study brings with it the possibility of additional costs. Features that supported the learning required individualized attention on my part with the participants. Observations with reflective conversations allowed the participants to focus on the learning experiences they provided within their classroom. Working with smaller numbers of participants in any professional development model will bring about increased cost. The use of technology would allow a greater number to be served. Teachers could be encouraged to examine their own practice through video recordings. Instead of working with an observer who attended the entire lesson, specific portions could be identified for further discussion and reflection. The choice will need to be made by those providing professional development on the new standards about which models will best meet the purposes for learning. If an orientation to the standards is the intent, then the large scale model employed by those who provided professional development to the GPS will be sufficient. But if the ongoing professional development envisioned by those who wrote the Framework is going to happen, then more models will need to be employed.

Analysis of the data in this study indicates that the model of professional development used in this study achieved an increased awareness on the part of the participants of the alignment of their practices with the standards' expectations. This is only one possible model for use with professional development about standards. The model design shown in Figure 6 is based on the work of this study and has been altered to reflect discussions that will be needed when the *Next Generation Science Standards* are implemented.

Figure 6 Cyclical, contextualized, reflective professional development model



This model was used with individuals in this study. The cyclical model allowed participants opportunities to refine their practice following review of observed lessons and discussion of the component of the standards the participants were considering during lessons. These included not only the content, but the characteristics of science. When used with the *Next Generation Science* Standards the ongoing discussion would be centered on the components emphasized in those standards.

An extension of this model could be used to provide opportunities for teachers to participate in planning sessions before implementing lessons. These planning sessions could be substituted in place of the lesson logs. Once lessons are implemented, participants could reflect on the success of specific lessons, either with professional developers, or in professional learning communities. The ongoing discussion could be based on developing additional skills and understandings based on analysis of the lesson as implemented, and student success during the lesson reviews. This form of professional development lends itself to implementation within individual schools as science teachers form professional learning communities that support each other's success with standards-based instruction. Technology use could enlarge these support communities to include discussions between teachers facing common contextual implementation of the standards in multiple locations.

Two factors to consider as future standards are implemented were found as important by the analysis of data from this study. First, participants in this study had an understanding of inquiry instruction. They did not need professional development about inquiry. The results of the ICQ indicated that participants' previous experiences in professional development had helped them develop a conceptual understanding. However, participants indicated during the Setting Interview that they did not think they were successfully implementing these practices in their classrooms. This would suggest that a general orientation to standards did not lead to change in teacher practice. Second, the model of professional development used in this study did lead to change in teacher understanding regarding standards, as well as change in practice. Participants expressed these understandings and goals for future practice during the Reflective Interview. As new standards are implemented it will be important to use multiple forms of professional development, including the more costly individual classroom support as well as traditional forms for orientation purposes, if teachers are expected to change teaching practices in order to implement standards-based instruction. As this study has indicated, change in teacher practice is possible if additional models of professional development are considered and implemented.

Implications for Future Research

The upcoming Next Generation Science Standards provide science educators with several areas of research. The findings of this study have shown several areas of research are needed if future standards implementations are to more successful than previous ones have been. These are related to teacher understanding and implementation of standards, alignment of standards with accountability assessments, professional development practices related to standard implementation, and issues of cost. I will describe each in more detail in the following pages.

Multiple states will be simultaneously implementing standards, research should be considered for teacher implementation of the standards in the different states. A comparison of practices implemented in the diverse settings within which these standards will be taught should provide insight into how teachers are interpreting the meaning of the standards in their specific setting and the constraints that may impede effective implementation. Several questions could be explored, including: Which settings lend themselves to success with standards? Are there infrastructure support in the form of materials, administrative support and facilities that lend themselves to the implementation of standards-based instruction? Are states in which previous standards had emphasized a similar approach to science instruction more successful at implementing new standards than those that were less aligned previously?

Accountability assessment is a part of current educational practices, often created at the state level. Research is needed to examine the success of alignment of new assessments with the new science standards. Analyzing the data from this study, it appeared that the participants did not see an alignment of the accountability test with the full set of standards. One question that could be explored: Will states who continue to use current assessments see changes in student success when new standards are implemented? For those states that change assessments research will be needed to examine the alignment of these new assessments to standards. Other questions include: Will aligning these new assessments to standards change teacher practice toward a more standards-based form of instruction? How will student success on newly created assessments be related to the form of instruction they receive?

As the *Next Generation Science Standards* are adopted by states, a great deal of professional development is anticipated by the developers of the Framework. As the integration of the dimensions is developed into standards, those writers will likely describe the kind of professional development they envision. This area is rich with potential questions, including: How will states that adopt the standards structure the professional development required at first implementation? What kinds of follow-up professional development models will be used, and which ones best support implementation of standards-based instruction? Which models of professional development related to the standards lead to changes in teacher practice that support student success on accountability assessments? How will professional development on standards instruction be tied to professional career ladder expectations for teachers?

Issues of cost often guide the selection of practices in public education. Research has shown that the multiple-choice form of assessment is cost effective and provides quick results for accountability purposes. If the new standards call for more complex assessments, will states that adopt the standards be willing to alter their assessment practices so that they better align with the kinds of measures that can capture the full learning experiences of students? Research into the various kinds of assessments developed and the success at capturing student learning, with the most efficient cost will be needed. Research is needed to examine whether teacher assessment practices are altered as a result of changes in accountability assessments. Data analysis from this study indicated that participants assessed students based on the need to prepare them for the

EOCT. If the EOCT were to change form, would the teachers change their assessment practices in order to better prepare students for success on the assessment?

Conclusion

It appears that the changes in science standards are inevitable, and imminent. This study and other research over the last fifteen years have provided a good deal of insight into the ways classroom teachers respond to changes in expectations for their instructional practices, and student success. The challenge for the next round of science standard implementation is to not only remake the standards taking into account what has been learned about previous standards, but also to examine the lessons learned from the previous standards implementation. Many of the research options for the next standards implementation can be guided from what has been learned from the previous one. This study has shown that changes in teacher practice require reflection, and examination of practice in the context of daily work. The hope of this researcher is that research into the most appropriate models of professional development, tailored to specific teacher and contextual needs, will guide future support for implementation of science standards, in order to achieve both teacher and student success.

References

Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlock-Naaman, R., Hofstein, A., Mansoor, N., Treagust, D., & Tuan, H. (2004). Inquiry in science education: International perspectives. *Science Education, 88*(3), 397-419.

Abrams, E., Southerland, S. A., & Evans, C. (2008). Inquiry in the classroom: Identifying necessary components of a useful definition**.** In E. Abrams, S. A Southerland, & P. Silva, (Eds.), *Inquiry in the classroom: Realities and opportunities* (pp. xi-xlii). Charlotte, NC: Information Age Publishing.

Abrams, L. M., Pedulla, J. J., & Madaus, G. F. (2003). Views from the classroom; Teachers' opinions of statewide testing programs. *Theory Into Practice*. *42*(1), 18-29.

Akerson, V. L., Cullen, T. A., & Hanson, D. L. (2009). Fostering a community of practice through a professional development program to improve elementary teachers' view of nature of science and teaching practice. *Journal of Research in Science Teaching. 46*(10), 1090-1113.

Ambert, A.M., Adler, P. A., Adler, P., & Detzner, D. (1995). Understanding and evaluating qualitative research. *Journal of Marriage and Family*. *57*(4), 879-893.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.

American Association for the Advancement of Science, National Science Teachers Association. (2001). *Atlas of science literacy*. Washington, DC.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1), 1-12.

Anderson, R. D., & Helms, J. V. (2001). The ideal of standards and the reality of schools: Needed research. *Journal of Research in Science Teaching*. *38*(1). 3-16.

Artzt, A., & Thomas, E. A. (1999). A cognitive model for examining teachers' instructional practice in mathematics: A guide for facilitating teacher reflection. *Educational Studies in Mathematics*. *40*, 211-235.

Au, W. (2007) High stakes testing and curricular control: A qualitative methodological synthesis. *Educational Researcher*. *36*(5), 258-67.

Ayres, L., Kavanaugh, K., & Knafl, K. A. (2003). Within-case and across-case approaches to qualitative data analysis. *Qualitative Health Research*. *13*(6), 871-883.

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino A., Zech, L., & Bransford, J. D. (1998). Doing with understanding: Lessons from research on problem- and project-based learning. *The Journal of the Learning Sciences*, *7*(3/4), 271-211.

Blanchard, M. R., Southerland, S. A., & Granger, E. (2009). No silver bullet for inquiry: Making sense of teacher change following an inquiry-based research experience for teachers. *Science Education. 93*(2), 322-360.

Blanchard, M. R., Southerland, S. E., Osborne, J. W., Smpson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is inquiry possible in light of accountability?: A quantitative comparison of the relative effectiveness of guided inquiry and verification of laboratory instruction. *Science Education*. *94*(4), 577-616).

Blumenfeld, P. C., Krajick, J. S., Marx, R. W., & Soloway, E. (1994). Lessons learned: How collaboration helped middle grade science teachers learn project-based instruction. *The Elementary School Journal*. *94*(5), 539-551.

Bransford, J. D., Brown, A. L. & Cocking, R.R. (2000). *How people learn brain, mind, experience, and school*. Washington, DC: National Academy Press.

Brickhouse, N. (2008). What is inquiry? To whom should it be authentic?. In R. A. Duschl, & R. E. Gandy (Eds), *Teaching scientific inquiry: Recommendations for research and implantation* (pp.284-287). Rotterdam: Sense Publishers.

Brousseau, K. R., Driver, M. J., Eneroth, K., & Larsson, R. (1994). Career pandemonium: Realigning organizations and individuals. *The Academy of Management Executive*. *10*(4), 52-66.

Burke, P., Fessler, R., & Christensen. (1984). *Teacher career stages: Implications for staff development*. Bloomington, IN: Phi Delta Kappa Educational Foundation.

Bybee, Rodger W. (1997). *Achieving scientific literacy*. Portsmouth, NH: Heinemann

Calwelti, G. (2006). The side effects of NCLB, *Educational Leadership*. *64*(3), 64-68.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. London, England: Sage Publications Ltd.

Cho, J. & Trent, A. (2006). Validity in qualitative research revisited. *Qualitative Research*. *6*(1), 319-340.

Colburn, A. (2000). An inquiry primer. *Science Scope*. *23*(6), 42-44.

Common Core State Standards Initiative. (2011). *Common standards* Retrieved from http://www.corestandards.org/

Cuban, L. (1995). The hidden variable: How organizations influence teacher responses to secondary science curriculum reform. *Theory Into Practice*. *34*(1), 4-11.

Darling-Hammond, L., & McLaughlin, M. W. (1995). Policies that support professional development in an era of reform. *Phi Delta Kappan*. *76*(8), 597-604.

Day, C. (1993). Reflection: A necessary but not sufficient condition for professional development. *British Educational Journal*. *19*(1), 83-91.

Deboer, G. (2002). Student-centered teaching in a standards-based world: Finding a sensible balance. *Science & Education*. *11*, 405-417.

Desimone, L. M., Porter, A., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teacher's instruction: Results from a three-year longitudinal study. .*Education Evaluation and Policy Analysis*. *24*(2), 81-112.

Diamond, C. T. B. (1993). In service education as something more: A personal construct approach. In P. Kahaney, L. A. M. Perry, & J. Janangelo (Eds), *Theoretical and critical perspectives on teacher change*. (p. 45-66). Norwood, NJ: Ablex Publishing Corporation.

Diamond, J. B. (2007). Where the Rubber Meets the Road: Rethinking the Connection between High-Stakes Testing Policy and Classroom Instruction. *Sociology of Education*. *80*(4), 285-313.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education*. *19*, 643-658.

Flick, Uwe. (2007). Triangulation revisited: Strategy of validation or alternative?. *Journal for the Theory of Social Behavior*. *22*(2), 175-197.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*. *12* (2), 219-245.

Franke, M. L., Carpenter, T. P., Levi, L., & Fenema, E. (2001). Capturing teachers' generative change: A follow-up study of professional development in mathematics. *American Educational Research Journal*. *38*(3), 653-689.

Fu, A. C., Raizen, & S. A, Shavelson, R. J. (2009). The nation's report card: A vision of large-scale science assessment. *Science*. *326*, 1637-1638.

Georgia Department of Education, *Georgia Performance Standards*. Retrieved December 3, 2008, from http://www.georgiastandards.org/science.aspx

Georgia Department of Education. *End of Course Test (EOCT) information page*. Retrieved December 8, 2009, from http://www.doe.k12.ga.us/ci_testing.aspx?PageReq=CI_TESTING_EOCT

Georgia Department of Education *Governor's Office of Accountability2008.* Retrieved September 21, 2011, from http://www.gadoe.org/ReportingFW.aspx?PageReq=102&CountyId=644&T=1&FY=2008

Georgia Department of Education. (2010). *The Ga DOE Source*. Retrieved from http://public.doe.k12.ga.us/DMGetDocument.aspx/Fall%202010.pdf?p=6CC6799F8C1371F68DF42F05FF356DF26B34A24A6F532B5532820E15A7D594E3&Type=D

Glaser, B. G. (1965). The constant comparative method of qualitative analysis. *Social Problems*, *12*(4), p. 436-445.

Governor's Office of Student Achievement. 2009-2010 Report Card, State of Georgia, retrieved from http://www.gadoe.org/ReportingFW.aspx?PageReq=102&StateId=ALL&T=1&FY=2010

Hall, D. T. (1996). Protean careers of the 21st century. *The Academy of Management Executive*. *10*(4), 8-16.

Hammer, D., Russ, R., Mikeska, J., & Scherr, R. (2008). Identifying inquiry and conceptualizing students' abilities. In R. A. Duschl, & Gandy, R. E. (Eds), *Teaching scientific nquiry: Recommendations for research and implantation* (pp. 138-156). Rotterdam: Sense Publishers.

Hilliard, A. G. (2000). Excellence in education versus high-stakes standardized testing. *Journal of Teacher Education*. *51*, 293-304

Holliday, A. (2007). *Doing and writing qualitative research*. Thousand Oaks, CA: Sage Publications.

Huffman, D., Kell, T., & Lawrenz, F. (2003). Relationship between professional development, teachers' instructional practices, and the achievement of students in science and mathematics. *School Science and Mathematics*. *103*(8). 378-387.

Ingersoll, R. M. (2001). Teacher turnover and teacher shortages: An organizational analysis. *American Educational Research Journal*. *38*(3), 499-534.

Ingersoll, R. M. (2003). *Is there really a teacher shortage?*. **(**co-sponsored byCenter for the Study of Teaching and Policy and The Consortium for Policy Research in Education Document R-03-4**).** University of Washington, retrieved January 3, 2011 from http://depts.washington.edu/ctpmail/PDFs/Shortage-RI-09-2003.pdf

Jeanpierre B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching*. *42*(6), 668-690).

Jones, M. G., Jones, B. D., Hardin, B., Chapman, L., Yargrough, T,. & Davis, M. (1999). The impact of high-stakes testing on teachers and students in North Carolina. *Phi Delta Kappan*. *81*(3), 199-203).

Jones, S. R. (2002). (Re)writing the word: Methodological strategies and issues in qualitative research. *Journal of College Student Development*, *43*(4), 461-473.

Kelly, J. M. (1999). Free to teach, free to learn: A model of collaborative professional development that empowers teachers to reach diverse student populations. *The Journal of Negro Education*. *68*(3), 426-432.

Koballa, T. R., Reeves, M., & Atkinson, J. (2008, October). *Are we speaking the same language? Science teachers' conceptions of inquiry.* Paper presented at the annual conference of the Southeastern Association of Science Teacher Education, Columbia, SC.

Lee, O., Buxton, C., Lewis, S., & LeRoy, K. (2006). Science inquiry and student diversity: Enhanced abilities and continuing difficulties after instructional intervention. *Journal of Research in Science Teaching*, *43*(7), 607-636.

Leonard, W. H., & Penick, J. E. (2005). Assessment of standards-based biology teaching. *The American Biology Teacher*, *76*(2), 73-76.

Levin, B. B. (2003). Case studies of teacher development: An in-depth look at how thinking about pedagogy develops over time. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Linn, R. L. (2000). Assessment and accountability. *Educational Researcher*, *29*(2), 4-16

Linn, R. L. (2006). Educational accountability systems: CSE technical report 687. retrieved July 29, 2011 from http://www.cse.ucla.edu/products/reports/r687.pdf

Little, J. W. (1993). Teacher' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis*. *15*(2), 129-151.

Lotter, C., Harwood, W. S., & Bonner, J. J. (2007). The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching*. *44*(9), 1318-1347.

Loucks-Horsley, S. Stiles, K. E., Mundry, S., & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics (3rd ed.).* Thousand Oaks, CA: Corwin, a SAGE Company.

Lynn, S. K. (2002). The winding path: Understanding the career cycle of teachers. *The Clearing House*. *75(*4), 179-182.

McDonald, S., & Songer, N. B. (2008). Enacting classroom inquiry: Theorizing teachers' conceptions of science teaching. *Science Education. 92*(6), 973-993.

Marczely, B. (1996). *Personalizing professional growth staff development that works*. Thousand Oaks, CA: Corwin Press, Inc.

Marx, R. W., Blumenfeld, P. C., Krajicik, J.S., & Soloway, E. (1997). Enacting project-based science. *The Elementary School Journal*. 97(4), 341-358.

Maxwell, J. A. (2005). *Qualitative research design: An interactive approach*. Thousand Oaks, CA: Sage Publications.

Meadows, L. (2008). Teacher knowledge about inquiry: incorporating conceptual change theory. In E. Abrams, S. A. Southerland, & P. Silva (Eds.), *Inquiry in the classroom: Realities and opportunities* (pp. 177-191). Charlotte, NC: Information Age Publishing.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction – what is it and does it matter? Results from a research synthesis years 1984-2002. *Journal of Research in Science Teaching. 47*(4), 474-496.

Moran-Ellis, J., Alexander, V. D., Cronin, A., Dickinson, M. Fielding, J., Sleney, J., & Thomas, H. (2006). Triangulation and integration: processes, claims and implications. *Qualitative Research. 6(*1), 45-59.

Muller, C., & Schiller, K. S. (2000). Leveling the playing field? Students' educational attainment and states' performance testing. *Sociology of Education. 73* (3), 196-218).

National Academy of Sciences. (n.d.). *A Framework for K-12 Science Education: Frequently Asked Questions*. Retrieved from http://www7.nationalacademies.org/bose/Framework_FAQ.html

National Center for Education Statistics. Characteristics of full-time teachers, Table A-27-2. *Contexts of elementary and secondary education*. Retrieved May 17, 2011, from http://nces.ed.gov/programs/coe/2010/section4/table-tsp-2.asp

National Center on Educational Outcomes, *State Web Sites for Graduation Requirements*. Retrieved December 4, 20009, from http://www.cehd.umn.edu/nceo/topicareas/graduation/StatesGrad.htm

National Council for Accreditation of Teacher Education. (2010). *Transforming teacher education through clinical practice: A national strategy to prepare effective teachers.* Washington DC: NCATE Blue Ribbon Panel on Clinical Preparation and Partnership for Improved Student Learning.

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

National Research Council. (2000). *Inquiry and the national science education standards a guide for teaching and learning*. Washington, DC: National Academy Press.

National Research Council. (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas*. Retrieved from http://www.nap.edu/catalog.php?record_id=13165

Next Generation Science Standards. (2011). *Lead state partners.* Retrieved from http://www.nextgenscience.org/states-lead-effort-write-new-science-standards

Ogawa, R. T., & Collom, E. (2000). Using performance indicators to hold schools accountable: Implicit assumptions and inherent tensions. *Peabody Journal of Education*. 75(4), 200-215.

Palsey, J. D., Weiss, I. R., Shimkus, E. S. , & Smith, P. S. (2004). Looking inside the classroom: Science teaching n the United States. *Science Education. 13*(1), 1-12.

Penfield, R. D., & Lee, O. (2010). Test-based accountability: Potential benefits and pitfalls of science assessment with student diversity. *Journal of Research in Science Teaching*. *47*(1), 6-24.

Peske, H. G., Liu, E., Johnson, S. M., Kauffman, D,. & Kardos, S. M. (2001). The next generation of teachers: Changing conceptions of a career in teaching. *Phi Delta Kappan*. *83* (4), 304-311.

Polman, J. L. (2004). Dialogic activity structure for project-based learning environments. *Cognition and Instruction*. *22*(4), 431-466.

Richer, S. (1975). School effects: the case for grounded theory. *Sociology of Education*, *48*(4), 383-399.

Saldaña, J (2009). *The coding manual for qualitative researchers*. Thousand Oaks, CA: Sage.

Schauble, L. (2008). Three questions about development. In R. A, Duschl, & R. E, Grandy, (Eds.), *Teaching scientific inquiry: Recommendations for research and implementation*. Rotterdam, The Netherlands: Sense Publishers.

Schein, E. H. (1996). Career anchors revisited: Implications for career development in the 21st century. *The Academy of Management Executive*. *10*(4), 80-88.

Schmoker, M. (2011). *Focus: Elevating the essentials to radically improve student learning*. Alexandria, VA: ASCD.

Schneider, R. M., Krajcik, J,. & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Education*. *42*(3), 283-312.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. United States of America: Basic Books, Inc.

Seashore,K., Febey, K., & Schroeder, R. (2005). State-mandated accountability in high schools: Teachers' interpretation of a new era. *Educational Evaluation and Policy Analysis*. *27*(2), 177-204.

Seidman, Irving (2006). *Interviewing as qualitative research*. New York, NY: Teachers College Press.

Settlage, J. R. (2007). Demythologizing science teacher education: Conquering the false ideal of open inquiry. *Journal of Science Teacher Education,18*, 461-467

Settlage, J., Meadows, L., Olson, M. & Blanchard, M. (2008). Teacher knowledge and enacting inquiry. In E. Abrams, S. A, Southerland, & P. Silva (Eds.), *Inquiry in the classroom: Realities and opportunities* (pp. 171-229). Charlotte, NC: Information Age Publishing.

Simon, M. A., & Tzur, R. (1999). Explicating the teacher's perspective from the researchers' perspectives: Generating accounts of mathematics teachers' practice. *Journal for Research in Mathematics Education*. *30*(3), 252-264.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage Publications, Inc.

Stanley, C. (1998). A framework for teacher reflectivity. *TESOL Quarterly*. *32*(3), 584-591.

Stinebrickner, T. R. (2001). A dynamic model of teacher labor supply. *Journal of Labor Economics*. *19*(1), 196-30.

Strahan, D. 2003. Promoting a collaborative professional culture in three elementary schools that have beaten the odds. *The Elementary School Journal*. *104*(2), 127-146.

Sykes, G. (1996). Reform of and as professional development. *Phi Delta Kappan*. *77*(7), 464-467.

Thomas, G. (2010). Doing case study: Abduction not induction, phronesis not theory. *Qualitative Inquiry*. *16*(7), 575-582.

Tobias, S., & Baffert, A.. (2010). *Science teaching as a profession: Why it isn't. How it could be*. Arlington, VA: NSTA Press.

Valli, L., & Buese, D. (2007). The changing roles of teachers in an era of high stakes testing accountability. *American Education Research Journal*. *44*(3), 519-558.

Wideen, M. F., O'Shea, T., Pye, I., & Ivany, G. (1997). High-stakes testing and the teaching of science. *Canadian Journal of Education/Revue Canadienne de l'Education*. *22*(4), 428-444).

Windschitl, M. (2002). Framing Constructivism in Practice as the Negotiation of Dilemmas: An Analysis of the Conceptual, Pedagogical, Cultural, and Political Challenges Facing Teachers. *Review of Educational Research*. *72*(2), 131-175.

Windschitl, M. (2006). Why we can't talk to one another about science education reform. *Phi Delta Kappan*. *87*(5), 349-355.

Windschitl, M. (2008). What is inquiry? A framework for thinking about authentic scientific practice in the classroom. In J. Lufts, R. L. Bell, & Gess-Newsome, J. (Eds). (2008). *Science as inquiry in the secondary setting*. (p. 1-20). Arlington, VA: NSTA Press.

Witz, K. G. (2007). 'Awakening to' an aspect in the other: On developing insights and concepts in qualitative research. *Qualitative Inquiry*. 13, 235-258.

Wood, D. (2000). Narrating professional development: Teachers' stories as texts for improving practice. *Anthropology and Education Quarterly*. 31(4), 426-448.

Yin, R. K. (2009). *Case study research design and methods* (4th ed). Thousand Oaks, CA: SAGE Inc.

APPENDIX A

Inquiry Conceptions Questionnaire (ICQ)

Part A. Demographics

1. How many years have you been a Biology teacher?

☐ 1-3 ☐ 4-8 ☐ 9-12 ☐ 12-20 ☐ 20+

2. Check the appropriate box:

☐ I majored in Biology.

☐ I did not major in Biology, but took more than one year of biology.

☐ I took no Biology courses in college.

3. How did you enter the teaching field?

☐ I earned an education degree as part of my undergraduate program

☐ I majored in science and immediately earned the education certification.

☐ I majored in science, had a career in a science field, and then earned the education certification.

Part B. Inquiry

Directions: Circle either A or B for each item. Even though you may not completely agree with either choice, select the one that most closely matches your thinking.

1. A. Inquiry is an instructional strategy for teaching science content.
   B. Inquiry is the means by which students learn about the processes of science.

2. A. An outcome of inquiry-based instruction is that students learn about the work of scientists.
   B. An outcome of inquiry-based instruction is that students learn more content.

3. A. Some instructional strategies are more inquiry-oriented than others.
   B. Inquiry can be an element of any instructional approach.

4. A. Open-ended inquiry is the optimal form of inquiry.

   B. The optimal form of inquiry is dependent on many factors, including teacher knowledge.

5. A. As a result of inquiry instruction, students are better able to relate science processes and content.
   B. From inquiry instruction, students better understand science concepts and principles.

6. A. In inquiry instruction, lecture follows laboratory.
   B. In inquiry instruction, the sequence of lessons is dependent on the intended outcome.

7. A. Inquiry lessons can take time away from covering the necessary course content.
   B. Inquiry can be a part of most science lessons.

8. In an optimal inquiry learning experience:
   A. Students are provided with materials and expected to develop and enact procedures.
   B. Students build conceptual models and argue about their models' strengths and limitations.

9. A. Inquiry has no more teaching-learning power than other instructional approaches.
   B. Some instructional approaches offer greater opportunity for inquiry teaching.

10. A. Inquiry lessons can lead to gaps in student understanding.
    B. Inquiry lessons help students comprehend the relationship between content and process.

11. A. Students are more likely to understand science inquiry from a lab than a lecture.
    B. All science lessons can involve student inquiry.

12. A. Students are engaged in inquiry only in the laboratory setting.
    B. Students can experience inquiry in association with reading or watching a video.

APPENDIX B

ICQ Scoring Key

Step 1 - Circle your answers from the ICQ in the following columns

Column I [Instructional Strategy]	Column II [Core Idea]	Column III [Instructional Goal]
1A	1B	
2B		2A
	3A	3B
	4A	4B
5B	5A	
	6A	6B
7A		7B
8A		8B
9A	9B	
10A	10B	
	11A	11B
12A		12B

Step 2 – Tally the number of circled items in each column and multiple by

Total responses to Column I ____ x 8.3 = ____________
Total responses to Column II ___ x 8.3 = ____________
Total responses to Column III ___ x 8.3 = ____________

Step 3 – Interpret the products obtained in Step 2. The product obtained for Column I is an approximate percentage of how often the respondent's beliefs reflect the conception of *Inquiry as Instructional Strategy* (Category I), whereas the products obtained in Columns II and III are approximate percentages of how often the respondent's beliefs reflect the conceptions of *Inquiry as Instructional Goal* (Category II) and *Inquiry as Core Idea* (Category III) respectively.

APPENDIX C

Setting Interview Protocol

1. As a science teacher, what are your major learning goals for your students?

2. When you plan lessons, how do you select strategies to reach these learning goals?

3. Pick a unit you have taught. Name___________________________________

Describe for me how you went about planning and implementing that unit.

4. In your ideal science classroom what would the interactions between you and your students and among your students be like?

5. How close do you come to achieving this in your classroom?

6. Can you give me an example of a time when the ideal interaction happened in you class?

7. What factors limit your ability to achieve these ideal science classroom interactions?

8. Can you give me an example of one of these factors in action in your class?

9. What are some topics you find especially difficult to teach? Why?

10. How do you go about solving this difficulty as you teach?

APPENDIX D

Initial Interview

Demographic Information

1. How many years have you been a teacher?

2. What was your major as an undergraduate?

3. What degree(s) do you hold beyond the undergraduate?

4. How much graduate work have you taken in Biology?

5. How have you maintained your content knowledge in Biology?

6. Have you enhanced your teaching skills other than with your degrees?

    Can you give me a couple of examples?

Curriculum sequencing and pacing

1. As you look at the current sequencing in the curriculum, would you alter the order of it?

    What would be your preferred sequence?

2. I notice that the time allotted to teach each unit is the same. Does this time allotment work well for your instruction?

    If not, how would you prefer to distribute the time?

3. Would you note for me on the curriculum sequencing the order in which you teach the topics within each unit? (topics are listed within the curriculum units)

4. How does the benchmark testing differ from your assessments?

Teaching co-requisite standards

1. Your curriculum sequence specifies the content GPS by number. I notice that the characteristics of science GPS are to be incorporated. It does not reference them by number. How do you understand that these are to be incorporated?

2. What are some ways you incorporate the characteristics of science in your teaching?

3. Describe for me how you have incorporated SCSh.1b into a lesson?

4. Describe for me how you have incorporated SCSh8c into a lesson?

APPENDIX E

Unit Teaching Log

Date	Content Standard/Element	Characteristics of Science Standard/Element	Activity	Assessment

APPENDIX F

Protocol for Classroom Observations

The observer will take field notes of the lesson observing the following interactions carefully:

The manner in which the teacher opens the lesson

The manner in which the teacher develops the lesson

The expectations of the teacher for student participation in class

The kinds of strategies used for instruction

The manner in which the teacher interacts with the students throughout the lesson

The manner in which the students interact with each other

The focus of the lesson (conceptual standards, process standards, blended standards)

The overall culture of the classroom as the lesson happens

The manner in which the teacher concludes the lesson

The assessments used to evaluate student learning

APPENDIX G

Lesson Review Protocol

1. What are some things you did to alter the lesson based on student feedback as you taught?

    1a. These are a few modifications I saw from your written plan.

2. Give a couple of examples when you knew the students were engaging well with the lesson.

    2a. These are some more examples I saw as I observed the class.

3. Based on the results of the assessment(s) you did of student learning, what will you need to elaborate on in further lessons?

    3a. These are a few areas where students appear to need further elaboration.

4. What were some differences between classes that you observed as you taught this particular lesson? What were some reasons for the differences?

5. How did the integration of the co-requisite standards enhance your lesson?

6. What modifications would you make to the lesson before you teach it again?

APPENDIX H

Essential Features of Classroom Inquiry and Their Variations

Essential Feature		Variations			
		Teacher guided			Teacher directed
1	Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by the teacher, materials, or other resources	Learner engages in question provided by teacher, materials, or other resources
2	Learner gives priority to **evidence** in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3	Learner formulates **explanations** from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence and how to use evidence to formulate explanation
4	Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	Learner told where information fits into current scientific knowledge
5	Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to use sharpen communication	Learner given steps and procedures for communication
More ---------------Amount of Learner Self-Direction --------------- Less Less ------------- Amount of Direction from Teacher or Material --------- More					

From: *Inquiry and the National Science Education Teaching Standards*, p. 29

APPENDIX I

Reflective Interview

1. How was your thinking about the co-requisite standards affected by maintaining the lesson log?

    Did it increase your focus on the characteristic standards?

    Did you look for more ways of incorporating the characteristics standards into your lessons?

    Did it influence your selection of activities?

    Did it influence your selection of assessments?

2. As you look over the unit sequence and the kinds of activities and assessments in your lesson log, how did this differ from the last time you taught this unit?

    Would you sequence the unit the same way next time you teach it?

    If not, what changes might you make?

3. Based on the various assessments you used during this unit, how well do you think your students learned what was expected?

4. Look through the log and select what you think might have been the three best lessons of the unit.

    Describe each one and the characteristics that you think made this a good lesson

    Explain how each contributed to the overall understanding of the unit concepts

5. What did you learn about yourself and your students that surprised you during this unit?

APPENDIX J

Phase I Participant Consent Form

Date:
Dear Science Teacher:

We are Dr. Thomas Koballa and Ms. Marion Reeves in the Department of Mathematics and Science Education at The University of Georgia. We invite you to participate in a research study entitled How Understanding of Inquiry Affects High School Science Teacher's Planning and Instruction.

The purpose of the study is to examine science teachers' understandings of inquiry and knowledge of inquiry-based teaching strategies. The study's findings could improve the effectiveness of inquiry-based teaching in Georgia's science classrooms.

Please do not participate if you are less than 18 years old and you are not a science teacher.

If you agree to participate in this study, you will be asked to respond to a fifteen minute questionnaire about your understandings of inquiry and knowledge of inquiry-based teaching strategies. A sample of questionnaire respondents will be interview. The interview will take approximately 30 minutes to complete and it will be audio-taped. After the interview you will be asked to send to us any artifacts, such as handouts and lesson plans**,** that elaborate your understandings of inquiry and knowledge of inquiry-based teaching strategies. You may skip any questions that you do not wish to answer on the questionnaire and during the interview, and you do not need to send artifacts if you do not want to do so.

Your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Any individually-identifiable information that is obtained in connection with this study and that can be identified with you will remain confidential. Questionnaires, audiotapes of interviews, and artifacts will be kept in a locked cabin Dr. Koballa's office. Only Dr. Koballa and Ms. Reeves will have access to them. When the data analysis is completed in the project year, the tapes containing data will be destroyed. Interview transcripts and questionnaire responses will be kept in a locked cabinet in Dr. Koballa's office for at least three (3) years after the completion of the study.

The benefit that you will likely receive is that we will provide questionnaire respondents with a written summary of the research findings on scientific inquiry and science learning. In addition, we will follow up interviews with a discussion about the research literature on scientific inquiry and science learning. Here, you will learn specifically how inquiry is understood within the scientific community and how inquiry-based teaching strategies can support students' science learning.

This are no known risks or discomforts associated with this research. The questionnaire items and interview questions are similar to those that might be asked by science teaching colleagues during a discussion of inquiry and inquiry-based teaching strategies.

The researchers can be contacted for any further questions about the research, now or during the course of the project. See contact information for the researchers at the bottom of the page. Additional questions regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

By signing this letter you are indicating your willingness to be interviewed, you are agreeing to participate in the above described research project.

Thank you for your consideration!
Sincerely,

Thomas R. Koballa, Jr.
Phone: 706.542.4640
E-mail: tkoballa@uga.edu
Department of Mathematics & Science Education

212 Aderhold Hall
Athens, GA 30602

Marion Reeves
Phone: 706.542.1763
E-mail: mmree@uga.edu
Department of Mathematics & Science Education
212 Aderhold Hall
Athens, GA 30602

APPENDIX K

Phase II Participant Consent Form

CONSENT FORM

I, ________________________________, agree to participate in a research study titled " Contextualizing Professional Development for Enhancing High School Biology Teacher Proficiency in Stadards-Based Instruction" conducted by Marion Reeves (404-378-0495) from the Department of Mathematics and Science Education at the University of Georgia (542-1736 under the direction of Dr Janette Hill (706-542-4035) , Department Lifelong Education, Administration and Policy, University of Georgia (542-4035). I understand that my participation is voluntary. I can refuse to participate or stop taking part at anytime without giving any reason, and without penalty or loss of benefits to which I am otherwise entitled. I can ask to have all of the information about me returned to me, removed from the research records, or destroyed.

The reason for this study is to examine the process of locally based professional development designed to enhance the teaching of Biology for better student success. If I volunteer to take part in this study, I will be asked to do the following things:

1) **Prepare and teach standards-based lessons which will be observed in the classroom. (The lesson duration will depend on the plan you create. Each lesson could be up to 90 minutes long with a total time spent of three hours. There will be at least two observed lessons during the research.)**
2) **Participate in recorded lesson reviews with observer of the teaching of the standards-based lessons. These will be transcribed for analysis. (There will be lesson reviews after each observation.) Each review will last about thirty minutes for a total of one hour.**
3) **Prepare and implement standards-based units of instruction. (One unit will be a part of the research.) This will be require any additional time since it is embedded in your usual work.**
4) **Provide copies of all observed lesson materials. (There will be at least two lessons.)**
5) **Allow the researcher to take field notes during classroom lesson observations and log review sessions. (At least two observations and four log review sessions.) The log should require about five minutes daily to complete and the reviews will last about fifteen minutes each for a total of one hour spent in reviews with me and about two hours total on maintaining the log.**
6) **Maintain a structured teaching log during one unit of instruction.**
7) **Participate in an introductory and a final interview. These will be recorded and transcribed for analysis. Each interview will last about an hour for a total of two hours. The total time spent in addition to your usual work to participate in this research is about six hours distributed over the time of the research.**

The benefits for me are: an opportunity to become more reflective about the way I teach standards-based Biology. I will also be able to use the materials developed in this research for documentation of my professional work. The results of this research will help in the design and implementation of future professional development for science teachers.

No risk or discomfort is expected.

No individually-identifiable information about me, or provided by me during the research, will be shared with others without my written permission unless required by law . Alternate names will be used to refer to me in any future work, and the school and system will not be identified. Recordings of lesson reviews will be transcribed with the alternate name as an identifier on the transcript. The recording will be saved for possible later use in further analysis beyond the immediate review of the transcripts in a locked space in the offices of the Science Education Department at UGA for five years and then they will be destroyed. At the end of the research time any written identifiers linking my real name to the alternate will be destroyed and the only remaining records will carry the alternate names.

The investigator will answer any further questions about the research, now or during the course of the project.

I understand that I am agreeing by my signature on this form to take part in this research project and understand that I will receive a signed copy of this consent form for my records.

Marion M. Reeves ________________________ __________

Name of Researcher Signature Date

Telephone: 404-378-0495
Email: mmree@uga.edu

_________________________ ________________________ __________

Name of Participant **Signature** **Date**

Please sign both copies, keep one and return one to the researcher.

Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 629 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

APPENDIX L

Phase I Tallied Interview Codes

- Jessica
- DT
- Paul
- Sarah
Ann
Jimmy
Flossie

- Flossie

Primary Codes for Biology Research

132 codes + Vocab

9th grade factor	Lower expectations	Technology use
Acrostic	Memorize work	Test information
Active engage	Misconceptions	Test pattern
Activity	Mixing concepts	Test value 30%
Activity description	Modify activity	Time issue
Application to daily life	Motivation	Time limits
Avoid controversy	Must earn grade	Too much content
Bridge learning gaps	Need for immediacy	Topic=inquiry
Build knowledge	No outside class	Understanding difficulty
Changed teaching	NOS	Unit topic
Class as a lab	Pacing chart	Use examples
Class size	Pairs	Use previous plans
Comparisons	Parental contact	Variation in approach
Concept map	Past taught more	Vocabulary
Conceptual learning	Personal cost	Webquest
Content competent	Plan past difficulties	Workbook
Critical thinking	Prefer quiz to test	Fundamental Knowledge
Cumulative test	Premade technology	Entertain students
Demonstrate learning	Prepared for the future	Video
Differentiation	Previous knowledge	Parental role
Discipline	Problems	student maturity
Discussion	Process=scientific method	Balance of ~~activities~~ strategies
Do well on state tests	Processes of science	Roots, pre + suffix
EOCT reason	Project	ESL ~~students~~ students
Evaluate for effective use	Project description	Sequencing problems
Excited about science	Quizzes	Worksheet
Exploratory work	Reading	Teacher as guide
Flashcards	Refusal to participate	Cheating
Focus on essentials	Research paper	Student not value education
Focus on some students	Retest	Process
Frayer model	Safety	concrete – not abstract
General reference	Science as career	problem-based
Gifted reference	Seating chart	collaborative planning
Give up on some students	Separate students	cartoons
GPS	Simpler ways	
Grading philosophy	Small amount on test	
Graduation test	Small chunks	
Grouping students	Small group disrupt whole	
Guiding activity	Spiral	
Having fun	Student interest	
Ideal: goes well	Student needs	
Incomplete success	Student personal belief	
Info exposure	Students asked to think	
Interactive notebook	Students engaged	
~~Interactive notebook~~	Students making connections	
description	Students not care	
Lab	Students teach	
Lab description	Teacher interaction	
Lecture	Teacher off-task	
Lecture description	Teacher sees connections	

APPENDIX M

Phase I Sample Assignment (Paul)

Name: ______________________________ Date: ________ #: ________

Lab: Surface Tension

2 3 4

A molecule is held together by chemical bonds. The type of bonds found in molecules are called covalent bonds.

Water is a molecule consisting of two Hydrogen atoms, and one Oxygen atom. Covalent bonds hold the two Hydrogen (H) atoms to a single Oxygen (O) atom. The three atoms together form a molecule. Covalent bonds are intramolecular bonds where valence (outer shell) electrons are shared between the respective atoms. 5

5 6

Water, H_2O is a polar molecule. A polar molecule has a positively charged portion, and a negatively charged portion. Hydrogen atoms share their outer (valence) electron with the oxygen atom. In effect, Hydrogen becomes somewhat positively charged, and since Oxygen shares each Hydrogen's electrons, it becomes a bit negative. The negative oxygen atom of one molecule of one water molecule attracts and lines up with hydrogen atoms (oppositely charged particles attract one another) in another molecule creating a vast web of molecules. This attraction is called
7 (unfortunately) a "Hydrogen Bond". It is unfortunate because true bonds only form within compounds, and not between compounds. However, we are stuck with the name Hydrogen Bond. Hydrogen Bonds are intermolecular attractions. 8

It turns out that Hydrogen Bonds create a good amount of surface tension and allow insects to walk on or under the surface film of water, create a meniscus in graduated cylinders, and allow water to "bead-up" on a surface. 9

Try this lab demonstration: Call me over to initial step one before completing step two.

Step 1. Fill a plastic cup to the ½ way point with water. Sprinkle some, but not a ton of pepper on the surface. Draw what you see in the circle for step one below left, and then call me over for my initials.

checks ea step

Step one __________ Step 2 __________

Notice how in step one the surface tension of the water "holds up" the pepper pieces. Water attracting water, or anything attracting another of its kind, is called cohesion. 10 Look carefully at the interaction between the water and the plastic cup. The water is clinging to the side, and it is trying to "climb" out of the cup. The attraction between two unlike things is called adhesion. 11. The down dropped area of water in the cup is called a meniscus. All liquid measurements are made from the lowest point of a meniscus.

Now, dip a toothpick in soap, and touch the center of the water in the cup. What happens? Draw what you see. Have me initial step 2. Soap disrupts the surface tension in the water, and the pepper moves. A practical application of this is that mosquito larva count on the surface tension of water to stay afloat. They stick their noses (proboscis) out of the surface of water to breath, and dangle. Some scientists have suggested putting a few drops of soap on water, and the larva will no longer be able to use water's surface tension to stay afloat. If the larvas sink, they will drown, and the number of mosquitoes will decrease. By the way, only female mosquitoes suck blood. They use blood for protein to feed their developing eggs. Males feed only on nectar.

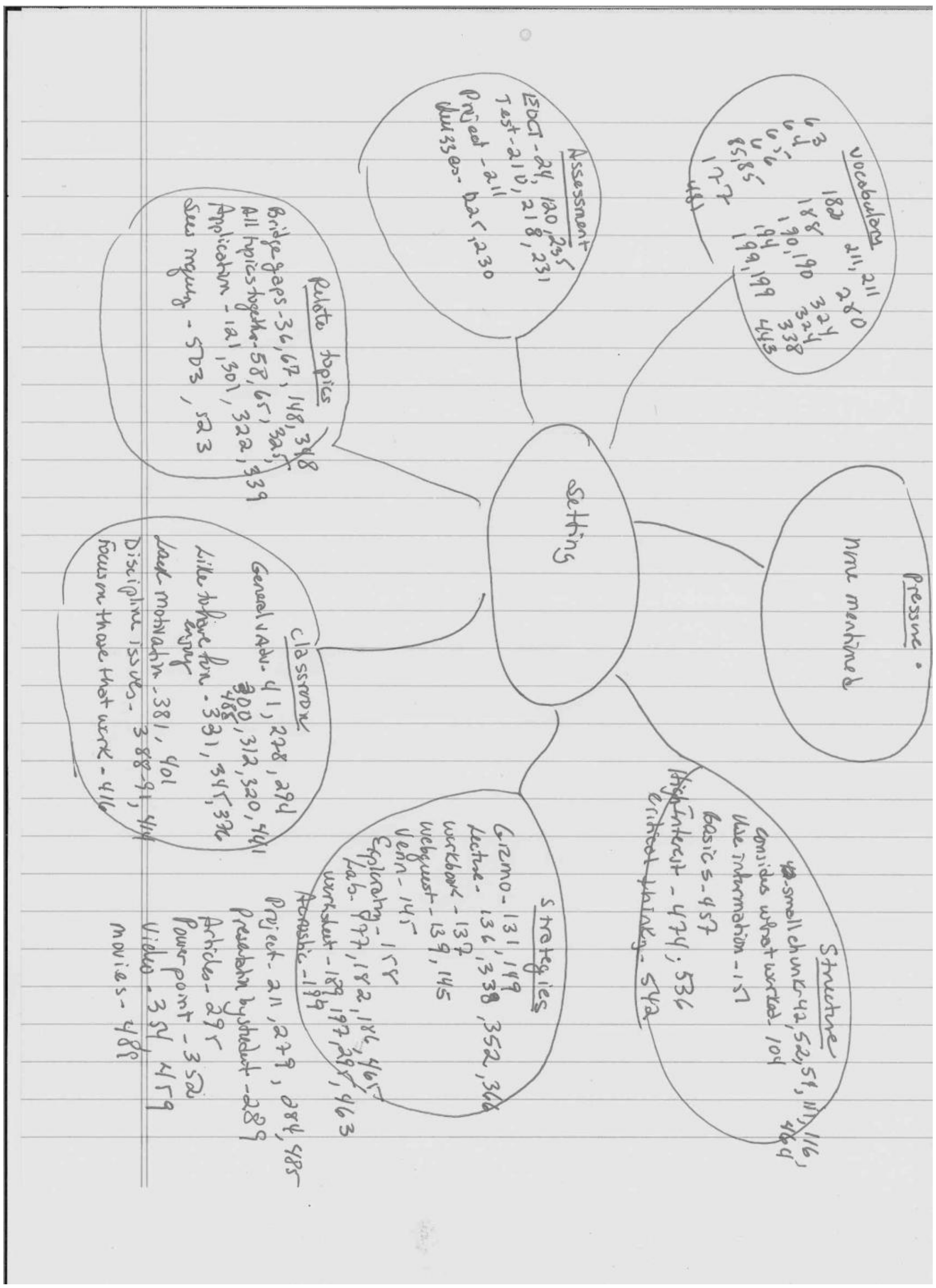
explained application

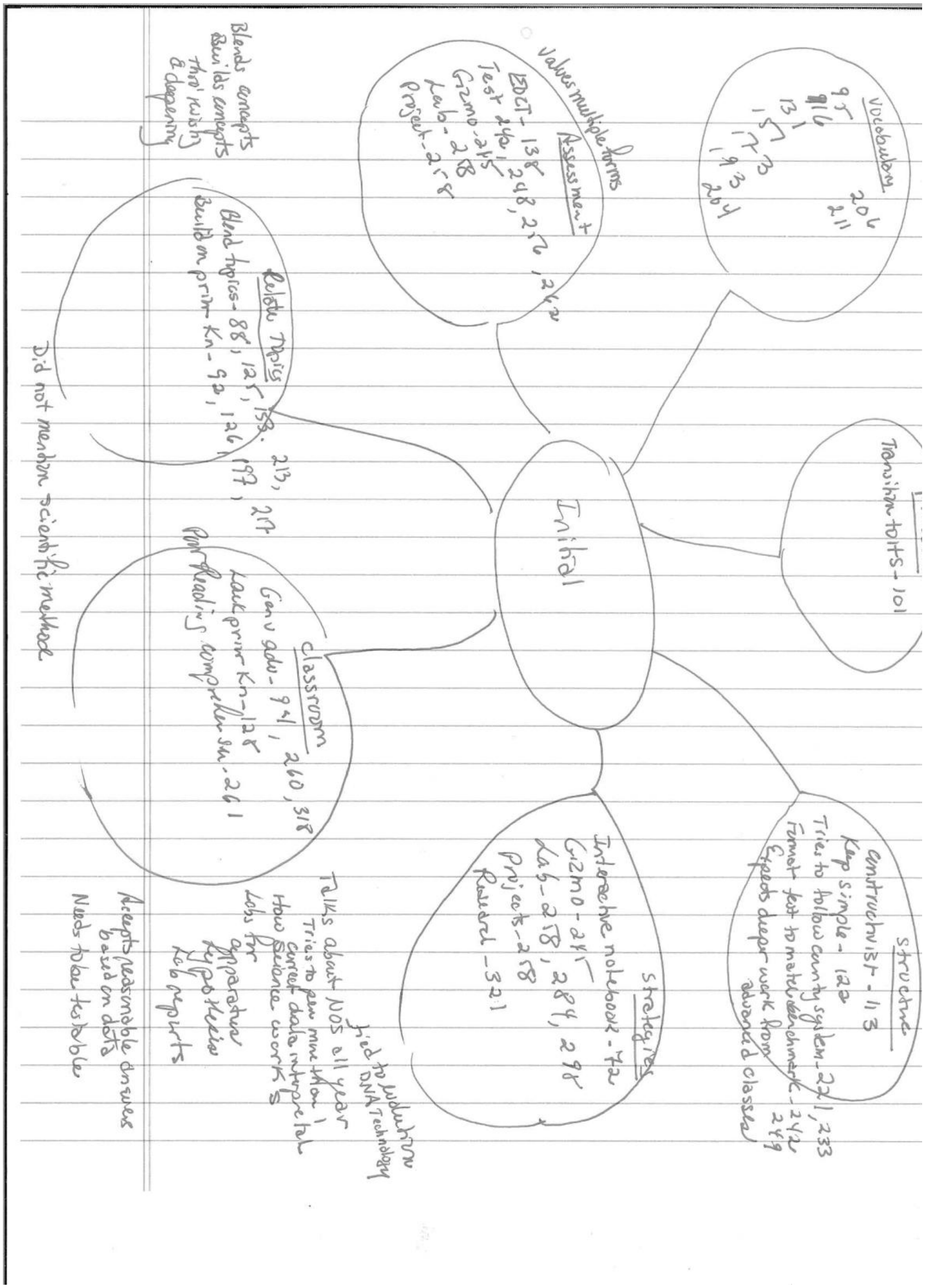
Can you think of other ways an understanding of surface tension can be used?
Your answer:

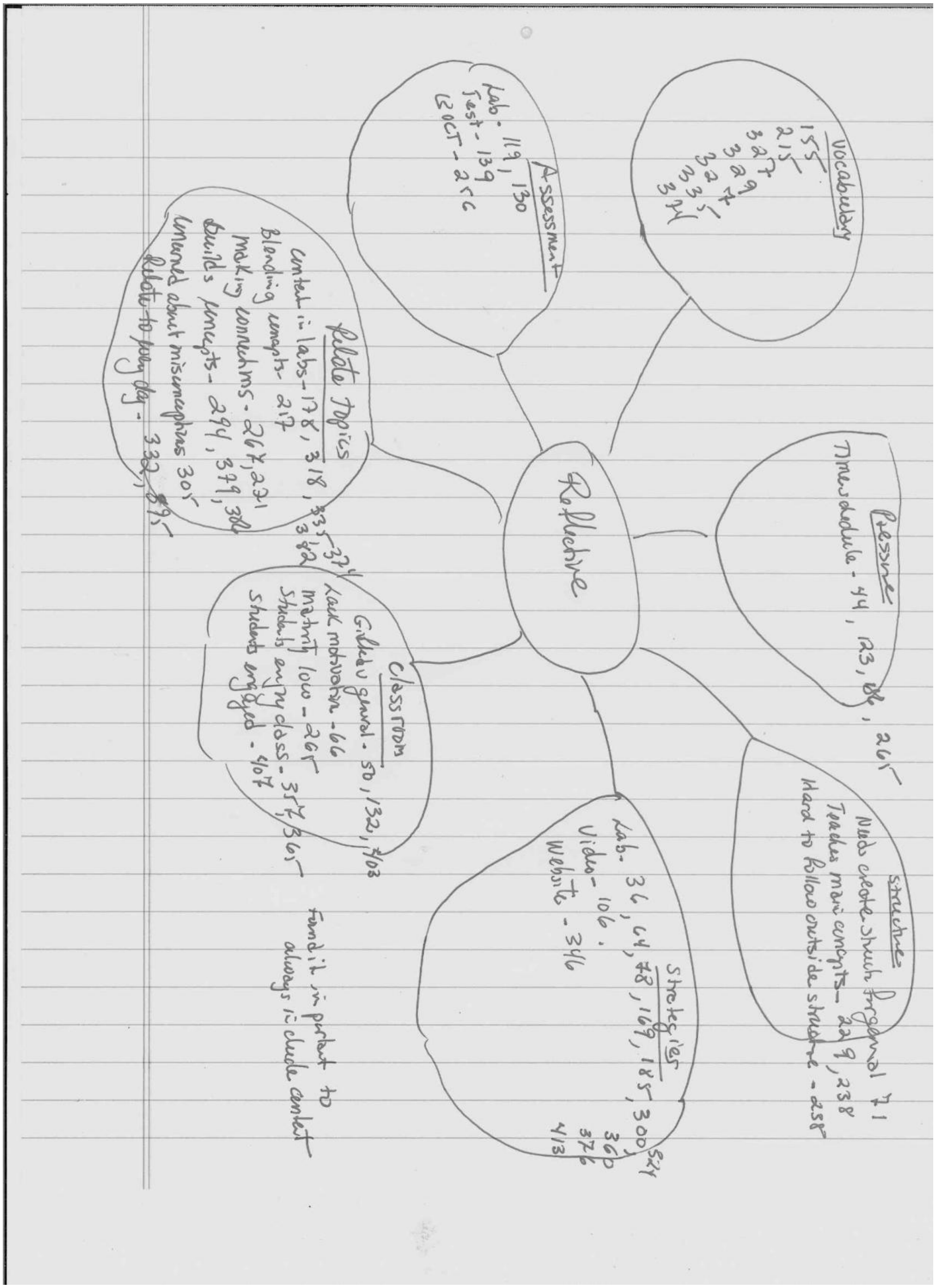
Terms = 11

APPENDIX N

Graphic Representation of Interview Analyses (Dot)




Initial
Vocabulary
95
116
131
157
173
193
204
206
211
Transition to ITS - 101
Structure
Constructivist - 113
Keep simple - 122
Tries to follow county system - 221, 233
Format test to match benchmark - 242
249
Expects deeper work from advanced classes
Strategies
Interactive notebook - 72
Gizmo - 245
Lab - 258, 284, 298
Projects - 258
Research - 321
Values multiple forms
Assessment
EOCT - 138
Test 242, 248, 256, 262
Gizmo - 245
Lab - 258
Project - 258
Related Topics
Blend topics - 88, 125, 153, 213, 217
Build on prior Kn - 92, 126, 197
Blends concepts
Builds concepts thro' revising & deepening
Classroom
Gen v adv - 94, 260, 318
Lack prior Kn - 128
Poor Reading comprehension - 261
Tied to evolution
DNA Technology
Talks about NOS all year
Tries to give more than 1 correct data interpretation
How Science works
Labs for
apparatus
hypothesis
Lab reports
Accepts reasonable answers based on data
Needs to be testable
Did not mention scientific method


Reflective
Vocabulary
155
215
327
329
327
335
374
Pressure
Time/schedule - 44, 123, 265
Structure
Needs create structure for general 71
Teaches main concepts - 229, 238
Hard to follow outside structure - 258
Strategies
Lab - 36, 64, 78, 169, 185, 300, 324, 360, 376, 413
Video - 106
Website - 346
Assessment
Lab - 119, 130
Test - 139
Test - 139
Relate Topics
Blending concepts - 217
Making connections - 267, 271
Builds concepts - 294, 379
Classroom
Lack motivation - 66
Maturity low - 265
Students enjoy class - 357, 365
Students engaged - 407

APPENDIX N

Sample Assignment (Jessica)

Name____ Date__________

Examine an Ecosystem

Materials: Jar ecosystem (for small group of two) - pond water, Thermometer, protoslo, toothpick, dropper, microscope (2), slide, coverslip, ?paper

open directions

Examine your ecosystem (jar of pond water) and record what you see.
1. Describe what you did to observe the jar and its contents.
2. Develop a data table for your observations.
3. Develop a graph using information from the data table.

Abiotic Factors
1. What abiotic factors are visible in the ecosystem?
2. What is the temperature of your ecosystem? __________
3. Is this a biotic or abiotic factor? __________
4. What other conditions could you test for? Explain your answer.
pH paper available

Biotic Factors
1. Use the pond identification sheet to help you identify organisms in your ecosystem.
2. What organisms are visible with the naked eye?
3. What organisms are visible under a microscope?
Differentiate

Compare Ecosystems
1. Compare your jar with three other jars (a-i) in the classroom.
2. Which one do you think is the "healthiest" ecosystem? Why? Describe the factors related to the jar.
3. Draw and identify two or more of the organisms you see in your ecosystem. Label organelles that you see in single celled organisms. Explain why you think they have these organelles.
4. What populations are observed in your ecosystem? Which organism is the highest population? Hypothesize as to why it is the highest; what characteristic does it possess for this ecosystem?

Specific yet hoping for plant/animal

I did for a count (Plan to use this as a sign of health)

APPENDIX P

Sample Lesson Log Page (Flossie)

☆ – Student w/ student teacher – Regular teacher teaching Jr pullouts "intervention" GHSGT

	Date	Content Standard/Element	Characteristics of Science Standard/Element	Activity	Assessment	
observation #1	3/14	SB3 a	SCSH 2 a b SCSH 3 c e SCSH 8 SCSH 1 6 c	Lab – Yeast Respiration · Are they alive? · How Do we know? · Do living things Respire?	· Lab write up · Sponge Q	
	3/15	SB3b	Where does O2 come from · ScSh 1	· PPT – Photosynthesis · Brain Pop – Photosynth	· Sponge · Guided note sheet · Discussion	
☆	3/16	SB3a	How Do we Know O2 came from H2O · ScSh 7	Photo/Resp Activity w/ Student Teacher	· Turn In Activity	Pull out
	3/17	SB 3a		· Photosynthesis · Leaf Structures –	· Sponge · H.W.	
☆	3/18	SB3ab		Photo/Resp Compare + Contrast w/ student teacher		Pull out

APPENDIX Q

Biology Georgia Performance Standards

Biology
The Biology curriculum is designed to continue student investigations of the life sciences that began in grades K-8 and provide students the necessary skills to be proficient in biology. This curriculum includes more abstract concepts such as the interdependence of organisms, the relationship of matter, energy, and organization in living systems, the behavior of organisms, and biological evolution. Students investigate biological concepts through experience in laboratories and field work using the processes of inquiry.

Co-Requisite – Characteristics of Science
Habits of Mind
SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism
in science.
a. Exhibit the above traits in their own scientific activities.
b. Recognize that different explanations often can be given for the same evidence.
c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.
a. Follow correct procedures for use of scientific apparatus.
b. Demonstrate appropriate technique in all laboratory situations.
c. Follow correct protocol for identifying and reporting safety problems and violations.

SCSh3. Students will identify and investigate problems scientifically.
a. Suggest reasonable hypotheses for identified problems.
b. Develop procedures for solving scientific problems.
c. Collect, organize and record appropriate data.
d. Graphically compare and analyze data points and/or summary statistics.
e. Develop reasonable conclusions based on data collected.
f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

SCSh4. Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.
a. Develop and use systematic procedures for recording and organizing information.
b. Use technology to produce tables and graphs.

c. Use technology to develop, test, and revise experimental or mathematical models.

SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.
a. Trace the source on any large disparity between estimated and calculated answers to problems.
b. Consider possible effects of measurement errors on calculations.
c. Recognize the relationship between accuracy and precision.
d. Express appropriate numbers of significant figures for calculated data, using scientific notation where appropriate.
e. Solve scientific problems by substituting quantitative values, using dimensional analysis and/or simple algebraic formulas as appropriate.

SCSh6. Students will communicate scientific investigations and information clearly.
a. Write clear, coherent laboratory reports related to scientific investigations.
b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.

The Nature of Science
SCSh7. Students analyze how scientific knowledge is developed.
Students recognize that:
a. The universe is a vast single system in which the basic principles are the same everywhere.
b. Universal principles are discovered through observation and experimental verification.
c. From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Major shifts in scientific views typically occur after the observation of a new phenomenon or an insightful interpretation of existing data by an individual or research group.
d. Hypotheses often cause scientists to develop new experiments that produce additional data.
e. Testing, revising, and occasionally rejecting new and old theories never ends.

SCSh8. Students will understand important features of the process of scientific inquiry.
Students will apply the following to inquiry learning practices:
a. Scientific investigators control the conditions of their experiments in order to produce valuable data.
b. Scientific researchers are expected to critically assess the quality of data including possible sources of bias in their investigations’ hypotheses, observations, data analyses, and interpretations.

c. Scientists use practices such as peer review and publication to reinforce the integrity of scientific activity and reporting.
d. The merit of a new theory is judged by how well scientific data are explained by the new theory.
e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.
f. Science disciplines and traditions differ from one another in what is studied, techniques used, and outcomes sought.
reading, researching, and learning. The Reading Across the Curriculum standard focuses on the academic and personal skills students acquire as they read in all areas of learning.

Co-Requisite – Content
SB1. Students will analyze the nature of the relationships between structures and functions in living cells.
a. Explain the role of cell organelles for both prokaryotic and eukaryotic cells, including the cell membrane, in maintaining homeostasis and cell reproduction.
b. Explain how enzymes function as catalysts.
c. Identify the function of the four major macromolecules (i.e., carbohydrates, proteins, lipids, nucleic acids).
d. Explain the impact of water on life processes (i.e., osmosis, diffusion).

SB2. Students will analyze how biological traits are passed on to successive generations.
a. Distinguish between DNA and RNA.
b. Explain the role of DNA in storing and transmitting cellular information.
c. Using Mendel's laws, explain the role of meiosis in reproductive variability.
d. Describe the relationships between changes in DNA and potential appearance of new traits including
Alterations during replication.
Insertions
Deletions
Substitutions
Mutagenic factors that can alter DNA.
High energy radiation (x-rays and ultraviolet)
Chemical
e. Compare the advantages of sexual reproduction and asexual reproduction in different situations.
f. Examine the use of DNA technology in forensics, medicine, and agriculture.

SB3. Students will derive the relationship between single-celled and multi-celled organisms and the increasing complexity of systems.
a. Explain the cycling of energy through the processes of photosynthesis and respiration.
b. Compare how structures and function vary between the six kingdoms (archaebacteria, eubacteria, protists, fungi, plants, and animals).
c. Examine the evolutionary basis of modern classification systems.
d. Compare and contrast viruses with living organisms.

B4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.

a. Investigate the relationships among organisms, populations, communities, ecosystems, and biomes.

b. Explain the flow of matter and energy through ecosystems by

Arranging components of a food chain according to energy flow.

Comparing the quantity of energy in the steps of an energy pyramid.

Explaining the need for cycling of major nutrients (C, O, H, N, P).

c. Relate environmental conditions to successional changes in ecosystems.

d. Assess and explain human activities that influence and modify the environment such as global warming, population growth, pesticide use, and water and power consumption.

e. Relate plant adaptations, including tropisms, to the ability to survive stressful environmental conditions.

f. Relate animal adaptations, including behaviors, to the ability to survive stressful environmental conditions.

SB5. Students will evaluate the role of natural selection in the development of the theory of evolution.

a. Trace the history of the theory.

b. Explain the history of life in terms of biodiversity, ancestry, and the rates of evolution.

c. Explain how fossil and biochemical evidence support the theory.

d. Relate natural selection to changes in organisms.e. Recognize the role of evolution to biological resistance (pesticide and antibiotic resistance