Utilizing the National Research Council's (NRC) Conceptual Framework for the Next Generation Science Standards (NGSS): A Self-Study in My Science, Engineering, and Mathematics Classroom

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ABSTRACT

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Given the reality that active and competitive participation in the 21st century requires American students to deepen their scientific and mathematical knowledge base, the National Research Council (NRC) proposed a new conceptual framework for K-12 science education. The framework consists of an integration of what the NRC report refers to as the three dimensions: scientific and engineering practices, crosscutting concepts, and core ideas in four disciplinary areas (physical, life and earth/spaces sciences, and engineering/technology). The Next Generation Science Standards (*NGSS*), which are derived from this new framework, were released in April 2013 and have implications on teacher learning and development in Science, Technology, Engineering, and Mathematics (STEM). Given the *NGSS's* recent introduction, there is little research on how teachers can prepare for its release. To meet this research need, I implemented a self-study aimed at examining my teaching practices and classroom outcomes through the lens of the NRC's conceptual framework and the *NGSS*. The self-study employed design-based research (DBR) methods to investigate what happened in my secondary classroom when I designed, enacted, and reflected on units of study for my science, engineering, and mathematics classes. I utilized various *best practices* including *Learning for Use (LfU) and Understanding by Design (UbD)* models for instructional design, *talk moves* as a tool for promoting discourse, and *modeling instruction* for these designed units of study. The DBR strategy was chosen to promote reflective cycles, which are consistent with and in support of the self-study framework. A multiple case, mixed-methods approach was used for data collection and analysis. The findings in the study are reported by study phase in terms of unit planning, unit enactment, and unit reflection. The findings have implications for science teaching, teacher professional development, and teacher education.

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ACKNOWLEDGEMENTS

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Finally, I would also like to thank my school district for providing me with the opportunity to conduct my study and my students, teaching colleagues, and administrators for their support of my study.

DEDICATION

This dissertation is dedicated to my wife, Gerry Corvo, and my daughter Allison Corvo for their continuing support and confidence in the belief that I could accomplish this.

CHAPTER 1

INTRODUCTION

Study Overview

This study employed a self-study theoretical framework that utilized design-based research (DBR) strategies to examine outcomes in my secondary chemistry, statistics, and engineering when integrating the National Research Council's (NCR) conceptual framework for science education and the Next Generation Science Standards (*NGSS).*

In Chapter 1, I describe the context for the study and define the research problem. I describe my background, experience, and approaches regarding the research that was undertaken. The purpose and goals of the study are subsequently stated along with a specific research question. The significance of the study is explained.

Chapter 2 discusses the relevant research that informed this self-study. Literature on K-12 Science, Technology, Engineering, and Mathematics (STEM) education is explored. A brief historical perspective of science standards implementation is presented. Research on teacher professional development (PD) is reviewed from the perspective of changes in teachers' knowledge, beliefs, and attitudes. Examples of self-study research in science education are considered. The self-study theoretical framework that grounded the study is examined. The theoretical underpinnings for this self-study framework are investigated. Trustworthiness and validity in self-study is considered. A discussion of design-based research (DBR) strategies in the context of self-study is presented as an introduction to the next chapter on study methodology.

Chapter 3 provides a description of the study methodology. The study's setting, participants, contextual factors, and timeline are described. Data sources and data measures are identified, along with a discussion of how the data was collected and analyzed. Study validity, reliability and rigor are explored. Ethical considerations are addressed. The chapter concludes with a presentation of study assumptions, limitations, and challenges.

Chapter 4 presents findings from the data collected and analyzed based on the systematic application of the study methodology.

Chapter 5 explores the study's conclusions, discussion of findings, and recommendations.

Additional documentation supporting this study is provided in the Appendices and referred to as appropriate throughout the study.

Definition of Key Terms

In this study I used several terms, which are described below:

Action research is a paradigm and not a method (Pine, 2008). As a paradigm, action research is a conceptual, social, philosophical, and cultural framework for doing research that "embraces a variety of research methodologies including case studies, descriptive studies, survey studies, interview studies, observational studies, phenomenological studies, quantitative studies including quasi-experimental designs, and historical research " (p. 67).

Best practices results from a rigorous process of peer review and evaluation that indicates effectiveness in improving educational outcomes for a target population. A best practice:

- Has been reviewed and substantiated by experts in the education field according to predetermined standards of empirical research;

- Is replicable, and produces desirable results in a variety of settings.
- Clearly links positive effects to the program/practice being evaluated and not to other external factors. (Best Practice, 2014)

Cross-cutting concepts are one of three dimensions of the *NGSS* and have application across all domains of science. As such, they are a way of linking the different domains of science. They include: Patterns, similarity, and diversity; Cause and effect; Scale, proportion and quantity; Systems and system models; Energy and matter; Structure and function; Stability and change (Next Generation Science Standards, 2014).

Design-based research is a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation. It is based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories (Wang & Hannafin, 2005).

Modeling instruction applies structured inquiry techniques to the teaching of basic skills and practices in mathematical modeling, proportional reasoning, quantitative estimation and technology-enabled data collection and analysis. The instruction is organized into modeling cycles which move students through all phases of model development, evaluation and application in concrete situation, thereby promoting an integrated understanding of modeling processes and acquisition of coordinated modeling skills (American Modeling Teachers Association, 2014).

Self-efficacy is defined as "Beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1977, p. 3).

Self-study is a personal, systematic inquiry situated within one's own teaching context that requires critical and collaborative reflection in order to generate knowledge, as well as inform the broader educational field (Sell, 2009).

Context for the Study

The NRC has identified STEM topics as being endemic to our 21st century lives in terms of the United States' (U.S.) ability to compete in a global economy and solve current and future challenges that the country and world face. Judith Ramaley, a former director of the National Science Foundation (NSF), coined the term STEM (Koonce, Zhou, Anderson, Hening & Conley, 2011). However, discussions with educators about STEM topics reveal the ambiguity of exactly what STEM means, and more precisely, its implications for classroom practice. Ramaley, in discussing experiences with the reform of STEM education, argued for the following perspective on STEM:

> We are starting to see a gradual blending of models and methods to create a different, more integrated approach that Gibbons et al. call "trans-disciplinary" to distinguish the phenomenon from "interdisciplinary" where a common problem is studied from several angles but the different perspectives do not co-mingle. (Science Technology Engineering Mathematics, 2013, p.7)

Thornburg (2008) provided an illustration of how these topics are related (see Figure 1-1) and constructs a case for treating them as an interdisciplinary whole, which strengthens the understanding of each of them. For the purposes of this study I viewed STEM in terms of Thornburg's model.

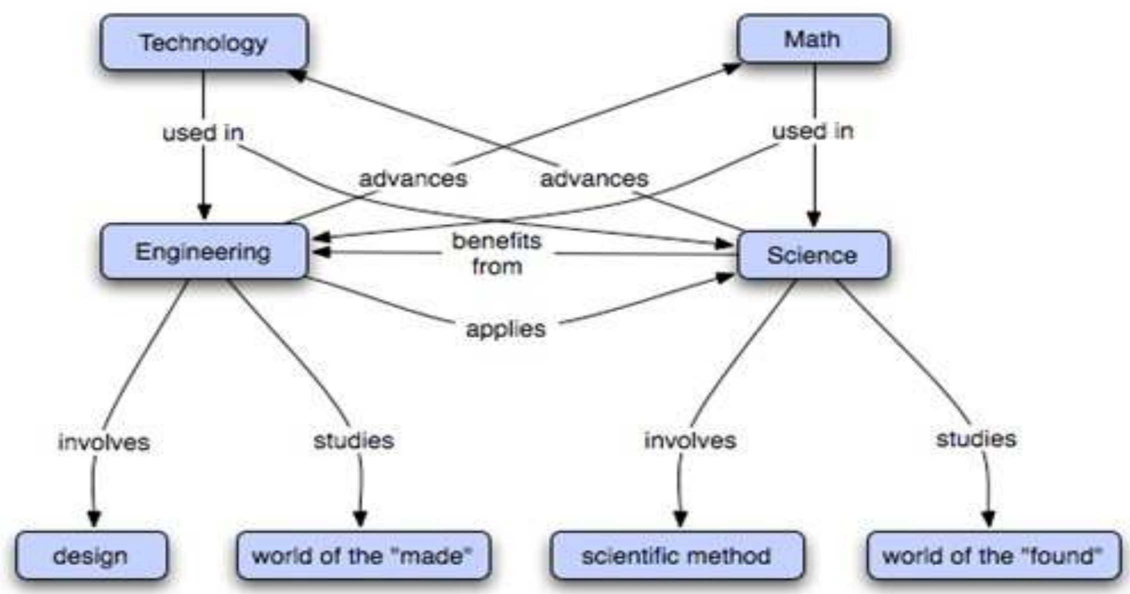

Figure 1-1. Thornburg's view: Why STEM topics are interrelated (Thornburg, 2008)

Concurrently, K-12 science education is focused less on the nature and practice of science and more on facts versus understanding. The focus on facts versus understanding, in addition to the many misconceptions teachers have about STEM, provides an educational experience that may not best prepare students for participation in the 21st century economy. In order to address these ongoing concerns, the NRC proposed a Framework for K-12 Science Education (hereinafter referred to as the *Framework*). The NRC report described the vision of the *Framework:*

> The *Framework* is based on a rich and growing body of research on teaching and learning in science, as well as on nearly two decades of efforts to define foundational knowledge and skills for K-12 science and engineering. From this work, the committee concludes that K-12 science and engineering education should focus on a limited number of disciplinary core ideas and crosscutting concepts, be designed so

> that students continually build on and revise their knowledge and abilities over multiple years, and support the integration of such knowledge and abilities with the practices needed to engage in scientific inquiry and engineering design. (NRC, 2012, p. 2)

Appendix A provides a more detailed description of the three dimensions of the *Framework*.

The Problem

Two national science education standards documents were developed during the 1990s to articulate a comprehensive vision for science teaching and learning: the *Benchmarks for Scientific Literacy* report (hereinafter referred to as *Benchmarks)* by the American Association for the Advancement of Science (AAAS, 1993) and the *National Science Education Standards* (*NSES*) by the National Research Council (NRC, 1996). Penuel and Fishman (2012) discussed how "coordinated efforts to support standards implementation fell short of achieving broad scale improvements in science education. In some instances, the new standards conflicted with the dominant forms of teaching" (p. 290). Loucks-Horsely and Matsumoto (1999) described predominate teaching practices in the following manner: "Many teachers hold deep-seated conceptions of knowledge as facts, teaching as telling, and learning as memorizing. These beliefs are anathema to the new reforms" (p. 261). Adopting practices that value deep comprehension about scientific inquiry requires a shift in understanding, not only STEM topics themselves, but also a shift in how students come to accommodate this type of learning. Thus, teachers' knowledge, beliefs, and attitudes play an important role in impacting their adoption of reforms.

In reviewing research on learning to teach to new standards, Loucks-Horsely and Matsumoto (1999) argued:

> In the push to implement both content and student performance standards, it is apparent that teacher learning is critical in helping instruction move beyond mechanistic implementation to maximize student learning. Exactly what teachers need to know to do so, and how they need to learn, are critical pieces of the picture that results in student learning. (p. 259)

Much of the literature on K-12 STEM education (Doyle & Yoon, 2011; Rittmayer & Beier, 2008) indicated that new models of teaching must be developed if STEM integration (a key goal of the *Framework*) is to lead to meaningful STEM learning. One factor that complicates the development of new models of teacher learning is that most current teachers have not learned disciplinary content using STEM contexts, nor have they taught in this manner (Wang, Moore, Roehrig, & Park, 2011). Successful models of integrating the NGSS standards would ultimately involve creating opportunities for teachers to learn in this context in order for them to fully understand the value in teaching their students in this context.

Darling-Hammond and Ball (1998) discussed aspects of teacher professional development that affect teacher learning:

> Five premises are especially pertinent to teachers learning opportunities:
>
> - Teachers' prior beliefs and experiences affect what they learn….
> - Learning to teach to new standards takes time and is not easy....
> - Content knowledge is key to learning how to teach subject matter so that students understand it….
> - Knowledge of children, their ideas, and their ways of thinking is crucial to teaching for understanding....
> - Opportunities for analysis and reflection are central to learning to teach… (p. 16)

Putnam and Borko (1997) argued that these learning opportunities must be situated in authentic classroom practice. Teacher learning is what Loucks-Horsely and Matsumoto (1999) posited as "critical" in moving instruction from literal and rote to conceptual and cross-cutting. Darling-Hammond and Ball's (1998) insights about the five aforementioned premises that influence teacher learning inform how a successful model of teacher learning in STEM education might look like. The authors argued, "The best way to improve teaching and teacher learning is to create the capacity for much better learning about teaching *as part of teaching*" (p. 17). Thus, a key insight for teacher learning by the authors is the investigation of practice.

The *Framework* acknowledges the fragile dynamic between teacher learning and instructional change. "Teachers are the 'linchpin' in any effort to change K-12 science education … the professional development of teachers of science will need to change in order to support implementation of the new standards" (NRC, 2012, p. 256). Penuel and Fishman (2012) posited, "Teachers will need to reorganize instruction to emphasize fewer ideas and develop strategies for integrating content, science and engineering practices, and crosscutting themes" (p. 293). Blanton (2012) offered that the *NGSS* "have the potential of transforming science education if work is done to inform and prepare the teachers who will be expected to implement these standards" (p. 259). Thus, teachers will need a significant amount of ongoing and sustained training, time, and support in order for the vision of *NGSS* reform to be realized.

To meet the task of changing current STEM education paradigms, research is required and necessary. Penuel and Fishman (2012) contended, "the coming implementation of next generation science standards offers a potential laboratory for developing and testing new methods of translational research" (p. 290). Additionally, the *Framework* recommended a broad-based research agenda aimed at investigating "changes in the understanding of science learning and teaching across the K-12 spectrum and changes in the understanding of how a given set of standards is interpreted, taken up, and used by a variety of players to influence K-12 educational practice and policy" (NRC, 2012, p. 311). To understand how to effectively influence current STEM practice, the research focus should be on teachers' knowledge of science and engineering practices, on effective professional development (PD) for supporting teachers' understanding and uses of the standards, and on curricula, instructional approaches, and assessments. In its summary remarks, the *Framework* emphasized a critical component of the research agenda:

> Perhaps most important, research is needed on classroom-level contexts, materials, and discourses that engage and support a wider range of students in high-quality teaching and learning experiences with the concepts, ideas, and practices. Action on this wide-ranging multilevel agenda would make it possible to advance the framework's vision and continue to improve access for all. (NRC, 2012, p. 325)

Given the research agenda proposed in the *Framework,* a study in an authentic school and classroom-level setting helps address this research need for "multilevel" understanding. After reviewing the literature on various research models, I came to the realization that I needed to construct a research model based on a self-study conceptual framework. The roots of self-study include teacher inquiry, action research, and reflection. I chose a DBR strategy to promote reflective cycles and feedback from one cycle or phase would be used to inform the design of the next phase. Additional discussion of the rationale for designing the study based on this research model is provided in the literature review in Chapter 2.

Researcher Background, Experiences, and Approaches

In my primary career, I was an electrical design engineer and engineering manager for 28 years. I subsequently transitioned to secondary level teaching through an alternate-route teacher certification program. In addition to my role as a high school teacher, I served as an adjunct instructor in the same program that I received my alternate route teacher training and certification. As an adjunct, I provided pre-service teachers with opportunities to examine, learn, and implement effective teaching practices in a classroom setting.

After becoming certified in mathematics and the physical sciences, I taught mathematics and engineering at the secondary level for six years. Though I enjoyed this role, I wanted the opportunity to apply my background in engineering and mathematics to other subject areas, specifically the physical sciences (i.e. physics and chemistry). During that time, there were no physical sciences positions available in my school district. Wanting to further investigate other components of STEM education, I took an educational leave of absence for two years from my school district and enrolled in a doctoral program in science education. The program provided opportunities to consider a rich and diverse set of perspectives on science education through formal coursework, to participate as an assistant investigator in an international study on promoting creativity and innovation, and to design and implement an afterschool STEM middle school program.

As a result of these varied educational experiences I have evolved an epistemological position that knowledge creation and construction is socially situated. Knowledge is processed inwardly within individuals' minds through social interaction (Driver, Asoko, Leach, Mortimer & Scott, 1994). When knowledge is constructed "socially," it is knowledge that is negotiated with other members of the social context to the extent that meaning is shared by the interacting individuals (Prawat & Floden, 1994). Thus, knowledge construction involves the individual's interpretation in the context of social practices (Cobb, 1994).

Upon my review of the *Framework* and the *NGSS*, I reacted with both excitement and concern. I was intrigued at the prospect of exposing students to engineering practices and helping them navigate STEM interrelationships. However, I was concerned that my present lesson design, discourse, modeling, and assessment strategies were incompatible with the tenets of the new standards, and as a result, would make implementation difficult.

In September 2012, after two years of coursework where I was exposed to varying ideas about science pedagogy, I returned to the secondary classroom in multiple roles as a science, engineering, and mathematics teacher. My teacher training and lesson design experiences from 2004-2010 had more emphasis on activities rather than assessment. Previous to attending Teachers College, I was not trained in science education practices and I had limited lesson design, discourse, assessment, and modeling dispositions. My PhD training from 2010 through 2012 promoted these dispositions in a science education context thus providing me with a strong foundation for examining my teaching practice. Given the *NGSS's* challenge of incorporating science and engineering practices and crosscutting concepts, I believed that I needed to develop instructional strategies for improved lesson design, implementation, and assessment as well as establish norms for both discourse and modeling in my classroom. In reviewing the literature on science education, I discovered *best practices* that assisted me in my learning. These *best practices* included: *Learning for Use (LfU)* and *Understanding by Design (UbD)* to design lessons, *talk moves* and the *questioning cycle* to promote discourse, and *modeling instruction* to engage active student participation in their learning.

Learning for Use (*LfU*) is a theory of learning that is intended to provide a framework for the design of instruction by supporting the instructor in the development of learning activities (Edelson, 2001). I selected the *LfU* model primarily because it framed designing instruction in terms of motivation processes to elicit learner curiosity. To create this motivation, Edelson (2001) argued that it is essential to setup up a context that the learner finds useful. Furthermore, Edelson (2001) discussed how *LfU*, in a technology supported inquiry unit, achieved both content and process learning. Given that a key goal of the *Framework* is to address the learning of both STEM disciplinary content and STEM processes, *LfU* offered a useful model for instructional design.

Edelson (2001) described three steps in the *LfU* model. *Motivation* (the first step) is framed in terms of processes of creating demand by setting up a context that the learner finds useful, and eliciting curiosity. *Knowledge construction* (the second step) is characterized by processes of observation through direct, firsthand experience, and learning through communications with others. *Knowledge organization and refinement* (the third and final step) is accomplished through processes of reflection and application. Embedded within each of the three steps of the *LfU* model is a "plan-enact-reflect" framework.

In a design-based research (DBR) study, Madeira (2010) investigated a PD model that involved secondary school science teachers engaging in several plan-enact-reflect cycles to explore their pedagogical content knowledge (PCK) development. Each of the processes articulated in each of the *LfU* model's three steps has an associated design strategy. This strategy may be helpful to me in creating instructional design solutions (Figure 1-2).

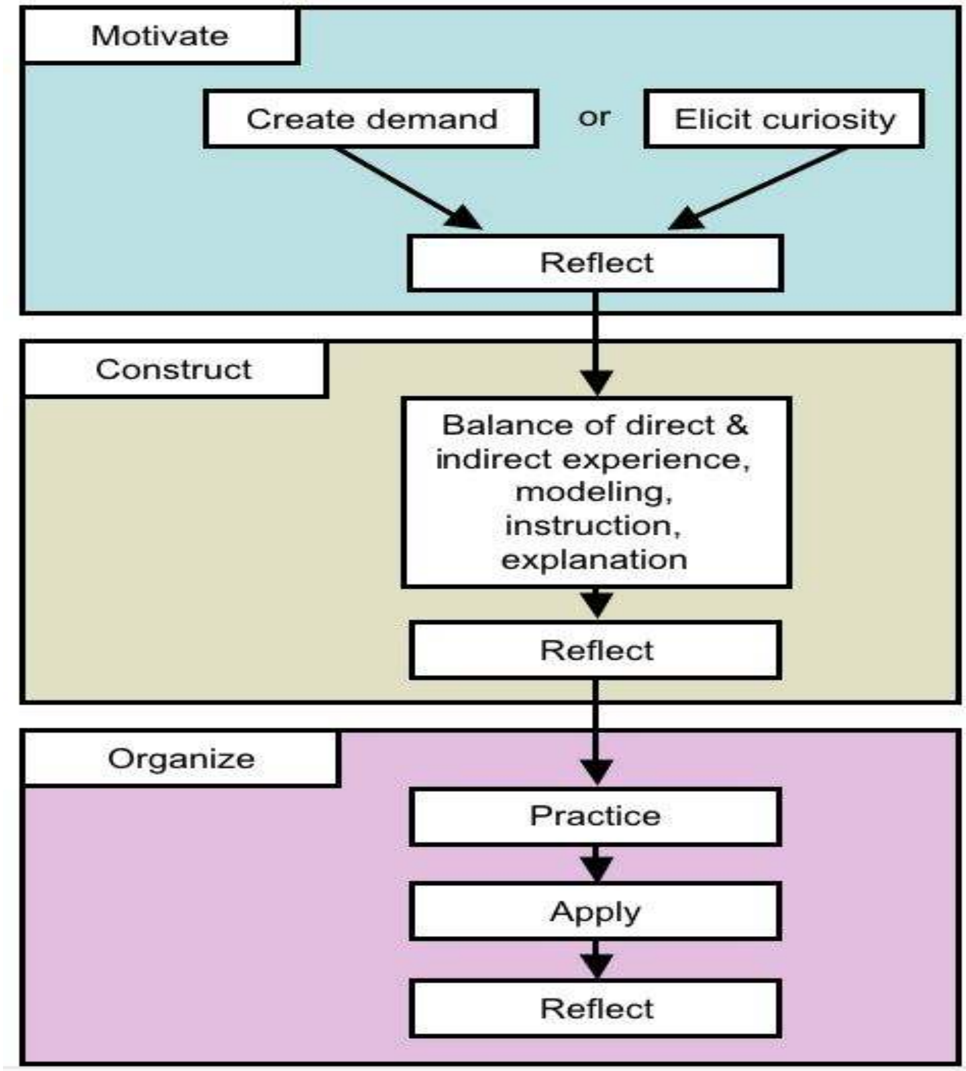

Figure 1-2. Learning for use (LfU) instructional design model (Edelson, 2002)

Understanding by Design (*UbD)* is a framework that focuses the teacher's role as an assessment designer rather than an activities designer (Wiggins & McTighe, 2005). Stern and Ahlgren's (2002) study of middle school curricula materials found "that curriculum development drives the assessment development, and that assessment is designed to align to the actual content included in the material. This would explain why so many assessment tasks appear tailored to fit incidental details of the curriculum rather than important generalizations" (p. 906). I chose the *UbD* model to help me articulate learning goals by identifying desired results, to design assessments to determine acceptable evidence of student learning, and to plan learning activities.

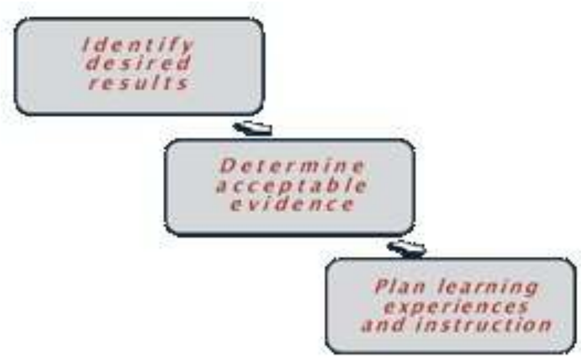

Figure 1-3. Understanding by design (UbD) design model (UbD_stages, 2014)

UbD's primary goal is to develop and deepen student understanding via "big ideas." These "big ideas" offer a conceptual framework allowing the learner to explore answers to the essential questions involving a unit of study (Wiggins & McTighe, 2005).

A potentially useful way to communicate these *UbD* "big ideas" is through discourse in order to promote student understanding. Michaels, Shouse, and Schweingruber (2008) illustrated how "talk" can be academically productive. The authors of *Ready, Set, Science (*a K-8 publication that has influenced the *Framework*) stated, "Representing ideas through talk and argument plays an essential role in the learning and practicing of science" (p. 106). Michaels and O'Connor (2012) argued, "through well structured talk, students are guided – or apprenticed, into fundamental practices of science" (p. 5). The authors further discussed that "research over the past 20 years … has led to the identification of a small number of general *talk moves* that are remarkably helpful tools for making discussions work" (p. 10). Given the promising results of the use of *talk moves* (see Appendix B), I selected this toolset in my study to promote discourse.

Fusco (2012) described the *questioning cycle* as "a systematic method for using questions to collect information about students' knowledge, encourage students to consider diverse ideas, and build a community of thinkers" (p. 11). Questions are developed by considering lesson objectives as well as students' prior knowledge, background and cognitive abilities. Avenues of scaffolding of students' learning are also considered in the development of questions. To use throughout the lesson to stimulate discussion, instructors include literal, inferential, and metacognitive questions. A key component of the questioning cycle is wait time. Studies have shown that if teachers pause between three and five seconds after asking higher-level questions, students respond with more thoughtful answers (Fusco, 1983; Rowe, 1974; Tobin, 1987).

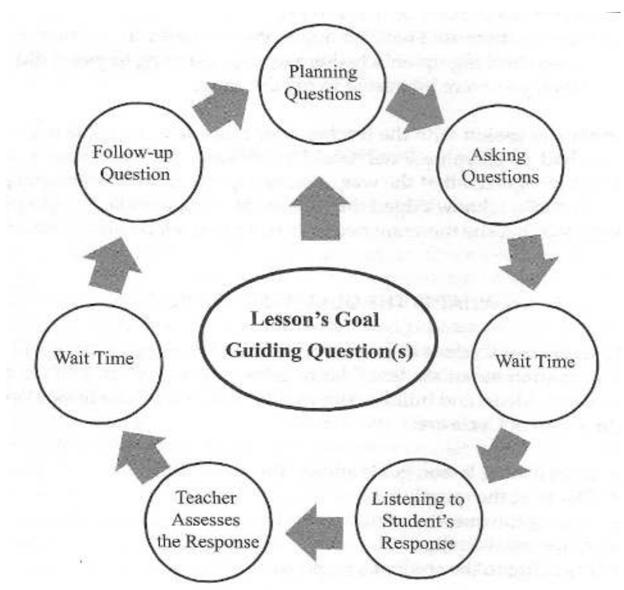

Figure 1-4. Steps in the questioning cycle (Fusco, 2012)

Fusco (2012) argued that the *questioning cycle* enables students to experience multiple points of view, interact with each other and the teacher, and elaborate on their individual responses. I selected the *questioning cycle* to help me design instruction to promote discourse in my classroom.

Scientists construct, evaluate, and revise models to aid in their understanding of the world. Krajcik and Merritt (2012) posited, “Models provide scientists and engineers with tools for thinking, to visualize and make sense of phenomena and experience, or to develop possible solutions to design problems” (p. 38). Megowan-Romanowicz (2010) argued, “Modeling Instruction is a guided-inquiry approach to science teaching. Students learn through ‘modeling:’ that is they construct, test, and apply conceptual models …to aid their reasoning and analysis process” (p. 995). According to Hestenes (2000), a modeling instructional method is used to “give students experience in constructing and using models to make sense of experience in a variety of situations … by engaging students continually in ‘model-centered discourse’ and presentations” (p. 2). Moore (2008) discussed using model eliciting activities (MEA) for getting students interested in materials science and engineering. Given that developing and using models is a key science and engineering practice that is promoted in the *Framework* and articulated in the *NGSS*, I chose modeling instruction to implement in this study.

Khan (2011) developed a framework for models-based teaching (MBT) called GEM (generate (G), evaluate (E), and modify (M)). This framework provides a rubric for representing teacher and student actions associated with core GEM processes. Khan (2011) stated, “the strategies in the rubric represent a composite set of teaching practices noted in the literature as being employed in practice or in theory to promote a particular MBT process” (p.

541). I selected this modeling rubric (see Appendix C) to assist me in the design and enactment of instruction.

The Purpose of the Study

Given the context of the *Framework* and the *NGSS*, as well as my background, experiences, and interests, a fundamental question arose for me: How will utilizing the *Framework* for science education and the *NGSS* impact my classroom teaching practices? Given this question, the purpose of this study was to examine my experiences in my secondary chemistry, statistics, and engineering classes through the lens of the *Framework* for science education and the *NGSS*. The following research question guided this study:

- What happened in my chemistry, statistics, and engineering classes when I employed a self-study framework using a design-based research (DBR) strategy to design, enact, and reflect on units of study that promoted the *Framework's* disciplinary core ideas, science and engineering practices, and crosscutting concepts?

Significance of the Study

This self-study is distinctive in that it is situated at the classroom level using the context of the *Framework* and the *NGSS.* The study has two key elements: (1) an intervention in which I used various *best practices* to promote the *Framework's* core disciplinary ideas, science and engineering practices, and crosscutting concepts, and (2) a cyclical reflective process that operated as a catalyst for feedback for my own learning. The self-study methodology emphasizes a systematic, self-critical approach to addressing the phenomenon of how I can utilize the *Framework* and the *NGSS* as an important framework for teaching STEM. I chose this self-study approach because I believed it would enrich my examination of my teaching knowledge, beliefs, attitudes, and practices and help me understand more deeply the complexities of STEM teacher education.

This study contributed to the understanding of my experiences as I progressed through the implementation cycles of self-study research using DBR methods in my classroom and the subsequent effects on my instructional practices and my students' learning experiences. Teachers may be able to utilize this research to aid them in constructing their own questions about the best way to improve their teaching and learning practices given the *NGSS*. The study also offered insights into models for teacher preparation and professional development when considering the *NGSS*.

The study may add to the knowledge base of *NGSS* teaching practice and may be able to refine, revise, or extend knowledge of *NGSS* teaching practice. What emerged from the study findings may have theoretical or methodological significance.

Chapter 1 Summary

Chapter 1 provided an overview of this study as well as of my teaching practice in my high school classroom. Examining the *Framework*, as well as lessons learned from previous standards implementations and from K-12 STEM education studies, shaped and defined the need for this study. Based on the stated research problem, the researcher's background, and the examination of potential *best practices,* the purpose and goals of the study were stated and accompanied by a specific research question. The significance of the study was explicated.

Chapter 2 provides for a literature review that considers the research related to K-12 STEM education, a history of standards implementation, teacher professional development, and self-studies in science education. This review examines the rationale for the self-study theoretical framework chosen for this study. Conceptual underpinnings, trustworthiness, and validity for this self-study are considered. A discussion of design-based research (DBR) methods in the context of self-study is presented.

CHAPTER 2

LITERATURE REVIEW

Overview

The purpose of this study was to examine my experiences in my secondary chemistry, statistics, and engineering classroom through the lens of the *Framework* and the *NGSS*. The study design was structured in three phases. The first phase (Phase One) was devoted to ”unit planning” and took approximately one week to complete. “Unit enactment” and “unit reflection” took approximately four weeks. Thus, each study phase consisted of five weeks in which a unit was designed, enacted, and reflected/analyzed upon. Data analysis in a previous phase was used to inform the design of the subsequent phase. Phase Two essentially followed the same process as in Phase One. Results from data analysis from Phase Two were applied to the next phase (Phase Three) of the study. Phase Three followed the same process as Phase Two. Results from data analysis from Phase Three informed the study’s overall results. The timeline for the entire study was approximately fifteen weeks. The research question posited for Phase One of this study was: What happened in my chemistry, statistics, and engineering classes when I employed a self-study framework using a design-based research (DBR) strategy to design, enact, and reflect on units of study that promoted the *Framework’s* disciplinary core ideas, science and engineering practices, and crosscutting concepts?

A review of the literature was necessary to establish the conceptual foundation for this study. This literature review is organized into eight sections. In the first section, K-12 STEM education literature is examined from the standpoint of STEM integration (a key element of the *Framework*) and *modeling* (an essential science and engineering practice). In the second section, a brief historical research perspective on previous *NSES* and *Benchmarks* implementations is provided to gain insight into lessons learned such as providing ongoing teacher support and designing curricula, instructional, and assessment materials that are better linked to standards. The purpose of this review was to understand how previous research informs future understanding of standards implementations. The third section reviews the literature on teacher learning and teacher PD. This examination sheds light on teacher learning as it relates to changes in teachers' knowledge, beliefs, and attitudes. The fourth section illustrates examples of self-studies in science education. In the fifth section, I report on the self-study theoretical framework that underlied and guided this study. Subsections explore the roots of self-study, which are teacher inquiry, action research, and reflection. A discussion of teacher inquiry and the action research process is undertaken. Various models for reflection are reviewed. The fifth section concludes with a discussion that connects reflection, action research, and self-study. The sixth section discusses the conceptual underpinnnings for this self-study. Findings from research on constructivism and social constructivism, situated cognition, conceptual change, efficacy, and ethic of care are considered. The seventh section discusses the criteria to assess the trustworthiness and validity of this self-study. The eighth section on DBR strategy is examined in the context of self-study and serves an prelude to the chapter on study methodology.

K-12 STEM Education

In recent years, research on K-12 STEM education has grown significantly. However, the extent to which the four components of STEM are integrated is not as thoroughly understood. Williams (2009) studied technological integration and advocated for cross-curricular links to develop interaction between STEM subjects. Thornburg (2008) illustrated

STEM topics being interrelated (Figure 1-1) and offered “connections between these four subjects are very powerful and make it easy to build a logical case for treating them together as an interdisciplinary whole” (p. 1).

In a STEM models-based multiple-case study with three middle school teachers, the authors reported:

> (1) The problem solving process is a key component to integrate STEM disciplines, (2) Teachers in different STEM disciplines have different perceptions about STEM integration and that leads to different classroom practices, (3) Technology is the hardest discipline to integrate in these cases, and (4) Teachers are aware of the need to add more content knowledge in their STEM integration. (Wang, Moore, Roehrig, & Park, 2011, p. 1)

These findings support the authors’ conclusion that STEM integration can be implemented successfully and that teachers believe that this manner of teaching encourages student learning and student confidence in mathematics and science courses (Wang et al., 2011). Moreover, Stone (2011) reported on a study in a Career and Technical Education (CTE) program that, “The study showed that the ‘M’ in STEM education can be successfully integrated with the ‘T’ and improve students’ math skills” (p. 1).

Moore (2008) discussed using model eliciting activities (MEA) for getting students interested in materials science and engineering. Furthermore, Moore stated,

> MEAs are realistic, interdisciplinary, team-based, nonroutine problems (Chamberlin & Moon, 2005); they allow researchers and teachers to observe students’ development of conceptual models as they go through the cycle of expressing, testing, and revising their solutions. MEAs have become powerful tools to help instructors and researchers

> become more observant and sensitive to the design of learning environments that engage learners in productive mathematical thinking (Lesh & Doerr, 2003). MEAs were originally designed for mathematics education. But they have been used increasingly in engineering education. (p. 146)

In summary, a review of K-12 STEM literature offered the following key points for this study's design: (1) viewing the components of STEM as an inter-related system with powerful cross-curricular links, and (2) using MEA within the STEM disciplines (Lesh & Doerr, 2003). The *Framework* articulates STEM integration as a key consideration for science education reform and modeling as an essential science and engineering practice.

A Brief History of Science Standards Implementations

The *NSES* and *Benchmarks* were two national science education standards documents that were developed during the early to mid-1990s. The purpose of these standards was to give both states and school districts a strong conceptual foundation for reforming K-12 science education. Moreover, this intention was to be accomplished by promoting K-12 coherence, rationalizing curriculum, instruction, and assessment, providing a basis for teacher ongoing professional development, and improving the achievement for all students. Efforts to support standards implementation were undertaken through several NRC committee reports on curriculum programs (NRC, 1999), inquiry (NRC 2000), and assessment (NRC, 2001) as well as through various federal and state initiatives.

Upon assessing the impact of the standards, Penuel and Fishman (2012) found that the standards reform efforts fell short of making broad-based improvement in science education. In some instances, the new standards conflicted with the dominant forms of teaching" (p. 290). When considering individual district implementation, Spillane and Callahan (2000) found that when policy makers do not fully understand the meaning and context of ideas, the implementation would not adhere to reformers intent. The lack of deep and meaningful understanding at the district level precludes deep and meaningful understanding at the classroom level. Evidence of the lack of filtered down understanding to the classroom level was documented in Kesidou and Roseman's (2002) research on how middle school programs support key scientific ideas specified by national science standards. The authors concluded, "none of the middle school programs examined are likely to contribute to the attainment of the key ideas" (p. 538). For these programs, the authors stated that the teachers were provided with minimal support. Without ongoing and sustained teacher support, it will be difficult to develop changes in teachers' knowledge, beliefs, and attitudes, which is crucial to changing practice (Borko, 2004; Fishman, Marx, Best, & Tal, 2003; Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley & Matsumoto, 1999).

As the *Framework* indicated, teachers are the "linchpin" of the reform. Thus, the success of the *NGSS* initiative hinges, in large measure, on the quality and effectiveness of teachers and the PD they receive. The complexity and reality of K-12 education reveals that teachers function in an ecosystem. Even though the *Framework* considers teachers as the "linchpin" of the reform, the current structures surrounding the "linchpin" must also change to accommodate for teachers' changes.

An Examination of Teacher Professional Development

Successful implementation of new standards requires changes in teacher knowledge, beliefs, and attitudes. This section examines previous research on recommendations for teacher PD. Loucks-Horsley and Matsumoto (1999) discussed several requirements for PD such as creating a sufficiently high level of cognitive dissonance, providing time, context, and support for teachers to resolve the dissonance, and providing continuing and ongoing help. However, the current body of PD literature (Avalos, 2010; Darling-Hammond & Richardson, 2009; Flint, Zisook, & Fisher, 2011; Webster-Wright, 2009)) concluded that the focus of most PD programs is on content rather than authentic learning experiences. In an attempt to re-conceptualize PD, Webster-Wright (2009) argued,

> Research is required that views the learner, context, and learning as inextricably interrelated rather than acknowledged as related, yet studied separately. The "experience" of that research is learning in everyday practice is rarely studied in a way that maintains the integration of all these aspects. There is a need for more research beyond the "development of professionals" that investigates the "experience of PL" as constructed and embedded within authentic professional practice. (pp. 712-713)

PD should focus on teacher learning in terms of changes in their knowledge, beliefs, and attitudes in order to acquire new skills related to their teaching (Fishman, Marx, Best, and Tal, 2003). Acquiring new skills and incorporating new behaviors requires a perceived sense of ability, or efficacy. A key aspect of learning is how the learner perceives his ability to perform tasks and take on new challenges. Though Fishman, Marx, Best, and Tal (2003) argued for a need to "make progress towards a linkage between teacher learning and student learning" (p. 644), much of the literature on teacher efficacy concludes that there are few studies that examine the relationship between teacher efficacy and student learning outcomes (Klassen, Tze, Betts, & Gordon, 2010). One reason for this conclusion might be the nature of the difficulties associated with attempting to establish such a linkage. There are several factors that influence both teacher and student learning such as changes in school culture, new policies, and administrator support (Loucks-Horsley & Matsumoto, 1999).

Goldsmith and Schifter (1997) explored the understanding of practices in relation to teacher beliefs. The authors further elaborated that “the issue is not simply one of having available a range of instructional strategies, but of knowing how and when such strategies can be most effectively employed” (p. 27). Thus, knowing how and when to use strategies involves a number of cognitive skills. Research is needed to understand how teachers' own perceived abilities might be linked to whether or not they continue the cycle of trying and reflecting on various strategies.

Examining teacher practice is a key factor explored by Loucks-Horsley and Matsumoto (1999) in discussing strategies and structures for effective professional development. The authors contended, “Professional development strategies focused on teachers’ own practice afford direct job-embedded learning” (p. 264). One kind of practice that can be the focus of this type of learning is related to “data collected by teachers conducting action research on questions of their choosing about their students’ learning” (p. 264). Action research, which is situated in the classroom, could afford me the opportunity to actively explore, through self-inquiry and reflection, my knowledge, beliefs, and attitudes in relation to their teaching practices. A key goal of the current study was for me to learn more about my teaching practices through the lens of the *Framework* and the *NGSS.*

Self-Study Research in Science Education

The research is extensive and rich in self-study and action research. I describe previous studies whose challenges and successes in science-specific self-study helped to inform the current research. For instance, Bullock (2012) in exploring the intersections of self-study, science teaching, and science teacher education discussed:

Science teaching and science teacher education are complex endeavors that demand

> far more than the assumptions underpinning what Schön called technical rationality (1983, p. 21). 'Self-study methodology offers one way to move beyond technical rationality toward a more productive understanding of professional knowledge, one that is inextricably grounded in socially constructed understandings' (p. 1).

Schön (1983) describes "technical rationality" as the model by which professionals conduct their practice. It is a process of problem solving using a series of rational steps to solve the problem. The goal of this self-study is improvement in my STEM teaching practice where I move beyond my technical rationality orientation to a more reflective practitioner orientation.

In addition to the idea that professional knowledge cannot be separated from its socially constructed context, a second consideration of self-study is the cycle of reflection and action in science education. Russell (2012) discussed Schön's (1991) notion of the idea of a "reflective turn" with regard to science education practice: "The reflective turn is … a kind of revolution. It turns on its head the problem of constructing an epistemology of practice. It offers, as a first-order answer to the question, what do practitioners need to know?" (Schön, 1991, p. 5). This knowledge can consist of content, pedagogical, and pedagogical content knowledge (Shulman, 1986). Russell further argued, "Self-study of one's own teacher education practices can be a powerful methodology for making reflective turns with respect to both content and pedagogy" (p. 195). Since teachers need to be able to recognize how and when to use strategies, the act of reflection, cognition, and identification is important in all aspects of education: eliciting student learning and furthering teacher learning. Thus, identifying a reflective turn might be a potential indicator that a self-study is successful in this manner. Additionally, the context of reflective turns might provide insight into how science teachers learn, reflect, and make changes to their practice. Understanding these contextual details may help illuminate structures that aid in professional development sessions and science teacher education.

There are several self-studies that address either pre-service or first year teachers in science education. These self-studies have focused either on the college instructor, the pre-service teacher, or both. Russell and Bullock (2012) offered a range of international contributions to self-study research in science education at the university level, as some universities have elevated self-study research and used it as a tool to transform their teacher education programs. For example, Capobianco's (2007) self-study examined a first-year science teacher educator's integration of technology into a science methods course. Results suggested that inviting pre-service teachers into reflective practice and modeling for them the development of professional practical knowledge allowed them to address the uncertainties in their own learning about using technology for inquiry-based science teaching.

In another study, Garbett (2011) conducted a self-study in the context of teaching a graduate elementary science methods course for pre-service teachers. Garbett described an important theme that emerged from the study, namely "A focus on science content knowledge gave a false sense of confidence and overshadowed our ability to engage in meaningful conversations about learning to teach—a practice challenged through self-study research" (p. 729). This finding mirrors the challenge of adapting to new standards set forth by Darling-Hammond and Ball (1998) and discussed earlier in this chapter. A challenge in incorporating new standards is that current pedagogical practice values facts over conceptual understanding of science. Larson (2011) examined her experiences with implementing an inquiry-based version of a chemistry course designed for elementary education majors. As Larson stated, "My experiences were riddled with frustrations and self-doubts that ultimately led to a more nuanced understanding of constructivism and other specific aspects of inquiry-based teaching" (p. 181). As a result of these findings on self-study that are content-specific, reflection was a significant component of my study design.

There are relatively few science education self-studies at the elementary, middle school, and secondary levels that are situated in the classroom and managed by the classroom teacher. This is not surprising, as self-study research requires an increased time commitment in an environment where there is great competition for teachers' time and attention. Working in a middle school setting, Dias, Eick, and Brantley-Dias (2011) discussed how self-study "shifted the science teacher educator's beliefs away …. from the structuralism espoused in prescribed curricula towards a more culturally responsive, student-driven approach to teaching science to middle grades students" (p. 53). This important finding supports the need for increased self-study at the classroom level. Given the lack of studies situated at the K-12 level, this current self-study of my classroom may add to the knowledge base for K-12 science education self-study research.

Theoretical Framework

Self-Study

A self-study theoretical framework was used to guide the research question, design principles, methods, data collection, and data analysis. Self-study is a personal, systematic inquiry situated within one's own teaching context that requires critical and collaborative reflection in order to generate knowledge, as well as inform the broader educational field (Sell, 2009). Loughran (2009) noted "Self-study emerged in the early 1990s as teacher educators began to take control of their profession by placing greater emphasis on the knowledge and learning derived from researching their own practice" (p. ix). Samaras and

Freese (2006) noted that self-study is key to building teacher self-efficacy which Bandura (1977) defined as “Beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” (p. 3). Furthermore, Samaras and Freese (2009) posited:

> Self-study builds on the personal processes of reflection and inquiry …. Self-study is not done in isolation, but rather requires collaboration…. Self-study research requires openness and vulnerability…. self-study is designed to lead to the reframing and re-conceptualizing of the role of the teacher. (p. 5)

Bullough and Pinnegar (2001) submitted, “while self-study researchers acknowledge the role of the self in the research project … self-study does not focus on the self per se but on the space between self and the practice engaged in” (p. 15). This review of self-study research reveals that researchers used their experiences as a resource with the goal of reframing their knowledge, beliefs, and attitudes about their teaching practice. The roots of self-study are embedded in teacher inquiry, action research, and reflection.

Teacher Inquiry and Action Research

Capobianco and Feldman (2010) stated,

> For more than 50 years action research has been promoted as a way for teachers to engage in inquiry into their educational situations to improve their practice, their students’ learning, and to add to the knowledge base on teaching and learning. (p. 909)

Given this timeframe, the literature on action research is extensive and rich (Altrichter, Feldman, Posch, & Somekh, 2008; Cochran-Smith & Lytle, 1993; Corey, 1953; Zeichner & Noffke, 2001).

Various researchers have found ways to define action research. Pine (2008) described action research as a paradigm and not a method. As a paradigm, action research is a conceptual, social, philosophical, and cultural framework for doing research, that "embraces a variety of research methodologies including case studies, descriptive studies, survey studies, interview studies, observational studies, phenomenological studies, quantitative studies including quasi-experimental designs, and historical research" (p. 67). Cochran-Smith and Lytle (1993) defined action research as "systematic, intentional inquiry by teachers about their own school and classroom work" (p. 7). Anderson, Herr, and Nihlen (2007) articulated the following definition, "In the field of education, the term *action research* connotes 'insider' research done by practitioners using their own site (classroom, institution, school district, community) as the focus of their study" (p. 2). Since I studied my own classroom, my research was situated in authentic practice, local and specific to my school. The systematic and intentional methods of action research ultimately allowed me to be purposeful about the conclusions in my study.

Furthermore, action research can be generalized and summarized as a cyclic process of planning, acting, collecting, and reflecting (Figure 2-1). Pine (2008) described action research as a recursive process: "The data, the generalizations, and even the research questions are reviewed, reconsidered, and revised along with other new and emerging data to develop tentative findings and conclusions" (p. 72).

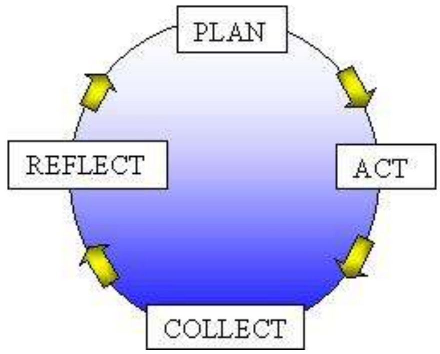

Figure 2-1. The action research cycle (Hingely, 2012)

The action research spiral, which is depicted in Figure 2-2 consists of multiple action research cycles. These cycles are repeated in sequence as the study progresses, creating an upward spiral of improving practice. Pine (2008) further elaborated on the most significant aspect of action research, which is that theory informs practice, and practice refines theory. Both of these processes act in a continuous transformation.

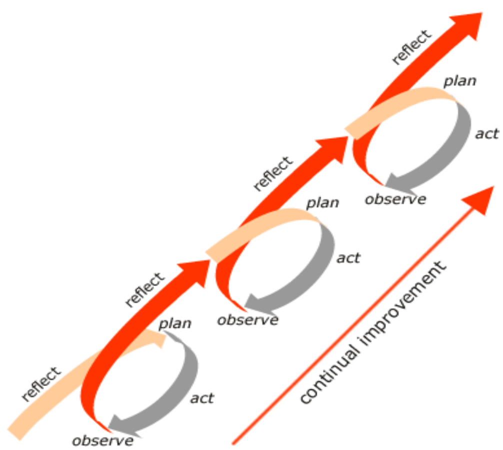

Figure 2-2. The action research recursive spiral (Hingely, 2012)

Teacher Reflection

The process of action research provides a structured, disciplined approach to reflecting about the teaching and learning process. It is a form of PD that encourages and develops the research skills of teachers and asks them to become more reflective practitioners. Reflection is an integral step and a recursive process necessary for changes in knowledge, beliefs, and attitudes.

Dewey (1933) posited that the purpose of reflection is "to transform a situation in which there is experienced obscurity, doubt, conflict, disturbance of some sort, into a situation that is clear, coherent, settled, and harmonious" (pp. 100-101). Pine (2008) suggested "that through the process of reflection, teachers' personal theories [regarding how they pedagogically behave in their classrooms] can be brought to the surface, examined, and questioned in terms of how they affect teaching practice" (p. 182). Sagor (2000) explained "when reflections on the findings from each day's work inform the next day's instruction, teachers can't help develop greater mastery of the art and science of teaching" (p. 7). Danielson and McGreal (2000) argued that reflection on practice is a powerful professional learning activity. Pine refers to the "process" of reflection and Sagor posited that reflections "inform" the next day's instruction. It is clear that reflective thought is integral to not only successful action research, but also successful teaching practice.

Schön's (1987) seminal work conceptualized reflection in the two ways where teachers reflect on their practice: reflection *in* action and reflection *on* action. Reflection *in* action refers to "reflection on one's spontaneous ways of thinking and acting, undertaken in the midst of action to guide further action" (p. 22). The author described this reflection *in* action as thinking about what one is doing while one is doing it. What characterizes this type of reflection is that it arises spontaneously from an ongoing activity. Pine (2008) described that reflection *on* action involves "taking time to consider any number of questions after the action in the classroom has been completed" (p.180). This type of reflection helps us gain a deeper understanding of what we already know. In addition to Schöns' (1987) conceptualization of reflection, there are several models of reflection (e.g. Killion & Todnem, 1991; Rearick & Feldman, 1999). For example, Valli (1997) described five different kinds of reflection that I chose to use for this study: (1) Technical *reflection* which focuses on general instruction and management behaviors that are based on research on teaching, (2) *Reflection in and on action* which focuses on the teacher's personal teaching performance, (3) *Deliberate reflection* which focuses on a whole range of teaching concerns, including students, the curriculum, instructional strategies, the rules and organization of the classroom, (4) *Personalistic reflection* which focuses on one's own personal growth and relationships with students, and (5) *Critical reflection* which focuses on social, moral, and political dimensions of schooling. Based on the literature discussed, reflection is a critical element of action research.

Connecting Reflection, Action Research, and Self-Study

This study's goal of improving my teaching practice was viewed through the lens of the *Framework* and the *NGSS*. In learning to teach to new standards, Darling-Hammond and Ball (1998) posited that "opportunities for analysis and reflection are central to learning to teach…. all learners benefit from self-monitoring and reflection on their own learning and the application of new knowledge to their practice" (p. 16). Given this research, how are reflection, action research, and self-study related? Capobianco (2007) contended, "In science teacher education, self-study practices are most commonly employed through teacher action research, whereby action research is used as a vehicle for prospective science teachers to engage in reflective practice" (p. 272). Feldman, Paugh, and Mills (2004) argued, "Action research has also had a strong influence on self-study research and has been referred to as a 'useful tool for self-study' because it provides a method to conduct systematic inquiry into one's teaching practices" (p. 970).

Theoretical Underpinnings for This Self-Study Framework

This section discusses the theoretical underpinnings for this self-study framework for the investigation of my teaching practice.

Constructivism and Social Constructivism

Constructivism refers to the notion that people actively construct or create their own knowledge based on their experiences (Driver et al., 1994). The implication of this theory for learning is that there is a need to focus on the learner who constructs knowledge as they learn. Teachers must take into account the learners' prior knowledge, engage learners in their own learning, and ensure adequate time for learners to reflect on their learning experiences. Social constructivism broadens constructivism by emphasizing the importance of other learners and the surrounding culture in creating knowledge and thus learning. Hence learners in a school setting engage in a social process of constructing new meaning based on their preexisting knowledge and experiences. The learners are connected to that social setting in ways that formulate their identity (Wenger, 1998a, 1998b). Ideas from social constructivism are necessary for understanding K-12 education, pre-service teacher education, and in-service teacher professional development.

Situated Cognition

Putnam and Borko (1997) argued that teacher education must be situated in classroom practice. Situated cognition theory posits that learning is a function of the activity, context, and culture in which it occurs. This contrasts with most classroom learning activities which involve knowledge that is abstract and out of context. According to Brown, Collins, and

Duguid (1989), "knowledge is not independent, but rather fundamentally 'situated' being in part a product of the activity, context, and culture in which it is developed" (p. 18). Not only are concepts situated by the activity in which they are experienced, they are also individually developed and constructed by, and with, those who engage in these experiences. Any given situation becomes a different meaningful experience for different individuals because of their past experiences and resulting beliefs and values.

Situated cognition relies heavily on the idea of cognitive apprenticeship. Here students, who are acting as apprentices, are enculturated into a social community (its practices and its culture) as they learn to use tools as novice practitioners within that community. Given the idea that learning is socially situated, Lave and Wenger (1991) proposed the notion of "legitimate peripheral participation" in which newcomers become part of a community of practice. Wenger (1998a, 1998b) made the argument that "communities of practice" (COP) are formed by people who engage in a process of collective learning in a shared domain of human endeavor. In terms of these endeavors in K-12 settings, situated theory guides inquiry in teachers' own classrooms and in the overall school setting.

Conceptual Change Theory

Conceptual change theory offers some additional insights into learning. It has been established that adopting new science standards requires changes in the ways teachers currently teach and the ways students currently learn. The conceptual change theory helps describe how changes occur within learners (both K-12 student as learner and K-12 teacher as learner). According to Piaget (1964), intellectual growth arises from a conflict between incoming information and what already exists in an individual's conceptual framework. Resolution of this disequilibrium results in a modification of existing knowledge thereby leading to learning (Piaget, 1978). Appleton (2007) argued for pedagogical approaches informed by a conceptual change model that employs cognitive conflict, sharing and justifying of ideas through discourse, using models and analogies, and scaffolding a series of learning experiences. Appleton further argued that use of the conceptual change model resulted in changes in beliefs and attitudes about teaching practice.

Efficacy

Efficacy can be defined as the "affirmation of a capability level as well as the strength of a belief that the teachers hold about their individual and collective capability to influence learning" (Klassen et al., 2011). The theoretical basis for efficacy is grounded in social cognitive theory and was developed by Bandura (1977) who defined self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Bandura (1986) pointed out "people regulate their level and distribution of effort in accordance with the effects they expect their actions to have. As a result, their behavior is better predicted from their beliefs than from the actual consequences of their actions" (p. 129). Finally, Nadelson, Moll, and Seifert (2011) conducted a study of elementary and middle school teachers aimed at developing their capacity to teach STEM using materials science, inquiry, and engineering design. The study's findings indicated significant increases in teachers' comfort levels for teaching STEM, inquiry implementation, and their efficacy for teaching STEM.

Ethic of Care Theory

Ethic of care theory, as it relates to education, aids in understanding the importance of building relationships in educational settings: relationships between teachers and students, teachers and teachers, teachers and administrators, teachers and parents, teachers and the community, etc. Bingham and Sidorkin (2004) discuss how relationship building is a central construct of teaching. In a study examining two experienced teachers' transformations as they implemented a writer's workshop curriculum with multi-lingual third grade students, the authors reported, "The shift to a renewed professional identity encouraged the teachers to assume an advocacy stance for their own professional lives and for the children they teach" (Flint, Zisook, & Fisher, 2011, p. 1168). This finding reveals that authentic growth and learning for all result when "the thoughts, beliefs and questions of each are valued and drive learning endeavors; and where more individuals relate in active care, jointly investing and participating" (p. 1168).

Noddings (2005a) identifies four components of care: modeling, dialogue, practice, and confirmation. Teachers need to demonstrate that they care for their students and model that caring through dialogue and practice. Confirmation is an act of affirming and encouraging and bringing out the best in others. Actively promoting and creating a caring learning environment is a key to facilitating student learning and an integral design element of the current self-study. I sought to help my students find their own voice for STEM and take ownership of their STEM learning. An ethic of care underpinned this endeavor.

Trustworthiness and Validity in Self-Study Research

A special interest group (SIG) of the American Educational Research Association (AERA) entitled "Self-Study of Teacher Education Practices (S-STEP)" was established in 1994 to represent the growth in self-study at that time. Since then, both the SIG and the self-study movement have continued to grow. However, despite its growth, development, and refinement, there is considerable concern about the validity of self-study research (Pine, 2008).

Self-study researchers offer various principles and recommendations to address trustworthiness and validity concerns. These concerns are based on issues, including but not limited to, the underreporting of data and/or the exaggeration of claims made. Bullough and Pinnegar (2001), drawing on "recognized literary traditions that are used to discuss what makes for an effective narrative" (p. 16), articulated a set of fourteen guidelines (see Appendix D) for establishing quality in self-study research scholarship. Herr and Anderson (2005) offered a set of five validity criteria (see Appendix E) that are linked to the goals of action research based dissertations. In addition, Feldman (2003) provided recommendations on self-study (see Appendix F). Based on this literature, these guidelines, criteria, and recommendations allow researchers to maintain the academic integrity of their findings. As I proceeded through my study, I consulted these composite criteria to address study trustworthiness and validity. I describe their usage more specifically in Chapter 3 on Methods.

Design-Based Research (DBR) Strategy

Given its cyclical and iterative nature, design-based research (DBR) offers methods that are complementary to action research. Cobb, Confrey, diSessa, Lehrer, and Schauble (2003) described successful iterations of interventions within naturalistic settings such as schools and classrooms. Furthermore, the authors noted that "the designed context is subject to test and revision and the successive iterations that result play a role similar to that of systematic variations in experiment" (p. 9). Wang and Hannafin (2005) described DBR as "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" (pp. 6-7). Given the complex learning environment of my classroom, DBR linked with action research was well suited for this context.

Although there is little research on self-study methodology using design-based methods, Aubusson, Griffin, and Steele (2010) utilized design methods in a self-study to examine pre-service teachers reflective practices. The findings revealed that the use of "contextual anchors" contributed to these students becoming reflective and exhibiting increasing levels of reflection. These "contextual anchors" were grounded in specific science teaching strategies that were utilized in real classroom settings by pre-service teachers. Furthermore, Aubusson et al. (2010) concluded in their self-study using DBR methods:

> The intervention is not an independent entity applied but a function of the teacher and students' interplay with it. This is broadly consistent with design-based interventions that are not frozen, applied and evaluated. Rather, they are required to respond to evidence about the process as it arises. (pp. 204-205)

Aubusson et al. (2010) findings inform this study's use of *best practices* as "contextual anchors" and the use of reflection in my teaching practice.

Chapter 2 Summary

Chapter 2 reviewed the literature to explain the self-study framework that guided the design of this study. K-12 STEM education literature was examined from the standpoint of STEM integration (a key element of the *Framework*) and modeling (an essential science and engineering practice). A brief historical research perspective on previous *NSES* and *Benchmarks* implementations was investigated to gain insight into lessons learned such as providing ongoing teacher support and designing curricula, instructional, and assessment materials that are better linked to standards. The literature on teacher PD related teacher learning to changes in their knowledge, beliefs, and attitudes. How teacher PD can focus on the teacher as a reflective practitioner in the context of action research was explored. Examples of self-studies in science education were reviewed. The self-study theoretical framework was discussed in terms of its roots in teacher inquiry, action research, and reflection. A examination of the action research process was undertaken. Various models for reflection were considered. Conceptual underpinnings for this self-study were explored. Findings from research on constructivism and social constructivism, situated cognition, conceptual change, efficacy, and ethic of care were considered. Criteria to assess the trustworthiness and validity of this self-study were investigated. Design based research (DBR) was reviewed in the context of the self-study framework. This review revealed that, given its cyclical and iterative nature, DBR provides this study with methods that are complementary to self-study.

Chapter 3 offers a discussion of the study methodology based on the goals and objectives of the study identified in Chapter 1 and the findings from the literature review in Chapter 2. Study setting, participants, contextual factors, and a timeline are described. Data sources and data measures are detailed along with an explanation of how the data was collected and analyzed. Study validity, reliability, and rigor are discussed. Ethical considerations are addressed. Study assumptions, limitations, and challenges are explored.

CHAPTER 3

METHODS

Overview

The study design was structured in three phases, namely Phase One, Phase Two, and Phase Three. In Phase One, I designed unit plans for my classes which consisted of two class sections of chemistry (Case 1 and Case 2), two class sections of statistics (Case 3 and Case 4), and one class section of engineering (Case 5). This "unit planning" took approximately one week to complete. "Unit enactment" and "unit reflection" took approximately four weeks. Thus, a study phase consisted of approximately five weeks in which a unit was designed, enacted, and reflected upon. Lessons learned from Phase One were used to inform the next phase (Phase Two) of the study. In Phase Two, I designed unit plans for my classes, which consisted of two class sections of statistics (Case 3 and Case 4). Lessons learned from Phase Two were applied to the next phase (Phase Three) of the study. In Phase Three, I designed a unit plan for my statistics (Case 3) class. Findings from Phase Three informed the study's overall results. The timeline for the entire study was approximately fifteen weeks.

In this chapter, the study's research questions are posited and followed by a description of the study methodology. Study setting, participants, context, and timeline are described. Data sources and data measures are identified along with a description of how the data was collected and analyzed. Study validity, reliability, and rigor are considered and ethical considerations are addressed. The chapter concludes with an examination of study assumptions, challenges, and limitations.

Research Questions

The research question posited for Phase One of this study was: What happened in my chemistry, statistics, and engineering classes when I employed a self-study framework using a design-based research (DBR) strategy to design, enact, and reflect on units of study that promoted the *Framework's* disciplinary core ideas, science and engineering practices, and crosscutting concepts? The use of the DBR strategy promoted reflective cycles, which resulted in three study phases. As the study progressed through its phases, refinements were made to the research question in the subsequent remaining two phases of this self-study. These refinements were based on findings from each study phase. More specifically, for Phase Two the research question was refined as: To what extent am I using "wait time", building conversations with my students, and incorporating modeling instruction in my statistics classes while I design, enact, and reflect on unit plans through the lens of the *NGSS.* Furthermore, for Phase Three the research question was further focused as: To what extent am I improving building conversations with my students and incorporating modeling instruction in my statistics class while I design, enact, and reflect on unit plans through the lens of the *NGSS.*

Methodological Description

This study employed a self-study framework that utilized design-based research (DBR) methods. LaBoskey (2004) posited that self-study might use existing methods in new ways, but that it is essential for the methods to be consistent with the goals and ontogeny of self-study. The overall goal of this self-study was self-improvement. Furthermore, Samaras and Freese (2006) noted that self-study is key to building teacher self-efficacy. Thus, the self-study framework provided the foundation for me to examine my teaching practice.

Design-based research (DBR) comprises successful iterations of interventions within naturalistic settings such as schools and classrooms (Cobb et al., 2003). Additionally, the authors noted that "the designed context is subject to test and revision and the successive iterations that result play a role similar to that of systematic variations in experiment" (p. 9). The DBR strategy was chosen to promote reflective cycles, which are consistent with and in support of the self-study framework and the action research process. Feedback from one cycle was used to inform the design of the next cycle.

A multiple case, mixed-methods approach was used for data collection and analysis. The rationale for using mixed methods was based on the following definition of mixed methods:

> Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the purpose of breadth and depth of understanding and corroboration. (Johnson, Onwuegbuzie, & Turner, 2007. p. 123)

This study used a convergent parallel mixed methods design (see Figure 3-1).

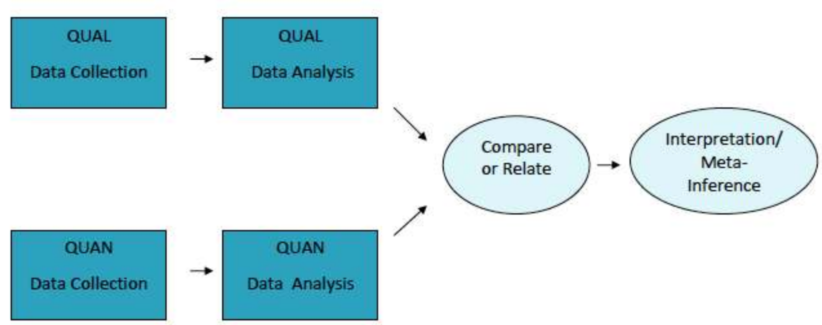

Figure 3-1. Study Use of Mixed Methods Convergent Parallel Design

The quantitative (QUAN) and qualitative (QUAL) strands were conducted separately in each study phase yet concurrently and merged during data analysis. This approach was used either to form a more complete understanding of the topic under study or for validation or corroboration. For example, in Phase Two, the Reformed Teaching Observation Protocol (RTOP) quantitative scores from Jim, a critical friend, were compared with the *discourse* and *modeling* qualitative self-report data. This comparison aided in mutually corroborating the critical friend RTOP data and self-report data. Given the iterative DBR nature of the study design, I chose the mixed methods approach from an emergent perspective. Creswell and Plano-Clark (2011) stated, “Emergent mixed methods designs are found in mixed methods studies where the use of mixed methods arises due to issues that develop during the process of conducting the research” (p. 53). Additionally, Creswell and Plano-Clark further posited:

> Bryman (2006) noted that many mixed methods studies make use of multiple reasons for mixing methods and that new reasons for mixing may emerge as the study is underway. Being responsive to new insights is an essential aspect of conducting mixed methods research, but we feel is it also important for researchers to design their mixed methods studies with at least one clear reason as to why they are planning to combine methods (p. 61)

Reasons for combining methods were based on Bryman’s (2006) framework. These reasons include: triangulation or greater validity, offset, completeness, process, unexpected results, credibility, and context. Appendix G provides a description from Bryman (2006) on definitions of these reasons.

Finally, Yin (2008) defined a case study in terms of the research process. “A case study is an empirical inquiry that investigates a contemporary phenomenon within its real life context" (p.18). Merriam (2009) stated, "The unit of analysis, not the topic of the investigation, characterizes a case study" (p. 41). In describing case studies, Creswell (2007) and Merriam described how multiple cases show different perspectives, greater variation, and more compelling interpretations. My chemistry, statistics, and engineering classes were the unit of analysis. I chose multiple cases as a strategy to enhance the external validity of my findings.

Study Design Principles

The study design was based on two design principles, which were guided by the self-study theoretical framework discussed, findings from previous research studies, and the research question being posed. These principles were: (1) I used my own classroom as an authentic setting, and (2) I was an active participant in my self-study operating as a reflective teacher practitioner.

Study Setting and Participants

The research was conducted at a public secondary high school located in a suburban township in the Northeastern United States. The school district consisted of seventeen elementary, middle, and high schools. The high school has approximately fifteen hundred students in attendance. School data from the 2011-2012 school year (National Center of Educational Statistics, 2012) is provided in Appendix H.

The participants in this study consisted of myself as the researcher, students in my chemistry, statistics, and engineering classes, three high school teachers from the same school acting as critical friends (Bambino, 2002), and a district administrator. Each of these study participants is described in further detail below.

Chemistry Classes

The two sections of chemistry classes in the study consisted of students who previously had significant absenteeism from the high school as a result of previous drug abuse. In several instances, these students came from dysfunctional families and had difficult home environments. The students found it difficult to trust others and even their own actions. Not surprisingly, they experienced problems with the academic work and social conflict issues with the overall school community. These students were enrolled in a district program (hereinafter referred to as *Stevenson Academy*) that offered them an opportunity to recover graduation credits through an alternative setting in the high school. I had previously taught Chemistry in *Stevenson Academy* during the 2009/2010 academic school year. Class schedules were arranged so as not to overlap with regular high school classes in order to limit interaction and conflict with regular high school programming. For *Stevenson*, classes would begin two hours later than regular high school and finish one hour prior to regular high school dismissal. Each chemistry class section typically met each day for a period of forty minutes. The class was a required course for graduation. Students had no choice as they had to take this class. Instructional methods included team teaching (with a mathematics teacher from the program), differentiated instruction, and thematic and interdisciplinary instruction. The purpose of this class was for students to gain an understanding of basic chemistry concepts including atomic structure, the nature of matter, chemical periodicity, chemical bonding, solids, liquids, gases, and elements through a series of discussions, demonstrations, and hands-on projects. Section one consisted of six students of which four were male and two were female. One male student and one female student were classified as special education. The class had grade level/age diversity with three juniors (all seventeen years old) and three seniors (two age seventeen and one age eighteen). All students in section one were White. Section two consisted of eight students of which six were male and two were female. There were no students classified as special education. In section two all eight students were juniors (all seventeen years old). All students in section two were White.

Statistics Classes

Two sections of statistics classes were used in this study. I had not taught statistics previously. Statistics is a required course for graduation. Students had no choice as they had to take this class. The purpose of this class was for students to gain an understanding of statistical concepts and methods including data collection techniques, data distributions, hypothesis testing, correlation, and regression analysis. Classes typically met every other day for a period of eighty minutes. Section one consisted of twenty-seven students of which ten were male and seventeen were female. One male student and two female students were classified as special education. Section one had grade level/age diversity with one junior (age seventeen) and twenty-six seniors (nineteen age seventeen and seven age eighteen). All students in section one were White. Section two consisted of twenty-seven students of which thirteen were male and fourteen were female. One male student and three female students were classified as special education. Section two had grade level/age diversity with twenty-seven students who were seniors (twenty-one age seventeen and six age eighteen). All students in section two were White.

Engineering Class

One engineering class was included in this study. I had previously taught engineering from 2006 through 2010. Engineering was an elective course; students had self-selected the class and were highly motivated to participate. The purpose of this class was for students to explore the conceptual foundations of engineering design by means of a hands-on, project-based approach. Class typically met every other day for a period of eighty minutes. The class consisted of twenty-four students of which twenty-two were male and two were female. One male student was classified as special education. The class had grade level/age diversity with five freshman (all age fifteen), four sophomores, (all age sixteen), eleven juniors (all age seventeen), and four seniors (three age seventeen and one age eighteen). All students were White.

Critical Friends

In 2009, my school district conducted a professional development session with the intention of promoting the notion of Critical Friends Groups (CFG) as a catalyst for school change (Annenberg Institute for School Reform, 1998). I learned from that training that a critical friend is someone who encourages and supports me to improve my teaching practice by providing honest and candid feedback. Samaras and Freese (2006) noted that in self-study practitioner research critical friends can provide both encouragement and critical analysis of the data collected. Thus, critical friends may be able to provide other viewpoints and interpretations of the data. Bambino (2002) posited, “By providing structures for effective feedback and strong support, Critical Friends Groups help teachers improve instruction and student learning” (p. 25). All three critical friends were teachers in the same high school as myself during the study. One teacher critical friend, John, was a PhD level instructor who taught advanced placement (AP) chemistry and honors level chemistry for the last fifteen years and who also was an adjunct instructor in chemistry at a local university. At the time of the study, he had been teaching in the district for four years. John and I both had Physics backgrounds and from the time of our meeting four years ago we instantly connected with each other and met over that timeframe frequently to discuss various science education matters. A second teacher critical friend, Jim, was a mathematics teacher with ten years of teaching experience in the district in AP statistics, computer science, and engineering. Like myself, Jim entered teaching via the alternate route teacher certification program. Jim and I also worked at and retired from the same engineering firm prior to teaching. We collaborated on various STEM initiatives in the high school including the design of the engineering curriculum. A third teacher critical friend, Mary was a mathematics teacher with over twenty years of teaching experience in the district. Mary served as my formal mentor during my first three years of teaching in the district. Throughout my tenure in the high school, she had been a supportive and trusted advisor.

District Study Administrator

An administrator (hereinafter referred to as the study administrator) was assigned to me by the district to support me for any study-related matters. The study administrator, Peter, was an assistant principal in the high school during the 2012-2013 academic year. One of Peter's responsibilities was the management of the aforementioned district program *Stevenson Academy.* I did not know Peter previously as he served as a principal in one of the elementary schools in the district. Peter had been an educator for the past thirty years. He taught at and was an administrator in various elementary, middle, and high schools during his career.

Study Setting Contextual Factors

I define the phrase "contextual factors" broadly in terms of the interrelatedness and interdependence of all facets of the study design and enactment. Three noteworthy contextual factors had an impact on this study and included: (1) the arrival and aftermath of Hurricane Sandy, (2) implementation of a block scheduling format, and (3) the piloting of a new teacher evaluation system. These factors were not the focus on this study. However, it is important to identify them and recognize their influence.

Hurricane Sandy

As identified in the Institutional Review Board (IRB) submission to the Office of Sponsored Programs to Teachers College, Columbia University of October 12, 2012 for this dissertation study (Institutional Review Board, 2012), the study timeline was tentatively planned for November 1st, 2012 through February 2013. IRB approval was expected by the end of the October 2012. On October 29, 2012, the weekend prior to beginning the planned study, Hurricane Sandy made its expected path for the coast of the Northeastern United States. IRB approval for the study was delayed until December 4, 2012 given Sandy's impact on Teachers College. Sandy had a devastating impact on the community in which the school was situated. The storm caused significant property damage resulting in a number of people being displaced from their homes.

All district schools were closed for a period of two weeks in which both community and school-related recovery efforts were underway. When schools reopened, a recovery plan was communicated to all school personnel by school administration that resulted in significant changes to the schools' academic calendar. The devastating effects of the storm required significant recovery time. I was directed by my study administrator to delay the study for at least three months and focus my efforts on the school's recovery plan. This action resulted in readjusting the study to begin in the middle of March 2013.

Converting to a Block Schedule Format

Throughout my K-12 teaching career, I have been accustomed to a daily 45-minute instructional period. For the 2012-2013 academic year, the high school converted to a block-scheduling format. With block scheduling, there was an 80-minute instructional period every other day. Queen (2000) argued that block scheduling is quite challenging for teachers. Most teachers have concerns such as the additional planning time required, the instructional strategies necessary, and the lack of adequate support and training. To address these concerns, Queen listed various teaching skills for success in a block class including thoughtful planning, implementation, evaluation and the ability to use several instructional strategies effectively. These instructional strategies include, but are not limited to, cooperative learning, case method, Socratic seminar, use of analogy, modeling and simulations, and the inquiry method. Many of these *best practices* instructional strategies align with the strategies that I identified in my literature review in Chapter 2 and used in this study. However, the change to block scheduling invoked concern and anxiety in the school community. Many teachers including myself expressed the need for more time to plan for their classes. For example, John, the chemistry critical friend was frustrated, angry, and overwhelmed. The conversion to the block schedule format had eliminated the weekly forty-eight minute "lab" period for all science classes. Laboratory time now had to be integrated with regular block schedule meeting time. John had to re-plan his instruction while covering the same chemistry curriculum with less instructional face time.

A New Teacher Evaluation System

A new teacher evaluation system (Danielson, 2013) was introduced to the high school community at the beginning of the school year in September 2012. Over the subsequent months, the district scheduled a number of information sessions organized as "teacher professional development" with the intention of orienting the teaching staff with the evaluation system. The evaluation consists of results from teacher observations as well as students attaining "growth" objectives based on standardized test achievement. Mary, the critical friend mathematics teacher, indicated that the metrics being used in the evaluation system would drive behaviors that promote a "teaching to the test" mindset. Several teacher colleagues wondered whether this evaluation system would provide honest and helpful feedback that could help them improve their teaching. Moreover, teachers were skeptical that they would get the appropriate training and support. Others argued that this new system would produce nothing but more paperwork. Finally, some teachers questioned how much the new teacher evaluation system would raise student achievement.

Impact of Study Setting Contextual Factors

The impact of Hurricane Sandy, the change to the block schedule, and the piloting of a new teacher evaluation system all came at a time when the school began their adjustment to the Common Core State Standards. These factors resulted in both teachers and administrators feeling overwhelmed with regard to how they would allocate their time given the degree of change. Moreover, these factors were present reminders throughout the academic year of the school community's increased feelings of anxiety. This climate influenced the nature of teacher conversations and resulted in reduced opportunities for both the critical friends and the study administrator to participate in this study.

Study Timeline

The study timeline occurred from mid-March 2013 through end of June 2013 and was designed in three phases. I began Phase One in mid-March 2013 by designing unit plans based on the *LfU* and *UbD* models, *talk moves, the questioning cycle,* and *modeling instruction* through the lens of my district's curricula and the *NGSS*. Specifically, one unit plan was designed for each subject (i.e. chemistry, statistics, and engineering). Given that there were three subjects i.e. chemistry, statistics, and engineering) for the study a total of three units (one unit for each subject) was ready for review by mid-March 2013. The designed unit plans were reviewed with critical friends and the study administrator to obtain their feedback prior to implementation.

The study design was structured in three phases. The first phase (Phase One) was devoted to ”unit planning” and took approximately one week to complete. “Unit enactment” and “unit reflection” took approximately four weeks. Thus, each study phase consisted of approximately five weeks in which a unit was designed, enacted, and reflected/analyzed upon. Data analysis in a previous phase was used to inform the design of the subsequent phase. Phase Two essentially followed the same process as in Phase One. Results from data analysis from Phase Two were applied to the next phase (Phase Three) of the study. Phase Three followed the same process as Phase Two. Results from data analysis from Phase Three informed the study’s overall results. The timeline for the entire study was approximately fifteen weeks.

Case Study Description

Merriam (2009) posited that the case study is an in-depth examination of a setting. Stake (2008) argued that case studies focus on an “individual unit” and what he calls a “functioning specific” or “bounded system” (pp. 119-120). Merriam concluded, “the single most defining characteristic of case study research lies in delimiting the object of study” (p. 40). Moreover, Merriam stated, “The unit of analysis, not the topic of investigation, characterizes a case study” (p. 41). The unit of analysis is the real object or unit in the real world context that is observed. For this study, my five classes were the unit of analysis.

Table 3.1 summarizes the description for each of the five cases considered.

Table 3.1. Case Study Descriptors

Case ID	Case 1	Case 2	Case 3	Case 4	Case 5
Grade	11,12	11	11,12	12	9,10,11,12
Subject	Chem (1)	Chem (2)	Stats (1)	Stats (2)	Engineering
Phase One Units	Periodic Table	Periodic Table	Hypothesis Testing	Hypothesis Testing	Electricity
Phase Two Units	Matter	Matter	Correlation	Correlation	Robotics 1
Phase Three Units	Bonding	Bonding	Regression	Regression	Robotics 2
Students	6	8	27	27	24
Gender	4M, 2F	6M, 2F	10M, 17F	13M, 14F	22M, 2F
Special Education	2	0	3	4	1

Data Sources and Measures

The principal data collection mechanism for this study was my electronic journal or e-journal. I used Garbett's (2011) self-study experience with an e-journal as a model. For example, Garbett explained the purpose and use of the e-journal for self-study:

> This professional-personal e-journal was a diary of practice and experience. Using the guidelines outlined by Holly (1989) and Bolton (2005), I recorded my impressions and descriptions of events, circumstances, experiences, discussions and reflections…. Writing in my e-journal was an opportunity … to enrich and expand this data set as I analyzed and reconstructed … in my teaching sessions, my conversations and

interviews with students and colleagues and my responses to them. (p. 34)

I structured the e-journal based on the data sources I collected. I created folders for each study phase, namely Phase One, Phase Two, and Phase Three. I organized each study phase folder by case (i.e. one for each class). Each case folder included folders for each data source. What follows is a description of each data source I collected.

Unit Plan Design

A unit plan is essentially a series of lesson plans designed around a specific topic or theme. I used my districts' curriculum guides (New Jersey Core Curriculum Content Standards (NJCCS) based), the *NGSS,* and the *best practices* models (*LfU, UbD, modeling instruction,* and the *questioning cycle*) to design unit plans for all cases in this study. I examined all four subject-related district curriculum guides in terms of *UbD's* process of "identifying desired results". These outcomes were structured in terms of the curriculum guide's standards-based objectives. I correlated and linked these objectives to those listed in the *NGSS* in terms of the three dimensions of the *Framework*: disciplinary core ideas, science and engineering practices, and cross-cutting concepts. For example, in an engineering unit plan on electricity (see Appendix I), I linked the district's objective of applying principles of electricity to systems design to the *NGSS* on waves and their application in information transfer. I implemented the *UbD* process of developing enduring understandings and essential questions for the unit topic. Consideration of these essential questions guided my understanding of what students need to know and what students are expected to do. The *LfU* model was utilized to evaluate common student misconceptions. Lesson activities were subsequently designed based on those student misunderstandings. For example, in the chemistry unit plan on the periodic table (see Appendix I), a common misconception by students is that science and its methods provide absolute truth rather than being tentative and evolving. To elicit curiosity in students, various historical models of the atom were constructed and discussed. The targeted knowledge and skills that students needed to know were subsequently used to "determine acceptable evidence". Discourse strategies (*talk moves and the questioning cycle*) as well as *modeling instruction* methods were designed into the lesson activities. For example, in the statistics unit plan on regression, students were asked to generate, evaluate, and modify mathematical models based on their analysis of data. All unit plans designed were stored in the e-journal (see Appendices I, J, and K). I also recorded my reflections in the e-journal while both designing the unit plans and after the unit plans were all completed. The following comments are illustrative of the reflections I included in the e-journal during the unit design process.

> "The *UbD* and *LfU* processes are very similar to the front-end process of engineering design that I am familiar with as a former design engineer".
>
> "Standards are key instructional design requirements".
>
> " The focus of the design of the instruction should be on students: their needs, misconceptions, their improvement, their involvement".

Meetings with Critical Friends

The purpose of meeting with critical friends was to provide me with feedback and support as the study progressed. The meetings were initially planned to occur once in each of the study's three phases and last approximately thirty minutes in duration. The agenda for these meetings was to discuss and review feedback on two key items: unit design for the first and subsequent phases of the study and unit implementation during each phase of the study. Given the study setting's contextual factors previously discussed in this chapter which impacted critical friend availability, one meeting with each critical friend was conducted in Phase One and one meeting in Phase Two of the study and both meetings were limited in duration to fifteen minutes each. No other meetings with critical friends took place during the study. I recorded my reflections of these meetings in my e-journal. Some examples of my personal reflections included:

> "Deeply concerned regarding the level of participation of John, Jim, Mary, and Peter in my study. I feel like I have no sounding boards."
>
> "I am not angry with them for their lack of feedback. I understand that they don't have the time to do this. This is what they have told me. Though, I wonder whether there is more to this than just lack of time.

Unit Enactment - Observations

Given the availability of both critical friends and the study administrator, there were no observations of classroom enactments either during Phase One or Phase Three of the study. Availability for critical friends was also impacted by class schedule conflicts. Furthermore, district policymakers wanted to ensure maximum instructional face time by their classroom teachers for their classes. For example, field trips were not encouraged and teacher absences were closely monitored. Getting regular school substitutes for class observations was not supported. Despite these difficulties, I proposed to Peter, the study administrator, to obtain coverage for classes for critical friends from other members of their departments who did not have schedule conflicts. I consulted with all critical friends in Phase One to determine their willingness for me to obtain coverage for their classes so that they could observe me in Phase Two of the study. All critical friends supported my coverage initiative. I supplied multiple dates to all critical friends regarding when instruction was occurring in my classes during

Phase Two that I would like them observe. Based on their feedback of acceptable dates to them, I was able to schedule the coverage with their colleagues and thus the class observations. I was successful in getting satisfactory class coverage for all but John, the chemistry critical friend. John, as well as all science teachers, were struggling given of the loss of the science lab period. Jim, the AP statistics critical friend, observed one statistics class (Case 3) during Phase Two. Peter, the study administrator, observed one chemistry class (Case 1) and one statistics class (Case 4) during Phase Two. One week in advance of the lesson enactment, I provided Jim with the following assessment tools for the purpose of providing feedback to me:

- The Reformed Teaching Observation Protocol (RTOP) (Sawada et al., 2002) an associated STEM rubric (Dayton Regional STEM Center, 2011). The RTOP with STEM rubric provides a quantitative assessment of STEM constructivist teaching (See Appendix L).
- A checklist to assess the use of *talk moves* in a class period (see Appendix B). Values were assigned from 0 (no observation of activity), 1 (seldom activity observed 1-2 times), 2 (moderate activity observed 3-5 times) or 3 (frequent activity observed greater than 5 times).
- The GEM Rubric (See Appendix C) assigns a value from 0 (no observation of activity), 1 (seldom activity observed 1-2 times), 2 (moderate activity observed 3-5) or 3 (frequent activity observed greater than 5 times).
- A questioning checklist (see Appendix M) adapted from Fusco (2012) to assess the use of the *questioning cycle*. The checklist was adapted to include a multiple-item, 5-point Likert scale along with percentage definitions for frequency.

Classroom observation feedback from Jim was provided in electronic format (see Appendix N). The feedback was electronically scanned and stored in my e-journal. I had subsequent discussions at brief (approximately fifteen minutes) meetings separately with Jim and Peter. Examples of the reflective entries in my e-journal for those meetings included:

> "I am disappointed that the measures I provided to Jim were not used by them. Jim used the RTOP only".
>
> "Feedback from Jim was meaningful by listing strengths and areas of improvement".

Unit Reflection Self-Assessment

During the study, I video recorded seven classroom enactments. I limited the total number of video recorded enactments to seven given the significant time involved in the collection and analysis of this video data. A continuing study challenge previously discussed was the increased time commitment for this study in a school climate where time was precious and limited. I was experiencing anxiety and feelings of being overwhelmed given the effects of Hurricane Sandy, the block scheduling format, new teacher evaluation system, and the study. I had to make choices that I believed would still preserve the integrity of the study yet not compromise my role as a teacher.

All video recordings were stored in my e-journal. Chemistry classes (Case 1 and Case 2) expressed that they did not want to be video recorded. I had suggested doing an audio recording as an alternative. They did not want to be audio-recorded. This was not surprising to me as these students, as previously discussed, had difficulties with trusting others. Despite my assurances that the purpose of the video or audio was only for me to evaluate, my students were suspicious and deeply concerned. They imagined that these recordings would be used by other school officials against them in some way if they said or did something inappropriate during the lesson. Although I felt that these students trusted me personally, I could not overcome the difficulties they had with school and district administration. In accordance with their wishes and given their aforementioned trust issues with *Stevenson Academy*, these classes were not video or audio recorded.

If the lesson plan detailed use of *modeling instruction* and the promotion of *discourse*, I video recorded that lesson. If the lesson plan consisted of major assessments and/or limited or no *modeling instruction* and *discourse*, I did not video record that lesson. The length of each video recording ranged from sixteen minutes to fifty-one minutes depending upon the amount of instructional time for that lesson. This time typically corresponded to the amount of instructional time using *modeling instruction* and *discourse* that I planned for in that lesson. However, during longer video recorded lessons, there were gaps in instruction for various reasons including dealing with school announcements, doing some formative assessments, and providing directions to students for various assignments. The total amount of classroom enactment video recorded time was approximately one hundred eighty minutes. I used the same tools that I provided to critical friends to reflect on my classroom experiences while viewing the video recordings. For example, I used the RTOP with STEM rubric, the questioning checklist, *talk moves*, and the GEM rubric measures to self-assess while I viewed the video enactments.

Reformed Teacher Observation Protocol (RTOP) with STEM Rubric

The RTOP with STEM (see Appendix L) rubric provided an observational tool for use in measuring "reformed" teaching, based on the theory of social constructivism. It examines principles that are unique to a STEM curriculum such as lesson design, implementation, and content, as well as classroom communication. There are twenty-five statements (each with a

Likert scale from 0 to 4) which provides a maximum possible score form the rubric of one hundred which can be interpreted as a percentage. The rubric is organized in three sections, which include lesson design and implementation (six questions), content knowledge (ten questions), and classroom culture (nine questions). After I viewed the video recording once, I proceeded to view the video recording a second time and then recorded my self-assessment.

The Questioning Checklist

The questioning checklist (see Appendix M) provided a means for me to self-assess the level of questioning in my classroom. There are nine questions (each with a Likert scale from 0 to 4). The Likert scale was coded categorically to never, seldom, moderate, and frequent. After I viewed the video recording once, I proceeded to view the video recording a second time and then recorded my self-assessment. Appendix M provides an example record of my assessment for my statistics class (Case 3) for Phase One of this study.

Talk Moves

The *Talk Moves* checklist (see Appendix B) provided a means for me to self-assess the level of discourse in my classroom. There are nine *talk moves* questions. Each of these moves was scored from 0 (no observation of activity), 1 (seldom activity observed 1-2 times), 2 (moderate activity observed 3-5 times) or 3 (frequent activity observed greater than 5 times). After I viewed the video recording once, I proceeded to view the video recording a second time and then recorded my self-assessment. Appendix B provides an example record of my assessment for my statistics class (Case 3) for Phase One of this study.

Generate-Evaluate-Modify (GEM) Rubric

The GEM Rubric (see Appendix C) provided a means for me to self-assess the level of modeling instruction in my classroom. The rubric has two columns (coded as “I” and “S”), which corresponds to instructor and student modeling activity. For each item in the rubric a value from 0 (no observation of activity), 1 (seldom activity observed 1-2 times), 2 (moderate activity observed 3-5) or 3 (frequent activity observed greater than 5 times) is scored. A mean score was then computed and related back to the "seldom", "moderate", and "frequent" categories. After I viewed the video recording once, I proceeded to view the video recording a second time and then recorded my self-assessment.

I viewed the video record once and recorded reflections in my e-journal. For example, I noted some characteristics about myself with the video during Phase One:

> "I frequently paused and said Umh". I walked around the classroom frequently. I was doing most of the talking and not the students. I was not using wait time when questioning".

I wondered whether those personal behaviors of pausing and moving around the room were distracting to students. In terms of building conversations with students it was evident to me that I needed improvement.

Table 3.2 provides for a summary of the classroom enactment video recordings by study phase.

Table 3.2. Summary of Class Enactment Video Recordings by Study Phase

Study Phase	Case ID	Number of Recordings
Phase One	Case 3 (Statistics)	1
	Case 4 (Statistics)	1
	Case 5 (Engineering)	1
Phase Two	Case 3 (Statistics)	1
	Case 4 (Statistics)	1
Phase Three	Case 3 (Statistics)	2

I selected all Phase One classes (with the exception of the Chemistry classes previous discussed) to be video-recorded in order to get a sampling by subject area of my use of *modeling instruction* and *discourse*. I selected Phase Two classes based on analysis of Phase One Data (discussed further in Chapter 4) and selected the Phase Three class based on analysis of Phase Two data (discussed further in Chapter 4). For example, the Phase One data revealed that I was seldom (1-25% of the time) using "wait time" and seldom "building conversations with my students" in the classes for statistics. Furthermore, there was seldom use of modeling in statistics classes. In contrast, I was making moderate (26-50% of the time) usage of *discourse* (other than using "wait time"*) and modeling* in the engineering class.

Student Survey

Aldridge, Fraser, Bell, and Dorman (2012) developed and validated (Cronbach alpha = 0.84 to 0.95) the Constructivist-Oriented Learning Environment Survey (COLES). The authors described the purpose of COLES: "To tap into students' perceptions of important aspects of the learning environment that could be used by teachers to help them to reflect on what is happening in their classroom through the eyes of their students" (p. 285). The COLES survey (see Appendix O) consists of fourteen subscales.

The COLES provided a source of independent data other than my own reflections and the feedback from critical friends and the study administrator. All students were invited to participate in this survey via informed consent. Students in both chemistry classes (Case 1 and Case 2) chose not to participate in the survey. In accordance with their wishes and given their aforementioned trust issues with the school environment, these classes were not surveyed. Details regarding the level of student survey participation survey for all other classes are provided in Chapter 4. The survey was conducted at the beginning and end of each phase of the study. Mary, the critical friend mathematics teacher, conducted this survey throughout each phase of the study. To preserve anonymity, I did not have access to student names that participated in the survey. Mary instructed all students participating in the study for each phase of the study to discuss all survey-related matters with her. No student was to discuss the survey with me at any time.

Following the administration of the Phase One pre-unit enactment COLES, students reported to Mary that the survey took a long time to complete. Each question in COLES had both an “actual” and “preferred” column selection. For example, in the subscale on Equity, one of eight questions is listed as “I am treated the same as other students in this class”. The “actual” column response reflects the student’s perception of the real classroom environment whereas the “preferred” column reflects what the student would prefer to happen. In analyzing all “preferred” column responses for all subscales, on average the Likert response were all greater than 4.5 out of 5. This result was similar to another study using the COLES survey (Aldridge et al., 2012) in which the “preferred” column responses averaged 4.5 out of 5. The meaning of a score of 4 indicates that the student preferred that item “often”. The meaning of a score of 5 indicates that the student preferred that item “almost always”. Based on this examination, I concluded that collecting this preference data would not be useful for this study I also reviewed each of the fourteen subscales and rated each subscale based on previously identified areas for improvement in my teaching practice. I selected those subscales that related to my support and treatment of students (ethic of care), namely “Teacher Support” and “Equity”. I selected the “Clarity of Assessment Criteria” subscale given my aforementioned study goal of improving my assessment capabilities. I selected the subscale “Attitude Towards Subject” to examine to what extent any student attitude changes occurred given the interventions in each study Phase.

Student Artifacts

How my students’ performed in meeting unit plan objectives was influenced by the assessments that I designed. Student work (artifacts) in the form of both formative assessments and summative assessments were collected throughout all three phases of the study. Formative assessments included practice quizzes and student journals. These assessments were typically examined weekly and then returned to students. These assessments were not graded however both verbal and written feedback was provided to students to aid in their understanding. Summative assessments included homework, quizzes, chapter tests, unit tests, and student projects. All of these summative assessments were graded. I found examination of student artifacts most useful in this study in the building of conversations with my students. I wanted to help them express themselves and construct an explanation of their understandings. For example with summative assessments, I provided the opportunity to earn back credit for incorrect responses. The requirement for earning back credit was to construct either a written response or verbal presentation to me to convince me that they understood the material. This strategy aligns well with two key *Framework* science and engineering practices: constructing explanations and engaging in argument from evidence. I also used summative assessments grades to compare with students’ COLES “Attitude Toward Subject” subscale data. For example, after the enactment of Phase One, eighty percent of the subscale scores were lower pre and post unit enactment. On average letter grades were reduced by a half letter grade (e.g. going from a B+ to a B) pre and post Phase One unit enactment. A possible explanation for these lower score results could be that the course material was more challenging to students. Students were asked to think in ways they had not done previously. More specifically, students had to consider the three dimensions (the content, the practices, and the cross-cutting concepts). Another possibility for lower scores could be related to the time it took students to complete the COLES survey. Student feedback on the survey to Mary was that the survey was long. This matter is discussed further in the quantitative data analysis section in this chapter.

Meetings with Study Administrator

Meetings with Peter, the study administrator, were planned to occur once in each phase and expected to last approximately twenty minutes in duration. The purpose of meeting with Peter in each phase was to: (1) obtain independent documentation of the classroom presentation of the lesson, (2) discuss feedback from the classroom observations as well as review study progress, (3) address any study issues, and (4) ensure study alignment with district goals and objectives. The role of the study administrator was to serve as an "independent observer" who has no personal or official interest in this research study other than his professional obligations. The administrator planned to use current district criteria for all lesson observations. In addition to Peter's assistant principal duties such as regular school attendance and discipline, he had total accountability for managing the *Stevenson Academy*. This program consisted of approximately forty enrolled students. Peter had to manage all interactions with *Stevenson Academy* students, teachers, parents, and the regular school community. Peter's availability to participate in the study was limited due to the nature of these responsibilities. Consequently, I had one meeting with Peter that was limited to ten minutes. No other meetings with Peter took place during the study. I recorded my reflections of this meeting in my e-journal. Some examples of my personal reflections are given below:

“Peter was quite agitated at this meeting. He exclaimed that he was getting no help with *Stevenson* Academy despite his pleas for assistance to his management. I could see how stressed out he was.”

“Peter mentioned in our meeting that he would email me feedback on his observations of the Chemistry class and Statistics class for section 2. I have concerns as I did not see Peter using the district observation checklist while observing me.”

I noted the following comments in my e-journal upon receiving it by email:

“I am disappointed in the feedback from Peter. I was hoping that he would use the district criteria for the new teacher evaluation system. We had discussed this earlier in the year.”

“Based on Peter’s feedback, how can I improve my teaching practice? Just telling me how great everything is going does not help me?”

Summary of Data Sources and Data Measures

Table 3.3 provides a detailed summary of each data source and data measure.

Table 3.3. Summary of Data Sources and Data Measures

Data Source	Data Measure	Data Type	Who (*)	When Used	Where Used
Unit Plan	Reflections	Qualitative	Self	Each Phase	Classroom
	Reflections	Qualitative	Critical Friends, Admin	Phase One	Meetings
Unit Enactments	COLES Survey	Quantitative	Students	Each Phase	Classroom
	Student Artifacts	Quantitative	Students	Each Phase	Classroom
	RTOP	Quantitative	Self	Each Phase	Classroom
	GEM Rubric	Qualitative	Self	Each Phase	Classroom
	Questioning Checklist	Qualitative	Self	Each Phase	Classroom
	District	Qualitative	Admin	Phase Two	Classroom
	RTOP	Quantitative	Critical Friends	Phase Two	Classroom
	GEM Rubric	Qualitative	Critical Friends	Phase Two	Classroom
	Questioning Checklist	Qualitative	Critical Friends	Phase Two	Classroom
	Talk Moves	Qualitative	Self	Each Phase	Classroom
			Critical Friends	Phase Two	
Unit Reflections	Reflections	Qualitative	Self	Each Phase	Classroom

Data Analysis

Both quantitative data and qualitative data were analyzed during each phase of the study. Using this approach allowed for perspectives from both types of data. The various cases explored in this study were compared and contrasted using techniques associated with cross-case analysis (Stake, 2006). The rationale for doing this analysis was to learn from both the common as well as the unique aspects of each case. The specific techniques I used included organizing data in various ways including diagrams and tables, and tabulating the frequency of events. I used a cross-case search for patterns both within each study phase and between study phases. According to Altrichter et al. (2008), “patterns are ‘regularities of behavior’ or forms of interaction that occur over and over again” (p. 181). In this study, analyzing the data from a pattern analysis perspective helped in identifying patterns, determining the significance and effects of the patterns, and shedding light on relationships between the patterns and the goals of the study. For example, in analyzing Phase One data on how well I used wait time for Case 3 through Case 6, it was apparent that I was not providing adequate processing time to students when I asked questions. As a consequence of this analysis, I made design changes to Phase Two of the study to improve that aspect of my discourse practice.

Quantitative Data Analysis

Quantitative data from student surveys (i.e. COLES) were examined using descriptive and inferential statistics (Creswell, 2007). The mean for each COLES subscale was calculated by averaging responses to all eight questions on the subscale. This composite mean was then compared pre and post unit enactment for each class during each phase of the study. A paired t-test of all pre and post unit enactment subscale means was completed to assess significance. Analysis and findings from one phase were used to guide the design of the subsequent phase and are further discussed in detail in Chapter 4. For example, Phase One subscale mean scores revealed no significant changes based on t-tests. However, analysis of Case 3 through Case 6 COLES Subscale mean scores revealed a drop in subscale scores eighty percent of the time. I hypothesized two possible explanations. One reason could be that the course material was getting harder for students as previously discussed. For example, students in both statistics classes were having difficulties with the unit topic on hypothesis testing. In reviewing the summative assessment data for statistics pre and post Phase One, it was clear that there was a reduction in grades by a half letter grade (e.g. going from a B+ to a B). Another possible reason could be related to the COLES survey. Students advised Mary that the survey was very long to complete. As a result of analysis of the survey data, design changes were made in Phase Two to reduce survey time.

For the RTOP with STEM rubric quantitative data, I developed a composite score for my unit enactments. The score was in terms of a percentage and was based on answers to twenty-five questions with each question ranging value from zero to four. Thus the maximum score attainable was one hundred percent. This composite score was used in cross-case analysis both within each study phase and across each study phase. For example, RTOP scores for Phase One for statistics (Case 3) and statistics (Case 4) were 52% and 45% respectively. RTOP scores for Phase Two for statistics (case 3) and statistics (Case 4) were 63% and 56% respectively. In addition, these RTOP scores were compared with Phase One and Phase Two data measures for *discourse, modeling instruction*, and COLES student "Attitude Toward Subject" subscale data.

Qualitative Data Analysis

Merriam (2009) noted "the much preferred way to analyze data in a qualitative study is to do it simultaneously with data collection" (p. 171). The suggestions by Bogdan and Biklen (2007) offer advice for analyzing data as they are being collected as well as after being collected. This DBR self-study design offered the opportunity to explore the data in a manner suggested by Merriam, Bogdan, and Biklen.

Qualitative data from my reflections on unit design, unit enactment, and unit reflection included identifying salient themes or patterns and displaying these data in table and figures. For example for the Phase One unit design, I noted reflections in my e-journal with words and phrases such as front-end, customer requirements, constraints, create, test, and evaluate. In analyzing these reflections, I noticed a pattern emerged that these items were elements of a generic engineering design process. I compared the generic engineering design process with the processes I was using in this study (namely *UbD, LfU,* and *action research*). I discovered similarities and relationships amongst all four processes.

The *talk moves*, questioning checklist, and GEM rubric were qualitative measures I used to analyze the degree of my *modeling* and *questioning* teaching dispositions. These data measures were coded *apriori* by the following categories of "never" (0%) "seldom" (1-25%), "moderate" (26-50%,) "frequent" (51-75%), and "always" (76-100%). I found these categories particularly useful in cross-case analysis both within each study phase and across each study phase. For example, in Phase One, the analysis of the data indicated an improvement opportunity to increase modeling, increase wait time, and build more conversations with my students. Based on this analysis, I made design modifications to the Phase Two study design to enable the improvement.

A constructivist method was used for qualitative data analysis in which the coding of the data used both a deductive as well as an inductive approach. In the deductive method, I used the previously discussed framework by Valli (1997) to guide and organize my reflections as this structure provided specific reflection considerations to be used in a classroom/school environment. Once my reflections were organized, I used an inductive method in which categories were developed after reviewing the data. For example, I examined my e-journal reflections in the *Deliberate reflection* category which focused on a whole range of teaching concerns, including students, the curriculum, instructional strategies, the rules and organization of the classroom. The analysis resulted in themes emerging such as standards, assessments, and student-centered, which related to changes in my attitudes and beliefs towards those themes.

Mixed Methods Data Analysis

As previously discussed in this chapter, this study used a convergent parallel mixed methods design (Figure 3-1). The quantitative (QUAN) and qualitative (QUAL) strands were conducted separately in each study phase yet concurrently and merged during data analysis. This approach was used either to form a more complete understanding of the topic under study or for validation or corroboration. For example, in Phase Two, the Reformed Teaching Observation Protocol (RTOP) quantitative scores from Jim, a critical friend, were compared with the *discourse* and *modeling* qualitative self-report data. This comparison aided in mutually corroborating the critical friend RTOP data and self-report data.

Validity and Reliability

Researcher Bias

The researcher was a secondary science, engineering, and mathematics teacher and was also in the role of participant-researcher. A concern with this role was that I may not able to distance myself from the situation being researched, and therefore might be unable to have an objective viewpoint. In order to gain some independent evidence of what was happening in all three phases of the study, I included three independent sources of documentation on the enactment of my unit plans: the student surveys, the study administrator, and the critical friends. The student surveys provided a source of independent data other than my own reflections. Unfortunately, both critical friends and the study administrator provided limited feedback. One critical friend did serve as independent observer to document the classroom presentation of the lesson as proposed in the lesson plan, and any alterations that occurred during enactment. By acknowledging my bias and elaborating on it throughout the course of the study, the validity and hence trustworthiness of the study would be enhanced.

Validity, Reliability, and Study Rigor

Previously stated, the study design was based on two design principles, one being the study was conducted in an authentic setting and second being I was an active participant in this self-study operating as a reflective teacher practitioner.

Merriam (2009) argued that triangulation is a principal strategy to ensure validity and reliability. Triangulation was critical to this study. Triangulation was used for both confirmation to corroborate findings and completeness to increase my in-depth understanding of the complexities of my teaching practice. This study used three types of triangulation, namely data triangulation, methodological triangulation, and environmental triangulation.

Data triangulation involved using different sources of information in this study such as students, critical friends, the study administrator, and myself. Methodological triangulation involved the use of mixed methods through surveys, instruments, and observations. Environmental triangulation involved the use of multiple cases and phases in this study.

Herr and Anderson (2005) offered a set of five validity criteria (see Appendix E) that are linked to the goals of action research based dissertations. In this section, I address each of these criteria as they relate to this study. For *outcome validity*, the research I conducted in this study resulted in conclusions (outcomes) that allowed me to improve my teaching practices. For example, I believe that my self-efficacy in promoting *discourse* and using *modeling* improved as a result of the study. For *process validity*, continual improvement in my learning occurred as I utilized both student feedback and my own self-reflections to guide the study to gain further improvements in my teaching practice. For example, results from student feedback as well as my own self-assessments resulted in changes in my attitudes about standards and assessment methods. For d*emocratic validity*, I used student feedback (in the form of student surveys), classroom enactments, and student artifacts (assessments) to inform changes in my teaching practices. Students were made fully aware that the purpose of the study was to improve my teaching practice. For example, the collection and analysis of these data informed changes in my becoming more student-centered. For *catalytic validity*, I used the self-study framework as a transformative approach to change my knowledge, beliefs, and attitudes about my teaching practices. For *dialogic validity*, I relied on critical friends, the study administrator, and my committee to help me with feedback on my study. It is unfortunate that dialogic validity was not strong given the limited feedback from critical friends and the study administrator.

Utilizing Yin's (2003) case study model, construct validity was managed by using a range of data collection models and explicitly detailed evidence to address the research question and the triangulation of multiple sources of data. Internal validity was addressed by focusing on a descriptive analysis rather than causal relationships. External validity was enhanced by considering environmental triangulation in terms of the different cases considered. Moreover, external validity was enhanced by developing rich, dense, and thick descriptions of the cases. According to Merriam (2009), the inclusion of multiple cases is a "common strategy for enhancing the external validity of your findings" (p. 50). Bullough and Pinnegar 's (2001) guidelines for quality in self-study (see Appendix D) and Feldman's (2003) recommendations for self-study (see Appendix F) offered additional validity criteria insights beyond the criteria previously discussed from Herr and Anderson (2005).

Lincoln and Guba (1985) were the first to re-conceptualize reliability in terms of dependability and consistency. These authors stress the close ties between study credibility and dependability, arguing, that in practice, a demonstration of the former goes some distance in ensuring the latter. For credibility, this study used well-recognized research methods, triangulation with the use of mixed methods and multiple cases, iterative questioning in students feedback surveys, descriptions of my background, qualifications, and experience, and a detailed analysis and reporting framework by study phase. For study dependability strategies included documentation of data, methods, and decisions made throughout the study.

Study rigor relates to how research is structured to utilize the appropriate tools to accomplish the goals of the investigation. To address study rigor, various methodological questions must be answered. For example, "Do the data collection techniques provide for sufficient detail necessary to address the research question? Do the data analysis strategies provide for the emergence of themes? I have addressed rigor through my examination of the previously discussed study validity and reliability considerations. I described what I did in explicit detail for both data collection and analysis.

Finally, Hoadley (2004) aptly characterized study rigor in DBR in the following passage:

> All empirical methods are faced with similar challenges for rigor—namely, to generate empirically consistent understandings and apply them appropriately with true consequential validity. Different research paradigms manage the need for rigor in different ways based on their different assumptions; naturalistic inquiry is inductive and (because it takes context as a primary independent variable) situation-specific, focused on developing and refining both an individual researcher's intimate understanding of the activities and practices through participation in the context. Interpretation is the core challenge… …Design-based researchers treat as fundamental the problem of context. Much as cultural anthropology cannot be conducted experimentally, when we do design-based research, we acknowledge the difficulty in educational research of ensuring control and assuming universality. Instead, design-based research views outcomes as the culmination of the interaction between designed interventions, human psychology, personal histories or experiences, and local contexts. All four impact the outcomes (which include the enacted, as opposed to designed, interventions). Hence, design-based researchers recognize the difficulty of experimental control, as dozens (if not millions) of factors interact to produce the measurable outcomes related to learning. Perhaps the most important commitment of design-based researchers is in understanding that treatments may not go as planned. (pp. 210-211)

Hoadley's notion of treatments not going as planned is illustrated by the lack of participation of critical friends and the study administrator and the lack of participation by chemistry students in the survey and video classroom enactments. In both examples, context played a key role in their decisions regarding participation.

Ethical Considerations

Approval for this research was secured through Teachers College, Columbia University's *Institutional Review Board* (IRB) before the study was initiated. The informed consent process was used to disclose to all study participants information needed to make an informed decision, facilitate the understanding of what has been disclosed, and promote the voluntariness of the decision about whether or not to participate in the research (Health and Human Services, 2012). The specific intervention within this study, which included the notions of both reflection and collaboration, was explicitly presented to the study participants so that no deception was apparent (Creswell, 2007). The anonymity of the students, teachers, and the school were preserved throughout all phases of the study. All surveys completed by the students were assigned pseudonyms with only one critical friend being able to view student names. Thus I was not aware of who was participating in the survey. Student grades or their status in the classroom was not affected due to their participation or non-participation in the survey. Participants were informed of their right to discontinue any survey activity involved in the study at any time without penalty. Thus, if they felt anxious or otherwise uncomfortable, they could stop responding. The critical friend observed all study survey activities. I was not present during any survey activities throughout the entire study. No students expressed any anxiety to nor asked the critical friend to withdraw from the survey activity. Over the course of the fifteen-week study, it was estimated that the loss of instruction time due to students filling out surveys was approximately sixty minutes. Class office hours/advisory times were made available to students during each class day to support them for inquiries on instructional and any study-related matters.

By participating in this study, the school benefited from professional development aimed at addressing my learning and improvements in teaching practice. The researcher did not expect any risks over and above the normal anxiety that could have occurred for various formative and summative assessments that were utilized in this educational setting regardless of the study. Students, teachers, administrators, parents and the board of education were assured that all materials, interviews, and surveys were used for the purposes of research.

Study Assumptions, Limitations, and Challenges

The assumptions I made for this study was that to have a robust study, I could not use just one method. I assumed that the self-study framework and the lens of the *NGSS* gave voice to STEM pedagogy by focusing on the improvement of my own teaching. Furthermore, I assumed that DBR methods would assist me in addressing the complex educational problem of examining my teaching practice. Finally, mixed methods study offered a practical way to explore multiple viewpoints.

The limitations of this study were the researcher bias and the self-report nature of the data collected as well as the participants' level of involvement. To the extent possible, researcher bias was addressed in the researcher statement described in Chapter 1 and the use of multiple sources of independent data. The participants' level of involvement was a major concern given the aforementioned "contextual factors" of Hurricane Sandy, the implementation of block scheduling, and the shift to a new teacher evaluation model. The reduced level of participation of critical friends and the study administrator was a validity concern for independent corroboration of my self-reported data.

Concurrent to the researcher bias, self-report, and contextual limitations, I faced the challenge of managing an extensive data collection and analysis study. I was concerned about an increased time commitment in a school climate where time was precious and limited. With regard to increased time commitment for a study, Cochran-Smith and Lytle (1993) pointed out, "Unlike other professions which are organized to support research activities, teaching is a profession in which it is extraordinarily difficult to find enough time to collect data . . . reflect, reread, or share with colleagues" (p. 91). Analysis of each study Phase data indicated a need to limit the scope of the study and increase study focus. A related challenge was my concern regarding the conflicts between the researcher and teacher roles. Wong (1993) described the conflict between researching and teaching roles when the author stated, "The purpose of research is to know and understand, while the purpose of teaching is 'to do the right thing'" (p. 7). During this study, curriculum and instruction were not ignored nor temporarily suspended in any attempts to focus and collect sufficient data for research purposes.

Chapter 3 Summary

Chapter 3 provided a discussion of the study methodology based on the goals and objectives of the study identified in Chapter 1 and the findings from the literature review in Chapter 2. Study setting, participants, contextual factors, and a timeline were described. Data sources and data measures were provided along with the description of the data analysis conducted. Study reliability, validity, and rigor were discussed. Ethical considerations were addressed. Study assumptions, limitations, and challenges were explored.

Chapter 4 presents findings from the data collected and analyzed based on the systematic application of the study methodology.

CHAPTER 4

FINDINGS

Overview

In order for the vision of the *Framework*'s STEM reform to be realized, teachers will need a significant amount of ongoing and sustained training, time, and support to implement the *NGSS*. The *Framework* proposed a research agenda "on classroom-level contexts, materials, and discourses that engage and support a wider range of students in high-quality teaching and learning experiences with the concepts, ideas, and practices" (NRC, 2012, p. 325). Given this research need and my motivation to improve my STEM teaching practice, I chose to focus this study on examining my experiences in my secondary chemistry, statistics, and engineering classes by designing, enacting, and reflecting on unit plans through the lens of the *Framework* and the *NGSS*.

The study design was structured in three phases, namely Phase One, Phase Two, and Phase Three. In Phase One, I designed unit plans for my classes which consisted of two class sections of chemistry (Case 1 and Case 2), two class sections of statistics (Case 3 and Case 4), and one class section of engineering (Case 5). This "unit planning" took approximately one week to complete. "Unit enactment" and "unit reflection" took approximately four weeks. Thus, a study phase consisted of approximately five weeks in which a unit was designed, enacted, and reflected upon. Lessons learned from Phase One were used to inform the next phase (Phase Two) of the study. In Phase Two, I designed unit plans for my classes, which consisted of two class sections of statistics (Case 3 and Case 4). Lessons learned from Phase Two were applied to the next phase (Phase Three) of the study. In Phase Three, I designed a unit plan for my statistics (Case 3). Findings from Phase Three informed the study's overall results. The timeline for the entire study was approximately fifteen weeks.

A restatement of the study's research questions is presented in terms of each study phase. A brief summary of methods is reviewed. A framework for reporting study data analysis and findings is provided. This framework consisted of organizing this chapter's discussion of each study phase in terms of unit planning, unit enactment, unit reflection, a summary of findings, and lessons learned from each phase.

Research Questions

The research question for Phase One posited for this study was: What happened in my chemistry, statistics, and engineering classes when I employed a self-study framework using a design-based research (DBR) strategy to design, enact, and reflect on units of study that promoted the *Framework's* disciplinary core ideas, science and engineering practices, and crosscutting concepts? Phase One consisted of five cases namely, chemistry (Case 1 and Case 2), statistics (Case 3 and Case 4), and engineering (Case 5). As the study progressed through its phases, refinements were made to the research question in the subsequent remaining two phases of this self-study. These refinements were based on findings from each study phase. More specifically, for Phase Two the research question was refined as: To what extent am I improving "wait time", building conversations with my students, and incorporating modeling instruction in my two statistics classes (Case 3 and Case 4) while I design, enact, and reflect on unit plans through the lens of the *NGSS.* Moreover, for Phase Three the research question was further focused as: To what extent am I improving building conversations with my students and incorporating modeling instruction in my one statistics class (Case 3) while I design, enact, and reflect on unit plans through the lens of the *NGSS.*

Methods Summary for Study Phases

I chose the self-study framework for this study as the literature review revealed that the overall goal of self-study is self-improvement. "Self-study research seeks as it hallmark not claims of certainty, but evidence that researchers, however stumblingly, demonstrate in their practice the understandings they have gained though their study" (Pinnegar, 1998, p.33). These self-study objectives were directly aligned with my motivation to improve my teaching practices. The DBR strategy was chosen to promote reflective cycles or phases, which are consistent with and in support of the self-study framework and the action research process. Feedback from one phase was used to inform the design of the next phase. The DBR strategy was based on two elements: (1) I participated as both researcher and teacher practitioner, and (2) I used a *best practices*[1] framework for improving different aspects of my teaching practice.

Given the iterative DBR nature of the study design, I chose the mixed methods approach for data collection and analysis from an emergent perspective. The rationale for using mixed methods was purposeful for breadth and depth of understanding. Furthermore, using an emergent perspective assisted in being responsive to new insights as the study progressed (Bryman, 2006). Finally, Yin (2003) defined a case study in terms of the research process. "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real life context" (p.18). In describing case studies, Creswell (2007) and Merriam described how multiple cases show different perspectives, greater variation, and more compelling interpretations. My chemistry (Case 1 and Case 2), statistics (Case 3 and Case 4), and engineering (case 5) classes were the unit of analysis. I chose multiple cases as a strategy

[1] *Best practices* are described more fully in Chapter 1

to enhance the external validity of my findings.

Framework for Reporting Data Analysis and Findings by Study Phase

A framework for reporting of findings by study phase is provided in Table 4.1. The table provides a summary of each study phase's actions (unit planning, unit enactment, and unit reflection) and the associated inputs used for that action (e.g. standards, *best practices*[1], etc.) and outputs generated (e.g. a designed unit test plan) as a result of that action.

Table 4.1. Findings Reporting Framework for Each Study Phase

Study Phase Action	Study Phase Inputs Used	Study Phase Outputs Generated
Unit Planning	• Standards • Best Practices • Critical friends -Study Administrator	• Reflections • Findings • Unit plan
Unit Enactment	• Unit plan	• Pre-post COLES Student Survey[2] • Critical Friends – Study Administrator Observations • Reflections • Findings

Unit Reflection	• Outputs from Unit Enactment	• Self-assessment[2]
		  o RTOP with STEM Rubric
		  o Modeling (GEM Rubric)
		  o Discourse
		    ▪ Talk Moves
		    ▪ Questioning Checklist
		• Reflections
		• Findings
		• Lessons learned

.

For example, during the study phase action of "unit planning", inputs such as standards (my district's curriculum guide and the *NGSS)*, *best practices* (instructional design,

[1] Best practices used in this study are described more fully in Chapter 1.
[2] Constructivist Oriented Learning Environment Survey (COLES) and self-assessment measures are described more fully in Chapter 3 on methods.

modeling, and discourse), and critical friend and administrator input were used to generate the outputs (reflections, findings, and a designed unit plan). During the study phase action of “unit enactment”, the input was the unit plan and the outputs generated included pre-post COLES student survey data and critical friend and administrator observational data. During the study phase action of “unit reflection” video recordings of selected classes (as described more fully in Chapter 3 on methods) were analyzed using various self-assessment[1] measures (i.e. Reformed Teaching Observation Protocol (RTOP) with STEM rubric, the Generate, Evaluate, Modify (GEM) Rubric, *talk moves*, and the *questioning checklist*). Moreover, both the pre and post COLES student survey was analyzed. During the study phase action of “unit reflection” the outputs generated included reflections, findings, and lessons learned. These lessons were used to inform the overall design of the subsequent phase of the study.

Phase One Data Analysis and Findings

This section describes the details of the Phase One study actions of unit planning, unit enactment, and unit reflection. Three unit plans were designed for the three subject areas namely chemistry, statistics, and engineering during the study phase action of “unit planning”. Furthermore, reflections and data analysis on “unit planning” resulted in study findings. These unit plans were implemented during the study phase action of “unit enactment” in my five class sections, which included chemistry (Case 1 and Case 2), statistics (Case 3 and Case 4), and engineering (Case 5). Both pre and post COLES student survey data, critical friend and study administrator observational data, and self-assessment data were analyzed during the study phase action of “unit reflection”. This analysis resulted in study findings and lessons learned to inform the design of Phase Two of the study.

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[1] These self-assessment measures are described more fully in Chapter 3 on methods.

Phase One Unit Planning

Phase One unit planning consisted of designing unit plans for each of the three subject areas namely chemistry, statistics, and engineering for my five class sections. Each class section was considered to be a unique case. A summary of the topics covered for each subject for the Phase One unit plans is provided in Table 4.2. The three unit plans for Phase One are provided in Appendix I.

Table 4.2. Phase One Designed Unit Plans for each Subject by Topic

Case ID	Case 1 & Case 2	Case 3 & Case 4	Case 5
Subject	Chemistry (Sections 1 & 2)	Statistics (Sections 1 & 2)	Engineering
Topic	Periodic Table	Hypothesis Testing	Electricity

I examined all three subject-related district curriculum guides for chemistry, statistics, and engineering in terms of Understanding by Design's (*UbD)* process of "identifying desired results." These learning outcomes were structured in terms of the curriculum's standards-based objectives. I correlated and linked these objectives to those listed in the *NGSS* in terms of the three dimensions of the *Framework*: disciplinary core ideas, science and engineering practices, and cross-cutting concepts. For example, in the statistics unit plan on hypothesis testing, one of the targeted standards-based objectives was testing a claim about a mean for large samples. This learning outcome was linked to the *NGSS* science and engineering practice of analyzing and interpreting data. I implemented the *UbD* process of developing "enduring understandings" and "essential questions" for the unit topic. For example in the statistics unit, an "enduring understanding" is that tests of significance and confidence intervals drive decision making in our world. Essential questions include: "What is a significance level? and What is a confidence interval?". Essential questions were included in all units and were used throughout multiple lessons in each unit. Consideration of these essential questions guided my understanding of the targeted knowledge (what students are expected to know) and targeted skills (what students are expected to do) that students needed to learn. The targeted knowledge and skills were subsequently used to design student assessments.

The learning for use (*LfU)* instructional design model discusses student engagement in terms of "creating demand" and "eliciting student curiosity". I used *LfU* in order to engage students by considering common misconceptions students they may have. For example, in the statistics unit plan, the evaluation of statistical significance and confidence interval interpretation are common student misconceptions. Lesson activities were subsequently designed based on those student misunderstandings. Discourse strategies (*talk moves and the questioning cycle*) as well as *modeling instruction* methods were designed into the lesson activities.

Prior to unit enactment, the documented plans were reviewed in short (ten minute) separate meetings with each critical friend and the study administrator. These meetings were originally planned to last approximately thirty minutes. I recorded notes from these meetings in my e-journal. Feedback from these meetings was limited to high-level overview comments such as:

> "Your chemistry unit is quite comprehensive." (John, the chemistry critical friend)
>
> "I have not seen that level of detail in a statistics unit plan." (Jim, the statistics critical friend)

"The engineering unit plan is significantly project-based." (Jim, the statistics critical friend)

Although, it was encouraging to receive feedback in the form of praise for my unit plans, a dilemma was beginning to emerge from my perspective with regard to the level of study participation from both critical friends and the study administrator. The meetings were not as long as originally planned and there was minimal detailed feedback.

During the design of the unit plans for Phase One for all three subject areas (chemistry, statistics, and engineering) I reflected "in action". Reflection *in* action refers to a type of reflection that happens during the action or process undertaken in real time. I experienced an "aha" moment during this reflective activity when I realized that I was applying an engineering design process (a process which I was formally trained in as a design engineer) to the design of my classroom instruction. The engineering model in my mind during this reflective activity is depicted in Figure 4-1.

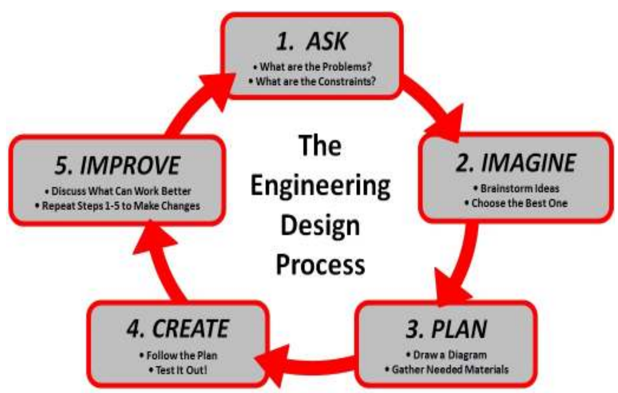


Figure 4-1: Engineering design process (Engineering Process, 2013)

I correlated the engineering design process framework in Figure 4-1with the *Understanding by Design (UbD) and Learning for Use (LfU),* and action research cycle frameworks that I was using for Phase One unit planning. A summary of these relationships is provided in Table 4.3. These relationships are explained more fully in the subsequent narrative.

Table 4.3. Summary of Relationships Amongst Unit Plan Design Frameworks

Step	Engineering Design Process	UbD Framework	LfU Framework	Action Research Cycle Framework
1	Ask Problems Constraints	Identify Desired Results	Motivate	
2	Imagine	Determine Acceptable Evidence	Construct	
3	Plan	Design Learning Experiences/ Instruction	Construct	Plan
4	Create		Organize	Act/Observe
5	Improve		Organize	Reflect

Relationship Between Engineering Design Process and Teachers Instructional Design Process

The purpose of Table 4.3 is to provide a cross-framework depiction of the relationship between the engineering design process that engineers use and the instructional design process that teachers use. Each step in the engineering design process identified in Table 4.3 as steps 1 through 5 are mapped into analogous steps in the *Ubd*, *LfU*, and action research cycle frameworks. For example, for the engineering design process in the "ask" stage, customer requirements are investigated. Engineers meet with customers to discuss what are their problems and needs and what are the criteria and constraints for the product that the customer wants. Analogously, when designing instruction teachers review what is required by examining criteria in terms of standards and review constraints such as time or perhaps how much they know about the subject they have to teach. Teachers also have to consider prior knowledge of students at this point in the design. Based on results from the "ask" stage engineers proceed to select the best ideas in the "imagine" stage and then build their project plan. In a similar manner, teachers in the "imagine" stage select the best instructional practices and strategies to construct their unit or lesson plan. In the "create" stage, engineers execute the plan by "following it" and "testing it out" whereas teachers enact their plan and use assessment to evaluate learning outcomes of their students. In the "improve" stage, engineers evaluate test results and discuss what can work better. Teachers reflect on the action in their classroom by determining what strategies worked in achieving student understanding and what did not work. Based on analysis from the "improve" stage both engineers and teachers return to the "ask" stage to begin the cycle again. Based on this cyclic, reflective activity engineers achieve further improvements in their product design and teachers gain further improvements in their students' understandings as well as their own teaching practices. The finding of this analogous relationship of engineering design and instructional design led me to conclude that I am an instructional design engineer.

Reflections on Unit Design

I next analyzed my personal e-journal reflections "on action" after the unit design process was completed. Reflection *on* action refers to the type of reflection that occurs after the activity is completed. I had organized my reflections in my e-journal using Valli's (1997) deductive framework by case. The following themes emerged from a cross-case and inductive pattern analysis of my reflections on all unit designs: standards, assessments, and student-centered. Each of these themes is discussed in detail in the following sections:

Standards are Critical Instructional Design Requirements

During my tenure at the high school from 2004-2010, the mathematics department focus was on lesson plans rather than unit plans. Thus, I did not have any practice with designing such unit plans. All of my lesson plans were based on the objectives listed in the district's curriculum guides. The curriculum guides provided a "script" for all of the lesson objectives that were required by the district as well as provisions for "suggested activities" and "lesson pacing". I never really connected with the standards. My attitude towards standards began to change during the Phase One unit design process. The process of examining my district's curriculum guides through the lens of the *NGSS* connected me to the standards like never before. I began focusing more on using the *NGSS* to assist me in designing my units to promote STEM integration. For example, in the chemistry unit plan (see Appendix I), I used the *NGSS* scientific practice of "developing and using models" to introduce the unit on the periodic table for chemistry (Case 1 and Case 2). Students documented their understandings of three atomic models (Dalton, Thompson, and Rutherford) as a prelude to understanding how to predict the behavior of atoms in interactions. The type of atomic models that most chemistry students (Case 1 and Case 2) initially had in their minds ranged a concentrated ball in which all of the protons, neutrons, and electrons existed (similar to Dalton or the plum pudding model) to a planetary model in which there was a nucleus which contained protons and electrons and orbiting electrons (Rutherford model). After reviewing the progression of each model most of the chemistry students (Case 1 and Case 2) had understandings that were associated with the planetary Rutherford model. Figure 4-2 shows the progression of one student's understanding of atomic models.

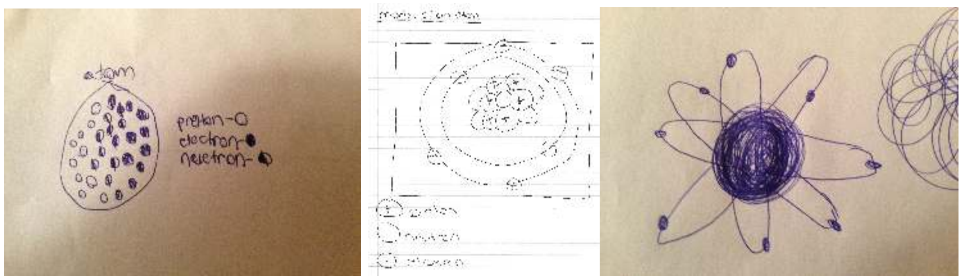


Figure 4-2. Student's Progressive Depictions of Atomic Models

Furthermore, chemistry students (Case 1 and Case 2) used the *NGSS* crosscutting concept of "scale, proportion, and quantity" to understand how much space exists in the atom. Students scaled the nuclear radius of a gold atom to 1 foot and then calculated the distance from the nucleus to the outermost electron, which they found to be approximately 3.3 miles. At this point most chemistry students (Case 1 and Case 2) connected more fully with Rutherford's gold foil experiment results of a small, dense, positively charged core (nucleus) surrounded by mostly empty space and very small, negatively charged electrons.

In the statistics unit on hypothesis testing, the *NGSS* practice of "analyzing and interpreting data" and the *NGSS* core idea regarding identifying mathematical relationships regarding the environment were incorporated into the unit. For example, the following question was asked of statistics students (Case 3 and Case 4) as part of a formative assessment activity of survey data, "Are you willing to pay much higher prices in order to protect the environment?" The statistics students (Case 3 and Case 4) were provided with the number of respondents to a survey totaling 1154 of which 511 were willing pay more. The statistics students (Case 3 and Case 4) had to find and interpret a 95% confidence interval for the population proportion of adult Americans willing to do so. Most statistics students (Case 3) did not have difficulty with this assessment. Approximately one third of the statistics class

(Case 4) had problems. This result was not unexpected as this third of the statistics class (Case 4) was not doing homework assignments nor fully participating in the class. Given the time of year was late April and that this statistics class (Case 4) constituted all seniors about to graduate in eight weeks, I suspected that they had begun to give up.

In the engineering (case 5) unit (See Appendix I) I used the *NGSS* standards of forces, interactions, and energy to introduce the unit on electricity by conducting an inquiry discussion on calculating the amount of energy in Hurricane Sandy (National Oceanic and Atmospheric Administration, 2013). The lesson integrated into this engineering class (Case 5) *NGSS* core physical science concepts of energy, practices including using mathematics and using models, and crosscutting concepts such as scale and energy flow. A model of how energy flows in a hurricane that was used to promote discussion is provided in Figure 4-3.

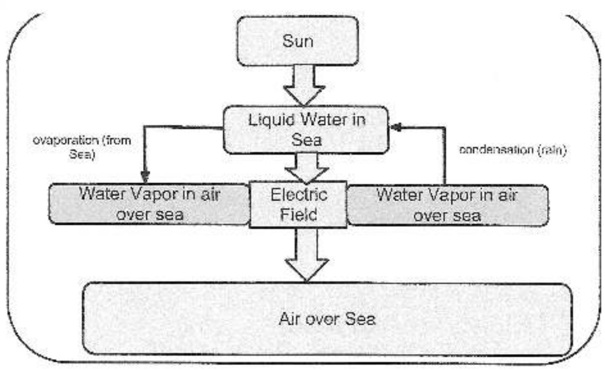


Figure 4-3. Energy Flow in a Hurricane

Engineering students (Case 5) compared their calculations to national and global electrical power generating capacity. Most engineering students (Case 5) enjoyed this discussion as it integrated thermodynamic topics in Chemistry (which several of them were taking concurrently) with the engineering class (Case 5). Students who primarily struggled with this were freshmen who had not yet taken Chemistry. All of the engineering students (Case 5) connected and were engaged with Hurricane Sandy topic given its recent devastating impact on their school and surrounding community. Moreover, the engineering students (Case 5) gained a sense of scale, proportion, and quantity, which is a *NGSS* cross-cutting concept.

I found myself considering the standards (like an instructional design engineer) as critical instructional design requirements. I used a key concept in the *UbD best practice* framework of "identifying desired results" by using standards. Once I understood the educational outcomes (as provided by the standards) I was better be able to assess those outcomes.

Designing Balanced Assessments

My teacher training and lesson design experiences from 2004-2010 had more emphasis on activities rather than assessment. Most of my assessments were summative rather than formative. I connected the idea of *UbD's* second stage of "determining acceptable evidence" with *NGSS's* science and engineering practice of "engaging in argument from evidence". My beliefs in assessment were changed as a result of my study focus on how was I going to "determine acceptable evidence" in my unit plans. A shift in my thinking unfolded regarding how to use formative assessments so that students can gain practice in various meaningful ways. For example, I included means of promoting practice for students that included formative assessments such as the use of practice quizzes and cooperative groups on projects. For student projects, cooperative groups would be formed to help students support one another. In the past I would have set up these groups and had the group responsible for one project and then assign a group grade. For this study, each group would select a theme for their project. Each individual had to select a project idea from that theme. Thus, the cooperative groups would become the means to an end. The group structure would provide the means of practice and support for each student. For the end, each student would be held accountable for the project to provide the evidence of their individual learning. My plan was to support these cooperative groups with several scaffolded practice sessions throughout the project.

As I considered various assessments during the unit design process, I found myself developing a mindset for more designing more balanced assessments. A balanced assessment system uses the strengths of summative and formative assessments to address instructional, accountability, and learning needs (Chappuis, Chappuis, & Stiggins, 2009). I noted a reflection in my e-journal regarding some things I should investigate for the future based on my becoming more of a balanced assessment designer.

> "I recently heard about the concept of standards-based grading. This practice might be worthwhile to investigate".
>
> "How can I get students to become more involved in their learning? How can I use assessments to build student's confidence in themselves"?

For example, in introducing the statistics (Case 3 and Case 4) unit on hypothesis testing, I included a formative assessment (See Appendix I) to assess student prior knowledge about study design as a prelude to the design of students' research study projects. The investigation entitled "Did you wash your hands?", posed a series of scaffolded questions regarding study design. After students completed this formative assessment individually, they met in groups to share their findings. This group activity was followed with a whole class discussion. I could see throughout the entire sequence of activities for this assessment (i.e. individual, cooperative groups, and whole class) that the statistics students (Case 3 and Case 4) were actively engaged.

From Teacher-Centered to Student-Centered Instruction

I began to notice a change in my thinking from being teacher-centered to becoming more student-centered after examining the reflections in my e-journal. I examined my comments related to students such as considering their needs, their skills, and their interests. I reviewed ideas that I recorded such as fostering more active student learning through discourse and modeling approaches, promoting more collaboration through teams, and presenting students with challenges to engage in the course material. For example, I noted that the *LfU* model was helpful to me in providing the design goals of "creating demand" and "eliciting curiosity" for my students. An illustration of achieving these design goals included the design and construction of a solar car (a STEM integrative activity) for both the chemistry (Case 1 and Case 2) and engineering (Case 5) classes (Ing, Ward, & Haberer, 2013). Discussion and activity items included, but were not limited to, how solar cells work, how gears and pulleys work, and how electric motors are constructed. Students found this activity both engaging and fun. Moreover, the activity promoted discourse not only between myself and the students but also amongst students in both the chemistry (Case 3 and Case 4) and engineering (Case 5) classes.

One item that particularly struck me was the notion of including real world applications in my lesson design. My background and experience were replete with a myriad of real world experiences. The key question for me was "Were my students connecting with my view of the real world?" I came to realize that I must design the instruction so that my students can connect with the lesson given their prior knowledge and linked to their view of their real world and not necessarily mine. An additional example of becoming more student-centered in the unit design was the consideration of student misconceptions. I learned that in order to address student misconceptions, questions must be posed. The *best practices* for questioning (e.g. *questioning cycle* and *talk moves*) offered the opportunity for discourse during the unit enactment.

Phase One Unit Enactment

Phase One unit enactment consisted of the activities of the administration of the COLES student survey, execution of the planned unit, and the subsequent administration of the COLES student survey. The duration of these activities was approximately three weeks of the five-week duration for each study phase.

COLES Student Survey Pre/Post Unit Enactment

The COLES student survey provided a source of independent data other than my own reflections and the feedback from critical friends and the study administrator. Mary, the critical friend mathematics teacher administered the COLES survey to students. I was not present when the survey was administered. Moreover pseudonyms were used by Mary to preserve anonymity. The relationship between student names and the pseudonyms were completely managed by Mary and were not disclosed by Mary to anyone. I did not have access to this relationship at any time either during the study or after the study was completed.

The Phase One response rate for the COLES survey is Table 4.4.

Table 4.4. Phase One COLES Response Rate and Demographic Information

Case ID	Case 1	Case 2	Case 3	Case 4	Case 5
Grade	11,12	11	11,12	12	9,10,11,12
Subject	Chemistry Section 1	Chemistry Section 2	Statistics Section 1	Statistics Section 2	Engineering
Level of Participation	None	None	15 out of 27	13 out of 27	18 out of 24
Gender	0M, 0F	0M, 0F	6M,9F	6M,7F	16M, 2F

The table provides a summary of student participation from my chemistry (Case 1 and Case 2), statistics (Case 3 and Case 4), and engineering (Case 5) classes. The chemistry classes (Case 1 and Case 2) expressed that they did not want to be surveyed. This was not surprising to me as these students, as previously discussed in Chapter 3 on methods, had issues with being video or audio recorded and had difficulties with trusting school administration. In accordance with their wishes, these chemistry classes were not surveyed using the COLES instrument. Out of the total of seventy-eight students for the statistics (Case 3 and Case 4) and engineering (Case 5) classes, forty-two students participated in the COLES survey. These forty-two students took the entire (fourteen subscale) Phase One pre/post-unit enactment COLES survey.

Analysis of the Phase One pre/post unit enactment survey process and survey data revealed that the survey took fifty percent longer than I previously predicted. Following the administration of the Phase One post-unit enactment COLES, students reported to Mary that the survey took a long time to complete. Each question in COLES had both an “actual” and “preferred” column selection. For example, in the subscale on Equity, one of eight questions is listed as “I am treated the same as other students in this class”. The “actual” column response reflects the student’s perception of the real classroom environment whereas the “preferred” column reflects what the student would prefer to happen. In analyzing all “preferred” column responses for all subscales, on average the Likert response were all greater than 4.5 out of 5. The meaning of a score of 4 indicates that the student preferred that item “often”. The meaning of a score of 5 indicates that the student preferred that item “almost always”. Based on this examination, I concluded that collecting this preference data would not be useful for this study. I also reviewed each of the fourteen subscales and rated each subscale based on previously identified areas for improvement in my teaching practice. I selected those subscales that related to my support and treatment of students (ethic of care), namely “Teacher Support” and “Equity”. I selected the “Clarity of Assessment Criteria” subscale given my aforementioned study goal of improving my assessment capabilities. I selected the subscale “Attitude Towards Subject” to examine to what extent any student attitude changes occurred given the interventions in each study Phase.

The Phase One COLES pre/post unit enactment subscale scores are used to indicate student perceptions of their learning environment in terms of the following subscales: “Teacher Support”, “Equity”, “Clarity of Assessment Criteria”, and student “Attitude Towards Subject”. Examples of statements about practices in my class that students assessed the level of occurring in my class included:

- The teacher in interested in my problems (Teacher Support)
- I am treated the same as other in this class (Equity),
- I understand how to complete assessment tasks successfully (Clarity of Assessment Criteria)

- Lessons in this subject interest me (Attitude Towards Subject)

The students were asked to describe how often each practice takes place in the class. The meaning of the score was as follows: 1 (Almost Never), 2 (Seldom), 3 (Sometimes), 4 (Often), and 5 (Almost Always). A summary of the Phase One COLES subscale mean scores (each out of a total of five) pre/post unit enactment for the statistics (Case 3 and Case 4) and engineering (case 5) classes is provided in Table 4.5. The Phase One COLES pre-unit enactment subscale scores indicate student perceptions of a learning environment in which "Teacher Support", "Equity", and "Clarity of Assessment Criteria" are positioned more toward the "often" rating. Students' "Attitude Toward Subject" varied from less than "seldom" (Score of 2) to "often" (Score of 4). The statistics classes (Case 3 and Case 4) had the lowest scores for "Attitude Toward Subject".

Table 4.5. Phase One COLES Subscale Mean Scores (each out of a total of 5) Pre/Post Unit Enactment

Case ID	Case 3 Statistics Section 1, (n=15)	Case 4 Statistics Section 2 (n=13)	Case 5 Engineering (n =18)
Subscale	Pre, Post	Pre, Post	Pre, Post
Teacher Support	3.82, 3.51	3.71, 3.15	3.61, 3.55
Equity	4.28, 3.87	4.67, 4.10	3.61, 3.97
Clarity of Assessment Criteria	4.05, 3.49	3.69, 3.02	3.95, 3.68
Attitude towards Subject	2.64, 2.29	2.68, 1.63	3.91, 4.10

For the engineering class (Case 5), "Attitude Towards Subject" was the highest score for all cases. A possible reason for these higher scores was that students in the engineering class elected to be in this class and thus may have been more motivated.

In another study, a high school biology teacher used COLES as part of her action research project over a period of six weeks (Aldridge et al., 2012). The "pre" results for this teacher's study were as follows: "Teacher Support" (4.2), "Equity" (4.3), "Clarity of Assessment Criteria" (3.7), and "Attitude Towards Subject" (3.1). When comparing these data to the data for this study in Table 4.5, I found that the numbers were similar to the "pre" Phase One results I had obtained.

A cross-case analysis of Table 4.5 indicated that I gave my students support as their science and mathematics teacher with scores ranging between "sometimes" (Score of 3) and "often" (Score of 4). Students perceived the learning environment as equitable mostly "often" (Score of 4). Student understanding of what they were being assessed on ranged between "sometimes" (Score of 3) and "often" (Score of 4). These scores were also supportive of my emerging belief in becoming a more student-centered practitioner and an improved assessment designer.

A paired t-test of all subscale means in Table 4.5 revealed two instances of statistical significance ($p < 0.05$) both for the statistics (Case 4) class: "Equity" ($p = 0.045$) and "Attitude towards Subject" ($p = 0.025$). After the enactment of Phase One, approximately eighty percent of the subscale mean scores were lower post-unit enactment than pre-unit enactment. For example, in the statistics class (Case 4), the subscale mean score for the "Equity" was 4.10 post-unit enactment and 4.67 pre-unit enactment. A possibility for these lower subscale mean scores post unit enactment could be related to the time it took students to complete the COLES survey. Student feedback on the survey to Mary, the critical friend who administered the survey, was that the survey was long. Another possible explanation for these lower mean subscale scores post unit enactment could be that the course material was more challenging to statistics (Case 3 and Case 4) students. On average letter grades were reduced by a half letter grade (e.g. going from a B+ to a B) pre and post Phase One unit enactment for the statistics (Case 3 and Case 4) classes. For the statistics classes (Case 3 and Case 4) all subscale mean scores were lower post unit enactment. An explanation for these lower scores in the statistics (Case 3 and Case 4) classes could be also that students in these classes (who were overwhelmingly seniors about to graduate in two months) were losing interest in the class. For the engineering class (Case 5) there was a modest increase in subscale mean score for "Attitude towards Subject" (3.91 to 4.10).

Observations During Unit Enactment

During Phase One there were no classroom observations made by either critical friends or the study administrator due to their availability. Thus, I had no feedback from knowledgeable practitioners on classroom enactments. The lack of involvement was due to the nature of the school climate previously discussed in which time was at a premium and they had other priorities.

Phase One Unit Reflections

The duration of these Phase One reflective activities was approximately one week of the five-week duration for each study phase. I selected the chemistry (Case 3 and Case 4) and engineering (Case 5) classes to be video-recorded each once in order to get a sampling by subject area of my use of STEM instructional orientations, discourse, and *modeling.* The exception to this selection were the chemistry (Case 1 and Case 2) classes whose students elected not to be video-recorded. This decision of the chemistry (Case 1 and Case 2) students not to participate in any video-recorded sessions was discussed in detail in Chapter 3 on methods.

I used the Reformed Teaching Observation Protocol (RTOP) with STEM rubric, the *questioning checklist, talk moves*, and the Generate, Evaluate, and Modify (GEM) rubric measures to self-assess while I viewed the video enactments. The RTOP with STEM rubric (Appendix L) provided an observational tool to examine principles that are unique to a STEM curriculum such as lesson design, implementation, and content, as well as classroom communication. There are twenty-five statements (each with a Likert scale from 0 to 4), which provides a total possible score from the RTOP with STEM rubric of one hundred, which can be interpreted as a percentage of total. The rubric is organized in three sections, which include lesson design and implementation (six questions), content knowledge (ten questions), and classroom culture (nine questions). The questioning checklist (see Appendix M) provided a means for me to self-assess the level of questioning in my classroom. There are nine questions (each with a Likert scale from 0 to 4). Numerical scoring in this checklist was translated to a categorical level of questioning activity, namely, none, seldom, moderate, and frequent. The *talk moves* checklist (see Appendix B) provided a means for me to self-assess the level of discourse in my classroom. Numerical scoring was translated to a categorical level of discourse activity namely, none, seldom, moderate, and frequent. The GEM Rubric (see Appendix C) provided a means for me to self-assess the level of modeling instruction in my classroom. The rubric has two columns (coded as “I” and “S”), which corresponds to instructor and student modeling activity. For each item in the rubric a value from 0 (no observation of activity), 1 (seldom activity observed 1-2 times), 2 (moderate activity observed 3-5) or 3 (frequent activity observed greater than 5 times) is scored. A mean score was then computed and related back to “seldom”, “moderate”, and “frequent” categories. These self-assessments were previously described in Chapter 3 on methods in terms of the type of assessments and how each measure was used to score the self-assessment.

After I viewed the video recording once, I proceeded to view the video recording a second time and then recorded my self-assessment. I selected a specific *talk moves* item (using wait time) after determining that I had scored myself lowest on this item. Furthermore, I selected a specific *questioning checklist* items (Did my questions build conversations?) after determining that I had scored myself lowest on this item.

A summary of my use of RTOP with STEM rubric, a specific questioning checklist items, a specific *talk moves* item, and the GEM rubric for Phase One unit enactment self-assessment is provided in Table 4.6.

Table 4.6. Phase One Unit Enactment - Self Assessment Data

Case ID	Statistics (Case 3)	Statistics (Case 4)	Engineering (Case 5)
RTOP with STEM Rubric	53 %	45 %	68 %
Talk Moves: Using Wait Time	Seldom	Seldom	Seldom
Questioning Checklist: Did my questions build conversations?	Seldom	Seldom	Moderate
GEM Rubric			
Generate	Seldom	Seldom	Moderate
Evaluate	Seldom	Seldom	Moderate
Modify	Seldom	Seldom	Moderate
Seldom = 1-25 % time Moderate = 26-50 % time Frequent = 51-75 % time			

The RTOP with STEM rubric self-assessment scoring for Phase One unit enactment reflections ranged from approximately 50% to 70%. The RTOP scores provided a comparative means for me to assess my STEM instructional orientations across cases. Furthermore, the highest RTOP score was associated with the engineering (Case 5) class. In reviewing the data displayed in Table 4.6, I wondered why was I making seldom use of *discourse* and *modeling* given I had planned to implement those *best practices* in my Phase One unit plan. I was having some moderate success at *modeling* in the engineering (Case 5) class. For example, in the engineering Case 5) class we discussed analogical models of electricity. Discourse was more evident in the engineering class (Case 5) class given the moderate score.

Analysis of the reflections in my e-journal revealed a theme of "confidence" with teaching the engineering (Case 5) class. I reasoned that since I had taught this engineering class previously, my confidence was higher. In addition, this reflection was not surprising given my previous background and experience in engineering as a former design engineer and engineering manager. Furthermore, my RTOP score of 68% for the engineering (Case 5) class was the highest in Table 4.6 in comparison to the RTOP scores of 53% and 45% for statistics (Case 3) and statistics (Case 4) classes respectively. In contrast, this year was the first time I had ever taught statistics. My confidence is teaching statistics was lower than the chemistry and engineering classes. After examining the video record for both statistics (Case 3 and Case 4) classes and my reflections, I concluded that I had not appropriately scaffolded *discourse* and *modeling* for students in these classes. I attributed this conclusion to not thinking through how to model "hypothesis testing" for students. Also, despite my attempts with *talk moves,* students were not engaged. Based on student assessments, I reasoned that the material was on “hypothesis testing” was quite challenging for them and they were struggling. I planned in Phase Two to improve the scaffolding of the course material. Finally, in viewing the video recordings, I could readily see that I was not using “wait time”. I was moving too fast. I planned in Phase Two to make explicit attempts to improve using “wait time” with daily reminders to myself to wait.

At this point in the study, it became apparent to me that I had collected and analyzed a significant amount of data and Phase One was just completed. I was not immune to feelings of anxiety and being overwhelmed given the study’s contextual factors. I decided that I would focus Phase Two of the study on my statistics classes. The rationale for this decision was based on two potential improvement opportunities: (1) the COLES data from Table 4.5 revealed that these statistics (Case 3 and Case 4) classes had the lowest “Attitude towards Subject” scores, and (2) The self-assessment unit enactment data from Table 4.6 indicated an improvement opportunity to increase wait time, build more conversations with my students, and improve *modeling* instruction.

Summary of Phase One Findings

A summary of Phase One findings and evidence to support the findings is provided in Table 4.7.

Table 4.7. Summary of Phase One Findings

Phase One Findings	Evidence
• Instructional design process is analogous to the engineering design process	• Table 4.3
• Importance of *NGSS* standards in STEM Integration	• Unit Designs
• Designing balanced assessments	• Unit Designs, Reflections • COLES (Table 4.5)
• Becoming more student-centered	• Unit Designs, Reflections • COLES (Table 4.5)
• Need to improve o Increasing wait time o Building more conversations with students o Improve modeling instruction	• Self-assessment data from (Table 4.6)

Analysis of the Phase One unit design process previously described earlier in this chapter revealed the finding of an analogous relationship between the instructional design process I used in constructing unit plans and the engineering design process. For example, when designing instruction teachers review what is required by examining criteria in terms of standards and review constraints such as time or perhaps how much they know about the subject they have to teach. Teachers also have to consider prior knowledge of students at this point in the design. Analogously, engineers meet with customers to discuss what are their problems and needs and what are the criteria and constraints for the product that the customer wants or needs. Table 4.3 provided the means for me to examine the relationships amongst the design frameworks and led to this finding.

As previously stated, I began focusing more on using the *NGSS* to assist me in designing my units to promote STEM integration. Several examples of STEM integration were provided and discussed. I found myself considering the standards (like an instructional design engineer) as critical instructional design requirements. This finding of realizing the importance of the *NGSS* standards led to a subsequent finding of my becoming a more balanced assessment designer. Design of assessments for learning (formative) and assessments of learning (summative) became more a part of my teaching practice. Student feedback from COLES data in Table 4.5 indicated their understandings of what they were being assessed on ranged between "sometimes" (Score of 3) and "often" (Score of 4).

I was becoming more student-centered in my teaching practice. During the unit design, I was focused on students' misconceptions and strategies for "eliciting curiosity" in my students. A cross-case analysis of Table 4.5 indicated that I gave my students support with scores ranging between "sometimes" (Score of 3) and "often" (Score of 4). Students perceived the learning environment as equitable mostly "often" (Score of 4). These scores were supportive of my emerging belief in becoming a more student-centered practitioner.

Finally, analysis of the Phase One unit enactment self-assessment data (Table 4.6) indicated that I needed improvement in increasing "wait time", building more conversations with my students, and getting students to think more about modeling.

Lessons Learned from Phase One

Barab and Leuhmann (2003) discuss how design-based research consists of a series of design experiments, which introduce design innovations and trace learning as it relates to each new intervention. The authors stated that, “Lessons learned are then cycled back in the next iteration of the design interventions, with a focused examination and reflection on how each release of the innovation impacts the learning process” (p. 460). Based on the analysis of the Phase One data and the findings, I focused on the statistics (Case 3) and statistics (Case 4) classes. The rationale for selecting these statistics classes was related to my self-assessment scores on *discourse* and *modeling* for these classes. Additionally, from Table 4.5 the statistics (Case 3 and Case 4) classes had the lowest COLES subscale mean scores on “Attitude Toward Subject” at 2.45 and 1.86 respectively. Furthermore, I identified improvement opportunities such as increasing “wait time”, building more conversations with my students, and getting students to think more about generating, evaluating, and modifying models. This focus would necessitate me to determine ways in Phase Two unit plan design and implementation to accomplish these outcomes. Give this design decision, the research question for the study was modified from Phase One to be: To what extent am I improving “wait time”, building conversations with my students, and incorporating modeling instruction in my statistics classes while I design, enact, and reflect on unit plans through the lens of the *NGSS*. Additionally, I expected that my learning in STEM integration, balanced assessments, and student-centered practice in Phase One would carry over into Phase Two.

Finally, I made a modification regarding the collection of COLES student data for Phase Two given student feedback on the survey being too long. For the COLES survey, students would only respond to questions from the following four subscales: “Teacher Support”, “Equity”, “Clarity of Assessment Criteria”, and “Attitude Toward Subject”. Furthermore, students would only respond to the “actual” column and not the “preferred” column of the COLES survey.

Phase Two Data Analysis and Findings

This section describes the details of the Phase Two study actions of unit planning, unit enactment, and unit reflection. One unit plan was designed for the one subject area namely statistics during the study phase action of “unit planning”. Furthermore, reflections and data analysis on “unit planning” resulted in study findings. This unit plan was implemented during the study phase action of “unit enactment” in my two statistics (Case 3 and Case 4) classes. Both pre and post COLES student survey data, critical friend and study administrator observational data, and self-assessment data were analyzed during the study phase action of “unit reflection”. This analysis resulted in study findings and lessons learned to inform the design of Phase Three of the study.

Phase Two Unit Planning.

Phase Two unit planning consisted of designing a unit plan for the one subject of statistics for my two class sections of statistics (Case 3 and Case 4). A summary of the topic covered for statistics for the Phase Two unit plan is provided in Table 4.8.

Table 4.8. Phase Two Designed Unit Plan for Statistics by Topic

Subject	Statistics (Case 3)	Statistics (Case 4)
Topic	Correlation	Correlation

Correlation is a way to measure how associated or related two variables are. The purpose of doing correlations is to allow students to make a prediction about one variable based on what is known about another variable. An advantage of the correlation method is that students can make predictions about things when they know about correlations. If two variables are correlated, students can predict one based on the other. A correlation tells students that the two variables are related, but students cannot conclude anything about whether one caused the other. This method does not allow students to come to any conclusions about cause and effect. The unit plan on correlation for Phase Two for the statistics (Case 3 and Case 4) classes is provided in Appendix J. The unit plan design experience in Phase One increased my self-efficacy in designing units that had STEM integrative experiences. I believed I was becoming a more balanced assessment designer based on use of both formative and summative assessments. Furthermore, I was becoming a more student-centered teacher with increased focus on student engagement. I applied this learning to the design of units for my statistics classes in Phase Two. For example in the statistics unit on correlation, students were asked to analyze data on altitude versus temperature and car weight versus gas mileage. The science behind this data was reviewed in the class to integrate scientific disciplinary ideas to provide context for the data. Students were subsequently asked to determine if there is a correlation between those paired items and if so, is the correlation significant. Students connected and were engaged by these real world examples in both statistics (Case 3 and Case 4) classes. Furthermore, as I designed unit plans for Phase Two, I noted in my e-journal how much more confident I felt about STEM integration.

Phase Two Unit Enactment

Phase Two unit enactment consisted of using the COLES survey from the Phase One post unit enactment, execution of the planned unit, and followed by a subsequent administration of the COLES survey. The duration of these activities was approximately three weeks of the five-week duration for each study phase.

COLES Survey Pre-Post Unit Enactment

Mary, the critical friend mathematics teacher administered the COLES survey to students. I was not present when the survey was administered. Moreover, as in Phase One, pseudonyms were used by Mary to preserve anonymity. The relationship between student names and the pseudonyms was completely managed by Mary and was not disclosed by Mary to anyone. I did not have access to this relationship at any time either during the study or after the study was completed.

The Phase Two response rate for the COLES survey is provided in Table 4.9. The table provides a summary of student participation from my statistics (Case 3 and Case 4) classes. Out of the total of fifty-four students for the statistics (Case 3 and Case 4) classes, twenty-eight statistics students participated in the COLES survey. The table provides a summary of the number of students who participated in the survey along with gender and grade level related data. The statistics students (Case 3 and Case 4) for Phase Two in Table 4.9 took the revised COLES survey from Phase One. Based on student feedback from Phase One given that the COLES survey was too long, I revised the COLES survey. Students would only respond to questions from the following four subscales: “Teacher Support”, “Equity”, “Clarity of Assessment Criteria”, and “Attitude Toward Subject”. Furthermore, students would only respond to the “actual” column and not the “preferred” column of the COLES survey. To facilitate students only responding to these items all other subscales and preferred columns were crossed out.

Table 4.9. Phase Two COLES Response Rate and Demographic Information

Case ID	Case 3	Case 4
Grade	11,12	12
Subject	Statistics	Statistics
Level of Participation	15 out of 27	13 out of 27
Gender	6M, 9F	6M,7F

A summary of the Phase Two COLES subscale mean scores (each out of a total of five) pre/post unit enactment for the statistics (Case 3 and Case 4) is provided in Table 4.10.

Table 4.10: Phase Two COLES Subscale Mean Scores (each out of a total of 5) Pre/Post Unit Enactment

Case ID	Case 3, Statistics Section 1, (n= 15)	Case 4, Statistics Section 2, (n=13)
Subscale	Pre, Post	Pre, Post
Teacher Support	3.51, 3.25	3.15, 3.57
Equity	3.87, 3.98	4.10, 4.26
Clarity of Assessment Criteria	3.49, 3.75	3.02, 3.43
Attitude towards Subject	2.29, 2.45	1.63, 1.86

The meaning of the score is as follows: 1 (Almost Never), 2 (Seldom), 3 (Sometimes), 4 (Often), and 5 (Almost Always). A cross-case analysis of Table 4.10 indicated that students felt supported by myself as their science and mathematics teacher with scores ranging between "sometimes" (Score of 3) and "often" (Score of 4). Students perceived the learning environment as equitable mostly "often" (Score of 4). Student understanding of what they were being assessed on ranged between "sometimes" (Score of 3) and "often" (Score of 4).

Students' attitude toward the subject varied from less than "seldom" (Score of 2) to "sometimes" (Score of 3).

A paired t-test of all subscale means in Table 4.10 revealed no instances of statistical significance ($p < 0.05$). In other than one instance of teacher support for Cases 3, all subscale mean scores were modestly increased (< 13% maximum) during the Phase Two unit enactment. Although not significant, the COLES data does show favorable results regarding my teaching practice from my students" perspective.

Observations During Unit Enactment

During Phase Two there were three classroom observations. The study administrator made two observations. Additionally, a critical friend made one observation. The study administrator, Peter, observed the statistics class (Case 4). The lesson observed was on correlation. The focus of the lesson was on students designing their own correlational studies. Feedback from the study administrator was provided via the following statement:

> The fact that the lesson was a practical application of difficult mathematical skills was outstanding. Students were better able to learn the concepts through practice and analysis. The student surveys that were being planned were exciting.

Peter also observed a chemistry class (Case 2). The lesson observed was on solids and liquids. The focus of the lesson was on students creating silly putty. Feedback from the study administrator was provided via the following statement:

> The class was designed to gain the interest of the students and to challenge them to problem solve. The experiment was designed not to produce perfect

results and to have students improve on experimental methods. The class expectations were to achieve rigor yet address the special needs of this alternate school. Differentiated learning and differentiated classroom management were observed through the lesson.

During Phase Two, I experienced what Schön (1991) referred to as a "reflective turn". with regard to "wait time". Russell (2012) discussed Schön's (1991) notion of the idea of a "reflective turn" with regard to teaching practice: "The reflective turn is … a kind of revolution. It turns on its head the problem of constructing an epistemology of practice. It offers, as a first-order answer to the question, what do practitioners need to know?" (Schön, 1991, p. 5). I reflected in my e-journal about this "wait time" experience in which a special education student in the back of the classroom was thinking about the questions I had posed. I continued to encourage all students to think about the questions as I waited. All of a sudden I noticed that this student was beaming with a big smile. She raised her hand to answer the question and explained her rationale to the class. I reflected about the ethic of care theory previously discussed in Chapter Two. The ethic of care theory aids in understanding the importance of building relationships in educational settings: relationships between teachers and students, teachers and teachers, teachers and administrators, teachers and parents, teachers and the community, etc. I felt that I truly cared about this student's success. This "wait time" experience crystallized for me a study finding that in order for me to be a successful teacher, I need to care about building relationships. Specifically, I need to tell students I care about them and I need to demonstrate to them that I truly care about them.

Jim, the critical friend statistics teacher, observed the statistics class (Case 3). The lesson observed was on correlation. The critical friend only used the RTOP with STEM rubric (maximum score attained 67%). An observational record from Jim with feedback detailing for areas of improvement and strengths is provided in Appendix N. I identified strongly with Jim's area of improvements with regard to using a case study to examine correlation and calling on people more often (which relates to building conversations with students).

Observations from Peter, the study administrator, were typically positive. Observations from Jim, the critical friend statistics teacher provided meaningful feedback in the form of area of improvement and strengths. As I reviewed the observational data, I reflected on whether I should have trained critical friends in the usage of the assessment tools and explicitly informed them of what I expected. Classroom observation and an in-depth critical analysis is a skill that needs to be developed and thus requires time. Given the study's contextual factors and overall school climate, time for school personnel was precious and limited.

Phase Two Unit Reflections

The duration of these Phase Two reflective activities was approximately one week of the five-week duration for each study phase. I selected the statistics (Case 3 and Case 4) classes to be video-recorded each once. I limited the total number of video recorded enactments given the significant time involved in the collection and analysis of this video data. A continuing study challenge previously discussed was the increased time commitment for this study in a school climate where time was precious and limited. Further details regarding the rationale for limiting video recordings in provided in Chapter 3 on methods.

I used the Reformed Teaching Observation Protocol (RTOP) with STEM rubric (for STEM instructional orientations), the *questioning checklist* (for discourse), *talk moves* (for discourse*)*, and the Generate, Evaluate, and Modify (GEM) rubric (for modeling) measures to self-assess while I viewed the video enactments.

A comparative summary from post Phase One unit enactment and post Phase Two unit enactment self-assessment data is provided in Table 4.11.

Table 4.11. Comparative Summary: Post Phase One/Post Phase Two Unit Enactment - Self-Assessment Data

Case ID Measure	Case 3, Statistics 1	Case 4, Statistics 2
RTOP with STEM Rubric	52 % to 63 %	45 % to 56 %
Talk Moves: Using Wait Time	Seldom to Moderate	Seldom to Moderate
Questioning Checklist: Did my questions build conversations?	Seldom to Moderate	Seldom to Seldom
GEM Rubric		
Generate	Seldom to Moderate	Seldom to Seldom
Evaluate	Seldom to Seldom	Seldom to Seldom
Modify	Seldom to Seldom	Seldom to Seldom
Seldom = 1-25 % of time	Moderate = 26-50 % of time	Frequent = 51-75 % of time

From Table 4.11 RTOP self-assessment score of 63% for the statistics class (Case 3) was similar to the RTOP score (67%) from Jim, the critical friend statistics teacher. I compared my scoring to Jim's scoring and found some minor differences. For example, I scored myself higher in connections to other content disciplines than Jim did. I scored myself lower on wait time than Jim did. I calculated the intra-class correlation coefficient from both Jim and my scores which resulted in an $r = 0.72$ which is statistically significant (for $N = 25$ and αlpha = 0.05).

A review of the data in Table 4.11 revealed modest improvements from Phase One to Phase Two in STEM orientations using the RTOP across all cases. Using “wait time” also improved across cases from “seldom” to “moderate”. Additionally, the activity of building conversations with my students modestly increased for the statistics (Case 3) class. The lack of activity in this building conversations activity for statistics (Case 4) is discussed later in this chapter.

Modeling instruction as measured by the GEM rubric consists of generating the initial model, (Generate), evaluating the model (Evaluate), and modifying by model through change and enrichment (Modifying). Modeling instruction in terms of generation of models modestly improved in the statistics (Case 3) class. The lack of activity in modeling for the statistics (Case 4) class is discussed later in this chapter. There were no instances of improvement in modifying models for either of the two cases in Phase Two. I attribute these results to my lack of designing appropriate scaffolding in my lessons for this type of modeling activity.

Upon review of data in Table 4.11, I concluded that I had made improvement from Phase One to Phase Two from “seldom to moderate” for *discourse* and *modeling* for the statistics class (Case 3) but not for the other statistics class (Case 4). I reflected on this difference in my e-journal:

> “Conversations in Section 1 stats are on the rise. They are getting the hang of thinking in terms of models. They are excited about their research projects using hypothesis testing and correlation. In contrast, Section 2 stats seem disinterested. Their focus just seems to be on finishing out the school year. With one more month to go they are anxious to finish their high school career. I feel that they have mailed it in and given up. Assessment data backs this up.”

Summary of Phase Two Findings

A summary of Phase Two findings as well as the references to the evidence to support the findings is provided in Table 4.12.

Table 4.12. Summary of Phase Two Findings

Phase Two Findings	Evidence
• Ethic of Care Emerged	• Unit Enactment Reflection
• Need to improve o Building more conversations with students o Improve modeling instruction	• Table 4.11

The ethic of care theory aids in understanding the importance of building relationships in educational settings: relationships between teachers and students, teachers and teachers, teachers and administrators, teachers and parents, teachers and the community, etc. In order for me to be a successful teacher, I need to care about building relationships. Specifically, I need to tell students I care about them and I need to demonstrate to them that I truly care about them.

Finally, analysis of the Phase One/Phase Two comparative summary in Table 4.11 indicated that I needed further improvements in building more conversations with my students, and getting students to think more about generating, constructing, and evaluating models.

Lessons Learned from Phase Two

Based on the analysis of the Phase Two data and the findings, I focused on the statistics (Case 3) class. The rationale for selecting this class was related to my self-assessment scores on *discourse* and *modeling* for these classes. More specifically, I identified improvement opportunities such as building more conversations with my students, and getting them to think more about generating, evaluating, and modifying models. This focus would necessitate me to determine ways in the Phase Three unit plan design and enactment to accomplish these outcomes. I expected that my learning in STEM integration, balanced assessments, and student-centered practice from previous study phases would carry over into Phase Three. Furthermore I expected similar carryover in learning on *modeling instruction* and *discourse*. Finally, I expected to carry over into Phase Three the ethic of care philosophy that emerged from Phase Two. Thus, the research question for this study for Phase Three was: To what extent am I improving building conversations with my students and incorporating modeling instruction in my statistics (Case 3) class when I design, enact, and reflect on unit plans through the lens of the *NGSS*.

Phase Three Data Analysis and Findings

This section describes the details of the Phase Three study actions of unit planning, unit enactment, and unit reflection. One unit plan was designed for the one subject area namely statistics during the study phase action of "unit planning". This unit plan was implemented during the study phase action of "unit enactment" in my one statistics (Case 3) class. Both pre and post COLES student survey data and self-assessment data were analyzed during the study phase actions of "unit enactment" and "unit reflection."

Phase Three Unit Planning

Phase Three unit planning consisted of designing a unit plan for one statistics class (Case 3). The unit topic was on regression. The unit plan is provided in Appendix K. Regression models are useful to predict one variable from one or more other variables. I explicitly included in this unit plan design the model eliciting activity (MEA) of having students use their project data to generate simple regression models. My design intent was to build conversations with students about modeling based on their self-selected project study data.

In terms of STEM integration and as a prelude to discussing regression, students were provided with a New York Times article. The article was entitled: "Why can some kids handle pressure while others fall apart?" (Bronson & Merryman, 2013). The article posited that part of the issue of handling pressure might be genetic. The students read the article individually and then discussed it in groups before having a whole class discussion. Guiding questions for group discussion included: Are the claims exaggerated? Did the authors consult the relevant literature and background science? The whole class discussion was quite engaging with students getting practice in the idea of engaging in scientific argumentation (an *NGSS* science and engineering practice). The statistics students (Case 3) were subsequently provided with the research study referenced in the New York Times article. This research study, conducted on Taiwan middle school children, was on the Catechol-O-methyltransferase (COMT) gene (Yeh, Chang, Hu, Yeh, & Lin, 2009). This gene carries the assembly code for an enzyme that clears dopamine from the pre-frontal cortex. Findings from the research study provide evidence that affective factors might overwhelm cognitive abilities in high stakes tests dependent upon variants of the gene. The purpose of providing my students with this article was twofold: (1) to have students examine a research study with some of the statistical concepts and methods they learned up to that point, and (2) discuss the study's claims in light of their review New York Times article. An interesting outcome of this discussion was that most students wondered whether the "n" was sufficient enough to conclude anything reliably about the genetic effects discussed.

Phase Three Unit Enactment

Phase Three unit enactment consisted of using the COLES survey from the Phase Two post unit enactment, execution of the planned unit, and followed by a subsequent administration of the COLES survey. The duration of these activities was approximately three weeks of the five-week duration for each study phase.

COLES Survey Pre/Post Unit Enactment

Mary, the critical friend mathematics teacher administered the COLES survey to students. I was not present when the survey was administered. Moreover, as in previous phases, pseudonyms were used by Mary to preserve anonymity. The relationship between student names and the pseudonyms was completely managed by Mary and was not disclosed by Mary to anyone. I did not have access to this relationship at any time either during the study or after the study was completed.

The Phase Three response rate for the COLES survey is provided in Table 4.13.

Table 4.13. Phase Three COLES Response Rate and Demographic Information

Case ID	Case 3
Grade	12
Subject	Statistics
Level of Participation	15 out of 27
Gender	6M,9F

The table provides a summary of how many students participated in the survey along with gender and grade level related data. A total of fifteen statistics (Case 3) students took the revised COLES survey from Phase Two. This number “n” was low considering previous

Phase One (fifty-four) and Phase Two (twenty-eight) total COLES participants. A summary of the Phase Three COLES subscale mean scores (each out of a total of five) pre/post unit enactment for the statistics (Case 3) class is provided in Table 4.14.

Table 4.14. Phase Three COLES Subscale Mean Scores (each out of a total of 5) Pre/Post Unit Enactment

Case ID	Case 3, Statistics Section 1, (n= 15)
Subscale	Pre, Post
Teacher Support	3.25, 3.67
Equity	3.98, 4.05
Clarity of Assessment Criteria	3.75, 4.01
Attitude towards Subject	2.45, 2.89

The meaning of the score is as follows: 1 (Almost Never), 2 (Seldom), 3 (Sometimes), 4 (Often), and 5 (Almost Always). An analysis of Table 4.14 indicated I gave my statistics students with a score closer to “often” (Score of 3.67). Students perceived the learning environment as equitable “often” (Score of 4.05). Student understanding of what they were being assessed on as “often” (Score of 4.01). Students’ attitude toward the subject approached “sometimes” (Score of 2.89).

An analysis of post Phase Three unit enactment data indicated that I gave my students support with a score more towards “often” (Score of 3.67). Students perceived the learning environment as equitable “often” (Score of 4.05). Student understanding of what they were being assessed on was “often” (Score of 4.01). Students’ attitude toward the subject was more towards “sometimes” (Score of 2.89).

A paired t-test of all subscale means for Phase Three in Table 4.14 revealed no instances of statistical significance ($p < 0.05$). All subscale mean scores were modestly increased (< 16% maximum) during the Phase Three unit enactment.

Observations During Unit Enactment

During Phase Three there were no classroom observations made by either critical friends or the study administrator. Thus, I had no feedback from knowledgeable practitioners on classroom enactments. The participants explicitly informed me that their lack of involvement was directly related nature of the school climate, which left them little time to assist with this final study phase.

Phase Three Unit Reflections

The duration of these Phase Three reflective activities was approximately one week of the five-week duration for this study phase. I selected the statistics (Case 3) class to be video-recorded twice during this phase. I limited the total number of video recorded enactments given the significant time involved in the collection and analysis of this video data. A continuing study challenge previously discussed was the increased time commitment for this study in a school climate where time was precious and limited. Further details regarding the rationale for limiting video recordings is provided in Chapter 3 on methods.

I used the Reformed Teaching Observation Protocol (RTOP) with STEM rubric (for STEM instructional orientations), the *questioning checklist* (for discourse), *talk moves* (for discourse*)*, and the Generate, Evaluate, and Modify (GEM) rubric (for modeling) measures to self-assess while I viewed the video enactments. I selected a specific *questioning checklist* item (Did my questions build conversations?) as I had done in Phase One and Phase Two. A comparative summary from post Phase Two unit enactment and post Phase Three unit enactment self-assessment data is provided in Table 4.15.

Table 4.15. Comparative Summary: Post Phase Two/Post Phase Three Unit Enactment - Self-Assessment Data

Case ID/Measure	Case 3 Statistics 1(Pre to Post)
RTOP	63 % to 67%
Did my questions build conversations?	Moderate to Moderate
GEM Rubric	
Generate	Moderate to Moderate
Evaluate	Seldom to Moderate
Modify	Seldom to Moderate
Seldom=1-25 % of time; Moderate=26-50% of time:	Frequent = 51-75 % of time

There was a minor increase in RTOP score from 63% to 67%. In reviewing the specific data from the scoring, there was not anything significant to note in the RTOP scores. Furthermore, there was no significant increase in building student conversations yet these conversations were maintained. All three elements of the GEM framework were utilized to a moderate level. The regression model from the unit plan provided an important vehicle for students to generate their project regression models, evaluate them, and modify their models to determine impacts. For example, students were given data on engine size versus mileage. Activities included determining if the correlation was significant, generating the regression equation, and evaluating the regression model in terms of estimating gas mileage given a specific engine size and vice versa. Furthermore, students evaluated the impact of outliers on their regression models. This resulted in modifications to their regression models. Most students in the statistic (Case 3) class could now generate, evaluate, and modify the regression model. They applied this learning to other data sets including Scholastic Achievement Test (SAT) math and reading scores and altitude versus temperature data.

Finally, a theme of student choice regarding assessments emerged from my actions in class. For example, to promote and build conversations, I provided students with an opportunity to discuss how they would like to be assessed in this phase of the study. Involving them in the discussion and the decision for how they would be assessed engaged them. Analysis of my reflections on these discussions provided evidence of my becoming more student-centered. More specifically, giving student choice was another means towards that end.

Chapter 4 Summary

This chapter began with an overview of this self-study. The study's research questions were presented. A brief summary of study methods was reviewed. Findings were reported from the data collected and analyzed by describing the systematic application of the methodology (Simon, 2006). Overall study findings by study phase were summarized.

Finally, Chapter 5 discusses a summary, interpretation, context, and implications of my findings for this self-study. The limitations of this study are examined. Findings are discussed in light of questions or issues that suggest future research directions.

CHAPTER 5

SUMMARY AND DISCUSSION

Overview

This study design was structured in three phases. The first phase (Phase One) was devoted to ”unit planning” and took approximately one week to complete. “Unit enactment” and “unit reflection” took approximately four weeks. Thus, each study phase consisted of five weeks in which a unit was designed, enacted, and reflected upon. I used my chemistry (Case 1 and Case 2), statistics (Case 3 and Case 4) and engineering (Case 5) classes for Phase One. Data analysis in Phase One was used to inform the design of Phase Two, which focused on my statistics (Case 3 and Case 4) classes with a more refined research question. Phase Two essentially followed the same process as in Phase One and took approximately five weeks. Results from data analysis from Phase Two were applied to the next phase (Phase Three) of the study, which focused on my statistics (case 3) class with a further refined research question. Phase Three followed the same process as Phase Two and took approximately five weeks. Results from data analysis from Phase Three informed the study’s overall findings. The timeline for the entire study was approximately fifteen weeks.

This summary and discussion chapter is organized in six sections. In the first section, I provide a summary of the study that includes the problem statement, the study’s purpose, the research questions posed, the literature review undertaken, the methods used, and the findings obtained. The first section concludes with a discussion of my findings as they relate to my research questions. Both expected and unexpected results are included. The second section presents interpretation of my findings and addresses the meaning of my findings. The third section provides a discussion of the context of my findings in terms of literature review fit and agreement. The fourth section considers the implications of my findings in terms of theory, research, and practice. The fifth section examines the study limitations as initially proposed and discusses those limitations that affected my findings. The sixth and final section examines future directions of research and the field.

Summary of the Study

The Problem

The *Framework* acknowledges the fragile dynamic between teacher learning and instructional change. "Teachers are the 'linchpin' in any effort to change K-12 science education … the professional development of teachers of science will need to change in order to support implementation of the new standards" (NRC, 2012, p. 256). Penuel and Fishman (2012) posited, "Teachers will need to reorganize instruction to emphasize fewer ideas and develop strategies for integrating content, science and engineering practices, and crosscutting themes" (p. 293). Thus, teachers will need a significant amount of ongoing and sustained training, time, and support in order for the vision of *NGSS* reform to be realized. I was concerned that my present lesson design, discourse, modeling instruction, and assessment strategies were incompatible with the tenets of the new standards, and as a result, would make implementation of *NGSS* difficult.

The Purpose

The *Framework* proposed a research agenda "on classroom-level contexts, materials, and discourses that engage and support a wider range of students in high-quality teaching and learning experiences with the concepts, ideas, and practices" (NRC, 2012, p. 325). Given this research need and my motivation to improve my STEM teaching practice, the purpose of this study was to examine my experiences in my secondary chemistry, engineering, and statistics classes through the lens of the *Framework* for science education and the *NGSS*. The research question posited for Phase One of this study was: What happened in my chemistry, statistics, and engineering classes when I employed a self-study framework using a design-based research (DBR) strategy to design, enact, and reflect on units of study that promoted the *Framework's* disciplinary core ideas, science and engineering practices, and crosscutting concepts? The use of the DBR strategy promoted reflective cycles, which resulted in three study phases. As the study progressed through its phases, refinements were made to the research question in the subsequent remaining two phases of this self-study. These refinements were based on findings from each study phase. More specifically, for Phase Two the research question was refined as: To what extent am I improving "wait time", building conversations with my students, and incorporating modeling instruction in my statistics classes while design, enact, and reflect on unit plans through the lens of the *NGSS.* Furthermore, for Phase Three the research question was further focused as: To what extent am I improving building conversations with my students and incorporating modeling instruction in my statistics class while I design, enact, and reflect on unit plans through the lens of the *NGSS.*

The Literature Review

Literature on K-12 STEM education was examined from the standpoint of STEM integration and teacher STEM efficacy. A historical research perspective on previous *NSES* and *Benchmarks* standard implementations was provided to understand how the previous research could inform future understanding of standards implementations. Literature on teacher learning and teacher PD was examined to shed light on teacher learning as it related to changes in teachers knowledge, beliefs, and attitudes in the context of action research. I reported on the self-study theoretical framework that underlied and guided this study. The roots of self-study: teacher inquiry, action research, and reflection were explored. A discussion of the action research process was undertaken and various models for reflection were reviewed. Examples of self-studies in science education were illustrated. Criteria used to assess the validity of this self-study were researched. Theoretical underpinings for the self-study framework were examined from findings from research on social constructivism, conceptual change, efficacy, and ethic of care theories.

The Methods

This study employed a self-study framework that utilized design-based research (DBR) methods. I chose the self-study framework for this study as the literature review revealed that the overall goal of self-study is self-improvement. The DBR strategy was chosen to promote reflective cycles, which are consistent with and in support of the self-study framework and the action research process. Feedback from one cycle was used to inform the design of the next cycle. A multiple case, mixed-methods approach was used for data collection and analysis. Given the iterative DBR nature of the study design, I chose the mixed-methods approach from an emergent perspective. I included multiple cases of my chemistry, statistics, and engineering classes as a strategy to enhance the external validity of my findings. The study design was structured in three phases. The first phase (Phase One) was devoted to ”unit planning” and took approximately one week to complete. “Unit enactment” and “unit reflection” took approximately four weeks. Thus, each study phase consisted of five weeks in which a unit was designed, enacted, and reflected/analyzed upon. Data analysis in a previous phase was used to inform the design of the subsequent phase.

Phase Two essentially followed the same process as in Phase One. Results from data analysis from Phase Two were applied to the next phase (Phase Three) of the study. Phase Three followed the same process as Phase Two. Results from data analysis from Phase Three informed the study's overall results. The timeline for the entire study was approximately fifteen weeks.

The Findings

The findings were reported using a framework that described each study phases' action, study phase inputs used, and study phased outputs generated.

A summary of study findings by study phase along with references to evidence is provided in Table 5.1.

Table 5.1: Summary of Study Findings by Phase

Phase	Findings	Evidence
One	• Instructional design process is analogous to the engineering design process	• Table 4.3
	• Importance of *NGSS* standards in STEM Integration	• Unit Designs (Examples of STEM Integration)
	• Designing balanced assessments	• Unit Designs • COLES (Table 4.5) • Unit Reflections
	• Becoming more student-centered	• Unit Designs • COLES (Table 4.5) • Unit Reflections
	• Need to improve o Increasing wait time o Building more conversations with students o Improve modeling instruction	• Self-assessment data from Table 4.6
Two	• Ethic of Care Emerged	• Unit Enactment
	• Need to improve o Building more conversations with students o Improve modeling instruction	 • Table 4.11 • Table 4.11
Three	• Becoming more student-centered	• Unit Reflections

The findings from this self-study support my research questions and reveal both expected and unexpected results. Expected results included improvements in unit design, assessment, *discourse*, and *modeling* instruction. I had stated in Chapter 1 that I was concerned that my present lesson design, discourse, modeling, and assessment strategies were incompatible with the tenets of the new standards. By using the *NGSS* coupled with best practices, I was able to design lessons that were integrative in terms of the *Framework's* three dimensions of disciplinary core ideas, science and engineering practices, and cross-cutting concepts. I introduced several STEM integrative lessons throughout the study. My confidence in my unit and lesson design skills increased. My assessments were more balanced with both formative and summative components. My discourse proficiency improved with using "wait time" and building more conversations with my students. My modeling instruction (a key *NGSS* science and engineering practice) frequency increased and my skills at generating, evaluating, and modifying models with my students improved. The goal of this self-study, which was improvement in my STEM teaching practices, was realized. Unexpected results included the emergence of an ethic of care philosophy, the engineering/instructional design process connection, the importance of standards as critical instructional design requirements, and becoming more student-centered. The experiences from this self-study were a valuable resource toward reframing my knowledge, beliefs, and attitudes about my teaching practices in STEM integration, assessment, discourse and modeling.

Interpretation of Findings

This section addresses the meaning of my findings. Conclusions are drawn from the findings and the results of the data analysis. I identified four conclusions based on my findings leading to insights posed by my research questions.

Improved Self-efficacy in Instructional Design

During the unit design process of Phase One, I found myself elevating the importance of standards. I considered the *NGSS* as critical design requirements for unit and lesson planning. This finding along with my realization that the instructional design process is analogous to an engineering design process advanced the notion in my mind of my being an instructional design engineer. I designed instruction based on various *best practices* to include balanced assessments, modeling, and discourse. This experience increased my confidence in my unit design skills. Unit enactment and unit reflection provided design improvements to successive study phases. Furthermore, by using best practices in modeling and discourse in the context of *NGSS* in this self-study*,* I valued the *NGSS* as considerate in scaffolding knowledge and in promoting STEM integration.

An Ethic of Care Philosophy Emerges

The *Framework* argued that equity should be at the forefront of efforts to improve students' educational experiences and outcomes in science and engineering. An ethic of care is essential in refining and implementing that educational equity (Noddings, 2005a). The emergence of an ethic of care was the most significant finding of this study for me. Prior to the study, I professed to care but not from a relational sense. Noddings argued that the relational sense of caring forces us to look at the relation. "It is not enough to hear the teacher's claim to care. Does the student recognize that he or she is cared for?" (2005b).The Phase Two reflections were a turning point for me taking my beliefs and attitudes on the ethic of care from gestural to relational. I began to embody the ethic of care in my interactions with students, colleagues, administrators, and parents. An illustration of this change in my attitude on care related to how I reacted to the reduced level of participation from critical friends and the study administrator. I cared about them. I realized the pain and frustration they were going through. I was experiencing similar pain given the discussion of this study's contextual factors. I was not going to add to it by complaining about their lack of participation. I thanked them for what they were able to do.

Becoming More Student-Centered

The literature discusses the benefits of a student-centered approach such as promoting the intrinsic motivation to learn, developing communication and social skills, and encouraging alternative methods of assessment. Moreover, student-centered teaching can be accomplished by connecting the teacher's experiences to students through the content. For example, I designed a STEM integrative activity (the design and construction of a solar car for both the chemistry (Case 1 and Case 2) and engineering (Case 5) classes. Although the students had seen solar panels at a distance, none had ever had the opportunity to see them up close and touch and interact with them. Students found this activity both engaging and fun. Furthermore, the activity promoted discourse not only between me and the students but also amongst students in both the chemistry (Case 3 and Case 4) and engineering (Case 5) classes.

I characterize becoming more student-centered as a process that is neither automatic nor are the benefits immediate. It is a process that involves both students and teachers and each need time to learn. The unit design process provided me with a sharp focus on students by considering their prior knowledge and misconceptions and using that information to plan questions in order to build conversations. Furthermore, a more balanced assessment design strategy emerged for me in which I designed assessments of my student learning as well as assessments to assist them in their learning.

Self-Study with DBR as a Professional Learning (PL) Tool

After experiencing this self-study, I am convinced that self-study provides a useful tool for me to continue improvements in my teaching practice through purposeful reflection. Design-based research (DBR) strategies were well suited for the complex learning environment of my classroom. Given DBR's cyclical and iterative nature, a number of expected and unexpected findings emerged over the course of the three phases of the study. The value of DBR in promoting reflective cycles is evident to me given how the ethic of care emerged in Phase Two. Self-study coupled with DBR is an empowering professional learning tool for my continued professional development.

Context of Findings

This section considers how my study findings fit the literature review discussed in Chapter 2. The emergence of an ethic of care philosophy during Phase Two of the study is consistent with the literature on ethic of care. For example, Bingham and Sidorkin (2004) discussed how relationship building is a central construct of teaching. In a study examining two experienced teachers' transformations as they implemented a writer's workshop curriculum with multi-lingual third grade students, the authors reported, "The shift to a renewed professional identity encouraged the teachers to assume an advocacy stance for their own professional lives and for the children they teach" (Flint, Zisook, & Fisher, 2011, p. 1168). I experienced a similar shift in my identity in terms of demonstrating that I care about my students and modeled that caring through my dialogue and practice.

My self-efficacy in designing, enacting, and reflecting on my STEM instruction increased with direct benefits to my STEM teaching practice in the design of instruction, assessment. *discourse*, and *modeling.* The self-study framework provided me with an empowering tool to examine my teaching practice. Bullough and Pinnegar (2001) submitted, "while self-study researchers acknowledge the role of the self in the research project … self-study does not focus on the self per se but on the space between self and the practice engaged in" (p. 15). I used my experiences in this study as a resource to reframe my knowledge, beliefs, and attitudes about my teaching practice. I found myself thinking of standards as critical design requirements for instructional design, becoming more skilled in constructing balanced assessments, and focusing my thoughts more frequently on my students in becoming more student-centered. These findings are consistent with Goldsmith and Schifter (1997) who explored the understanding of practices in relation to teacher beliefs.

Implications of Findings

This section addresses the issue of whether my research findings improve the field's understanding of the phenomenon that I investigated in this self-study. Implication of findings is considered in the areas of theory, research, and practice.

Theory

The findings are consistent with the self-study theoretical framework and the conceptual underpinnings for this self-study described in Chapter 2. Samaras and Freese (2006) noted that self-study is key to building teacher self-efficacy which Bandura (1977) defined as "Beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Furthermore, Samaras and Freese (2009) posited:

> Self-study builds on the personal processes of reflection and inquiry …. Self-study is not done in isolation, but rather requires collaboration…. Self-study research requires openness and vulnerability…. self-study is designed to lead to the reframing and re-conceptualizing of the role of the teacher. (p. 5)

Self-study research reveals that researchers used their experiences as a resource with the goal of reframing their knowledge, beliefs, and attitudes about their teaching practice as I had done in this study.

Research

This self-study adds to and advances the research methodology of design-based research (DBR) in classroom settings. Given its cyclical and iterative nature, DBR offered methods that promoted reflective cycles, which are consistent with and in support of the self-study theoretical framework and the action research process. I found a number of benefits to using a mixed methods design. The design was efficient where both quantitative data and qualitative data were collected during each study phase concurrently. Each type of data was collected and analyzed separately and independently utilizing strategies typically associated with each type of data and then merged during further data analysis. Mixed methods also provided a means to triangulate findings in order that they are mutually corroborated. For example, in Phase Two, the Reformed Teaching Observation Protocol (RTOP) quantitative scores from Jim, a critical friend, were compared with the *discourse* and *modeling* qualitative self-report data. This comparison aided in mutually corroborating the critical friend RTOP data and self-report data. Finally, my choice of the mixed-methods approach from an emergent perspective coincident with DBR led to both previously discussed expected and unexpected results.

Practice

This study includes an in-depth examination of my teaching practice through the lens of the *Framework* and the *NGSS*. The findings in the study have important implications for teacher professional development (PD) and teacher education. One recommendation is to foster an ethic of care mindset and actively create and promote a caring learning environment. One way to accomplish this recommendation is to explicitly teach caring as a concept to both per-service and in-service teachers and engage them in conversations about caring. Noddings (2005a) provides a useful model for these conversations by considering the four components of care: modeling, dialogue, practice, and confirmation. Teachers need to demonstrate that they care for their students and model that caring through dialogue and practice. Confirmation is an act of affirming and encouraging and bringing out the best in others.

Another recommendation is to create meaningful opportunities for both pre-service and in-service teachers to practice and improve their skills in instructional design, questioning, conducting critical analyses, and giving meaningful feedback. Explicitly teaching these processes in pre-service and in-service settings would be an important first step. For example, relating the instructional design process to the engineering design process may help pre-service and in-service STEM teachers overcome their fears of not understanding what engineering is about. By explicitly teaching them skills common to “design”, this effort may increase their confidence in discussing engineering practices identified in *NGSS*.

Both pre-service and in-service teachers frequently do not know where to begin when considering their own professional development. Moreover, suggestions are provided without how to implement the recommended practice. The use of *best practices* can serve as a “contextual anchor” or starting point for teachers to begin studying their practice. Usage of *best practices* provided that starting point for me in this self-study to investigate my teaching practices. Aubusson, Griffin, and Steele (2010) found that the use of “contextual anchors” promoted increasing levels of reflection in pre-service teachers.

Teachers learn best by studying, doing, reflecting, and collaborating with other teachers. Explicit teaching of research methods including self-study and design-based research can provide both pre-service and in-service teachers with an empowering professional learning (PL) tool in becoming more reflective practitioners. School structures such as critical friends groups, professional learning communities, and induction programs can promote the self-study dispositions of reflection, openness, and collaboration. For example, administrators can design induction programs that are self-study based which help focus the support of the mentor and the administrator on areas that the teacher believes are critically important to improving their practice. Furthermore, results of teacher evaluations, given the onset of new teacher evaluation systems, can be used by teachers to develop individual professional development plans for self-study to inform their instructional improvement. Moreover, developing research skills will also further the previously recommended skills development in questioning, conducting critical analyses, and giving meaningful feedback.

Finally, the *NGSS* provided the means for me to examine my practices by not only by focusing on core disciplinary areas content but also on science and engineering practices and cross-cutting concepts. These three dimensions helped to think more broadly and become more STEM integrative and student-centered in my instructional design and enactment. The *NGSS* can be used with *best practices,* as in this study, to serve as means by which teachers can investigate their practice to learn more about both themselves and their students.

Study Limitations

The limitations of this study originated from two sources: the study's design and the study's problems during implementation. Limitations included the researcher bias and the self-report nature of the data collected as well as the participants' level of involvement. To the extent possible, researcher bias was addressed in the researcher statement described in Chapter 1 and the planned use of multiple sources of independent data. The participants' level of involvement was a significant concern given the aforementioned "contextual factors" of Hurricane Sandy, the implementation of block scheduling, and the shift to a new teacher evaluation model.

Concurrent to the researcher bias, self-report, and contextual limitations, I faced the challenge of managing an extensive data collection and analysis study. I was concerned about an increased time commitment in a school climate where time was precious and limited. Analysis of each study phase data indicated a need to limit the scope of the study and increase study focus. A related challenge was my concern regarding the conflicts between the researcher and teacher roles. These concerns influenced the amount of data I had collected in my attempts to narrow the focus as the study progressed. In doing so, I limited the number of cases I collected data for as well as analyzed thereby reducing the validity of my findings.

Finally, given time limitations, the scope of this study did not include analysis of student artifacts in their learning of various science and mathematics concepts. Furthermore this study did not measure the conceptual change that may have occurred for students through their experiences in this study. These learning outcomes are compelling and suggest further exploration in future studies.

The reduced level of study participants, the narrowing of the study focus with fewer cases, and the lack of analysis of student artifacts for student learning was a validity concern for independent corroboration of my self-reported data.

Future Directions

Self-study has provided me with an empowering tool to examine my teaching practice.

Coupled with DBR's promotion of cycles of reflections, self-study has yielded me new insights into developing my teacher identify and reframing my teaching practice. Given my involvement in this self-study, I now have strategies to engage myself as a reflective practitioner in researching my own practice with a continual improvement mind set.

An ethic of care philosophy emerged for me from this self-study. Ethic of care goes beyond the easy gesture of saying that I care. For the community of students, teachers, administrators, parents, and community ethic of care focuses on trust, responsiveness to needs, and the cultivation of caring relationships. A further exploration of this study finding may be telling to examine to what extent I demonstrate caring in my practice and what affects my ability to care. A key question for me might be how do I come not to care rather than how do I gain the capacity to care.

Based on a cyclic and reflective design process engineers gain further improvements in their product design. Analogously, by going through a similar design process, teachers can gain further improvements in their students' understandings as well as their own teaching practices. The finding of this analogous relationship of engineering design and instructional design led me to conclude that I am an instructional design engineer. The *Framework* indicates that having teachers incorporate a wide range of engineering practices is likely to be a challenge. A future study could be aimed at improving teacher self-efficacy in engineering by having teachers work through the instructional design process.

As described by the *UbD best practice,* standards and assessments are inextricably linked. I have learned that standards provide the means for identifying learning outcomes and drive assessment design. Assessing student learning is a key component on my teaching practice. My present assessments use a score-based grading system. A future study could be designed to investigate my practice using a standards-based grading process. This alternative system addresses the need to directly assess how well students are developing toward meeting the course standards or objectives. Thus, the course objectives are the focal point of the grading system.

Given the study's contextual factors, both critical fiends and the study administrator had significantly reduced levels of participation in this study. Aside from the importance of enhancing the trustworthiness and validity of the study, a future study could explore, given higher levels of participation from these study participants, examining the processes of these study participants in providing critical analysis and meaningful feedback. Moreover, a future study could be directed at the building of a collective efficacy among participants. Bandura (1977) defined collective efficacy generally as "the groups' shared belief in its conjoint capabilities to organize and execute courses of action required to produce given levels of attainments" (p. 477). Thus, collective efficacy extends self-efficacy to the social level and is modeled by a group or community of teachers. Teacher efficacy, both self and collective, is an important component for the reforms articulated in the *Framework* and the *NGSS.*

Although not the focus of this study, examining the impact of the intervention on student learning for the various classes may be a fruitful endeavor. It would be useful to know a more detailed level of comprehension that students had for the science, engineering, and mathematics concepts that were designed in each unit. For example, to what extent did students understand the concepts based on the unit design and enactment? What assessment, discourse, and modeling strategies worked for students and what did not work. A further examination of collected assessment data from this study may be a valuable undertaking for a future study.

Final Thoughts

This self-study was transformative to me as a science and mathematics teacher. My identity as a teacher changed. An ethic of care philosophy emerged. My self-efficacy in designing, enacting, and reflecting on my STEM instruction increased with direct benefits to my STEM teaching practice. The self-study framework provided me with an empowering tool to examine my teaching practice. As I proceeded (stumbled) through the study, I could not help but think about Pinnegar's (1998) characterization of self-study, "Self-study research seeks as it hallmark not claims of certainty, but evidence that researchers, however stumblingly, demonstrate in their practice the understandings they have gained though their study" (p.33). Moreover, I strongly identified with Hamilton, Pinnegar, Russell, Loughran, and LaBoskey's (1998) introduction to *Reconceptualizing Teacher Practice: Self-Study in Teacher Education*:

> A teacher educator must indeed be open to ideas from other teacher educators, from other disciplines, and from students themselves in order to help students develop their teaching potential. Further, such a teacher educator must be willing to risk collaborating with the student, who will become a teacher, and other colleagues interested in the education of teachers. We maintain that this kind of openness and collaboration will potentially lead one to think and act differently in teacher education practice—reframing. Self-study of teacher education practices is a formalization of reframing. Those involved in self-study systematically collect evidence from their practice, allowing them to rethink and potentially open themselves to new interpretations and to create different strategies for educating students that bring their practice into concert with the moral values they espouse. (pp. 1-2)

REFERENCES

Aldridge, J. M., Fraser, B. J., Bell, L., & Dorman, J. (2012). Using a new learning environment questionnaire for reflection in teacher action research. *Journal of Science Teacher Education*, *23*(3), 259-290.

Altrichter, H., Feldman, A., Posch, P., & Somekh, B. (2008). Teachers investigate their work: An introduction to action research across the professions (2nd ed.). New York: Routledge.

American Association for the Advancement of Science AAAS (1993). *Benchmarks for science literacy.* Washington, DC: AAAS.

American Modeling Teaching Association AMTA (2014). Retrieved from *http://modelinginstruction.org*

Anderson, G. L., Herr, M., & Nihlen, S. (2007). *Studying your own school: An educator's guide to practitioner action research*. 2nd Ed. Corwin Press: Thousand Oaks, CA.

Annenberg Institute for School Reform (1998). *Critical friends groups in action: Facilitators guide*. Providence, RI: Brown University.

Appleton, K. (2007). Elementary science teaching. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research in science education (2nd ed., pp. 493–535). Mahwah, NJ: Lawrence Erlbaum Associates.

Aubusson, P., Griffin, J., & Steele, F. (2010). A design-based self-study of the development of student reflection in teacher education. *Studying Teacher Education*, *6*(2), 201–216. doi:10.1080/17425964.2010.495905.

Avalos, B. (2011). Teacher professional development in teaching and teacher education over ten years. *Teaching and Teacher Education*, *27*(1), 10-20.

Bambino, D. (2002). Critical friends. *Educational Leadership*, *59*(6), 25-27.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Bulletin,* 84, 191-215.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman

Barab, S., & Luehmann, A. (2003). Building sustainable science curriculum: Acknowledging and accommodating local adaptation. *Science Education*, *87(4),* 454-467.

Best Practice (2014). Best practices categories and criteria. Retrieved from http://www.amchp.org/programsandtopics/BestPractices/Pages/BestPracticeTerms.aspx#best

Bingham, C., & Sidorkin, A. (2004). *No education without relation*. New York: Peter Lang.

Blanton, P. (2012). People get ready, there's a train a-comin'. *The Physics Teacher*, *50*(5), 316.

Bogdan, R. C. & Biklen, S. K. (2007). *Qualitative research for education: An introduction to theories and methods*. Boston; Pearson.

Bolton, G. (2005). *Reflective practice: Writing and professional development*. London/Thousand Oaks, CA/New Delhi, India: Sage Publications.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3-15.

Bronson, P. & Merryman, A. (2013, February 6). Why some kids handle pressure while others fall apart? *The New York Times*. Retrieved from http://www.nytimes.com/2013/02/10/magazine/why-can-some-kids-handle-pressure-while-others-fall-apart.html?_r=0

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18, 32-42.

Bryman, A. (2006). Integrating quantitative and qualitative research: How is it done? *Qualitative Research, 6*(1), 97-113.

Bullock, S. M. (2012). Chapter 1: Exploring the intersections of self-study, science teaching, and science teacher education. In S.M. Bullock and T. Russell (eds.), *Self-Studies of Science Teacher Education Practices,* Springer. doi10.1007/978-94-007-3904-8.

Bullock, S. M., & Russsell, T. (Eds.) (2012). *Self-studies of science teacher education practices,* Springer.

Bullough, R.V. & Pinnegar, S. (2001). Guidelines for quality in autobiographical forms of self-study research. *Educational Researcher, 30*(3), 13-21.

Capobianco, B. M. (2007). A Self-study of the role of technology in promoting reflection and inquiry-based science teaching. *Journal of Science Teacher Education*, *18*(2), 271-295.

Capobianco, B. M., & Feldman, A. (2010). Repositioning teacher action research in science teacher education. *Journal of Science Teacher Education*, *21*(8), 909-915.

Chamberlin, S. A. & Moon, S. M. (2005). Model-eliciting activities as a tool to develop and identify creatively gifted mathematicians. *The Journal of Secondary Gifted Education, 17*(1), 37-47.

Chappuis, S., Chappuis, J. & Stiggins, R.J. (2009). The quest for quality. *Educational Leadership, 67*(3), 14-19.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13-20.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32(*1), 9-13, 35-37.

Cochran-Smith, M., & Lytle, S. (1993). *Inside outside: Teacher research and knowledge*. New York: Teachers College Press.

Corey, S. (1953). *Action research to improve school practices*. New York: Teachers College Press.

Creswell, J. W. (2007). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd Edition). Thousand Oaks, CA: Sage

Creswell, J. W. (2009). *Qualitative inquiry & research design: Choose among five approaches* (2nd Edition). Thousand Oaks, CA: Sage.

Creswell, J. W. & Plano Clark, V. L.. (2010). *Designing and conducting mixed methods* (2nd Edition ed.). Thousand Oaks, CA: Sage.

Danielson, C. (2013). The framework for teacher evaluation instrument (2013 edition). The Danielson Group. Retrieved from http://www.danielsongroup.org/userfiles/files/downloads/2013EvaluationInstrument.pdf

Danielson, C., & McGreal T. (2000). *Teacher evaluation: To enhance professional practice*. Alexandria, VA: Association for Supervision and Curriculum Development.

Darling-Hammond, L., & Ball, D. L. (1998). *Teaching for high standards: What policymakers need to know and be able to do* (CPRE Research Rep. No. JRE-04). Philadelphia: University of Pennsylvania, Consortium for Policy Research in Education.

Darling-Hammond, L., & Richardson, N. (2009). Research review/teacher learning: What matters? *How Teachers Learn 66*(5), 46-53.

Dayton Regional Stem Center DRSC (2012). Retrieved from http://www.daytonregionalstemcenter.org/uploads/documents/rtop_with_rubric_smp-1.pdf

Dewey, J. (1933). *How we think*. Boston: Houghton Mifflin Co.

Dias, M., Eick, C. J., & Brantley-Dias, L. (2010). Practicing what we teach: A self-study in implementing an inquiry-based curriculum in a middle grades classroom. *Journal of Science Teacher Education*, *22*(1), 53-78.

Driver, R., Asoko, H., Leach, J., Mortimer, E. F., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*, 5-12.

Doyle, K. J. B., & Yoon, S. A. (2011). Professional Development in Education In search of practitioner - based social capital : a social network analysis tool for understanding and facilitating teacher collaboration in a US - based STEM professional development program. *Professional Development in Education*, *37*(1), 75-93.

Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *Journal of Research in Science Teaching*, *38*(3), 355-385.

Edelson, D. (2002). The value of teaching with data : insights from learning science. Retrieved from http://www.sesp.northwestern.edu/people/ls/d_edelson.html

Engineering Process (2013). Retrieved from http://www.engr.ncsu.edu/theengineeringplace/media/pdf/design-process.pdf

Feldman, A. (2003). *Self-study through action research. International handbook of self-study of teaching and teacher education practices* (pp. 943–978). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Feldman, A., Paugh, P., & Mills, G. (2004). Validity and quality in self-study. *Educational Researcher, 32*(3), 26-28.

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*(6), 643-658.

Flint, A. S., Zisook, K., & Fisher, T. R. (2011). Not a one-shot deal: Generative professional development among teachers. *Teaching and Teacher Education*, *27*(8), 1163-1169.

Freese, A. R. (2006). Reframing one's teaching: Discovering our teachers selves through reflection and inquiry. *Teaching and Teacher Education*, *22(1),* 100-119.

Fusco, E. (1983). *The relationship between children's cognitive level of development and* *their responses to literature*. Doctoral dissertation, Hofstra University, Hempstead, NY.

Fusco, E. (2012). *Effective questioning strategies in the classroom: A Step-by-step approach to engaged thinking and learning, K-8.* New York: Teachers College Press.

Garbett, D. (2011). Developing pedagogical practices to enhance confidence and competence in science teacher education. *Journal of Science Teacher Education*, *22*(8), 729-743.

Garet, M. S., Porter, A. C., Desimone, L. M., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915–945.

Goldsmith, L. T., & Schifter, D. (1997). Understanding teachers in transition: Characteristics of a model for the development of statistics teaching. In E. Fenemma & B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 19–54). Mahwah, NJ: Lawrence Erlbaum Associates.

Hamilton, M. L., Pinnegar, S., Russell, T., Loughran, J., & LaBoskey, V. K. (Eds.), (1998). *Reconceptualizing teaching practice: Self-study in teacher education.* London: Falmer Press.

Health and Human Services HHS (2012). Informed consent. Retrieved http://answers.hhs.gov/ohrp/categories/1566.

Herr, K., & Anderson, G. (2005). *The action research dissertation; A guide for students and faculty* (pp. 1-148). Thousand Oaks: Sage Publications, Inc.

Hestenes, D. (2000). *Findings of the modeling workshop project* (pp. 1-15). Retrieved from http://modeling.asu.edu/r&e/research.html.

Hingeley, V. (2008). *Action research diagrams*. Retrieved June 28, 2012 from the Hospitality, Leisure, Sport, and Tourism Network Web site: http://www.heacademy.ac.uk/hlst/resources/detail/resources/heinfe/Action_research_diagrams.

Hoadley, C. (2004). Methodological alignment in design-based research. *Educational Psychologist, 39*(4), 203-212.

Holly, M. L. (1989). *Writing to grow: Keeping a personal-professional journal*. Portsmouth, NH:Heinemann.

Ing, M., Ward, M., & Haberer, E. (2013). Buildings on Student's Knowledge of Solar Cells. *Science Scope, 36*(6), 21-29.

Institutional Review Board IRB (2012). Office of Sponsored Programs. IRB number 13-063.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, *1*(2), 112-133.

Kesidou, S., & Roseman, J. E. (2002). How well do middle school science programs measure up? Findings from project 2061's curriculum review. *Journal of Research in Science Teaching, 39*(6), 522–549.

Khan, S. (2007). Models-based inquiries in chemistry. *Science Education* 91: 877-905.

Khan, S. (2011). What's missing in model-based teaching. *Journal of Science Teacher Education*, *22*(August), 535-560.

Killian, J., & Todnem, G. 19912). A process of personal theory building. *Educational Leadership, 48*(6*),* 14-17.

Klassen, R., Tze, V., Betts, S., & Gordon, K. (2010). Teacher efficacy research 1998–2009: Signs of progress or unfulfilled promise? *Educational Psychology Review*, *23*(1), 21-43.

Koonce, D.A., Zhou, D., Anderson, C.D., Hening, D.A., & Conley, V.M. (2011). *What is STEM?*. Retrieved from http://www.asee.org/public/conferences/1/papers/289/view

Krajcik, B. J., & Merritt, J. (2012). Engaging students in scientific practices : What does constructing and revising models look like in the science classroom? *Science Teacher*, 38-42.

LaBoskey, V.K. (2004). The methodology of self-study and its theoretical underpinnings. In J.J. Loughran, M.L. Hamilton, V.K. LaBoskey, & T. Russell (Eds.), International handbook of self-study of teaching and teacher education practices (pp. 817–870). Dordrecht, The Netherlands: Kluwer.

Larson, T. (2011). *A self-study of designing and implementing an inquiry-based chemistry course for elementary education majors*. University of Wisconsin-Madison. Proquest LLC: UNI UMI 3471392.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lesh, R. & Doerr, H. (2003). (Eds.), *Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching*, Lawrence Erlbaum, Mahwah, NJ.

Lincoln, Y. S., & Guba, E. G. (1986). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science : The state of the scene. *School Science and Mathematics*, *99*(5), 258-271.

Loughran, J. (2009). Series editor's foreward. In J. John Loughran (Ed.). Self-Study Research Methodologies for Teacher Educators Sense Publishers: Rotterdam.

Madeira, M. C. (2010). *The development of pedagogical knowledge in science teachers through technology-mediated reflection and peer-exchange*. Retrieved from http://hdl.handle.net/1807/26422

McGrath, D. (2003). Developing a community of learners. *Learning and Leading with Technology*, *30*(7), 42-45.

Megowan-Romanowicz, C. (2010). Inside out: Action research from the teacher–researcher perspective. *Journal of Science Teacher Education*, *21*(8), 993-1011.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementati*on. San Francisco, CA: Jossey-Bass.

Michaels, S., & O' Connor, C. (2012). *Talk science primer* (pp. 1-20). Cambridge, MA.

Michaels, S., Shouse, A.W., & Schweingruber, H. A. (2008). *Ready, set, science: putting research to work in K-8 science classrooms.* Washington, D.C.: The National Academic Press.

Moore, T. J. (2008). Model-eliciting activities: A case-based approach for getting students interested in material science and engineering. *Journal of Materials Education*, *30*(5–6), 295–310.

Nadelson, L. S., Moll, A. J., & Seifert, A. L. (2011). Living in a materials world : Materials science and engineering professional development for K-12 educators. *118th ASEE Annual Conference & Exposition: Your Passport to Engineering Education.*

National Center of Educational Statistics (2012). Retrieved from https://nces.ed.gov/ccd/schoolsearch/school_detail.asp?Search=1&InstName=Middletown&Zip=07748&SchoolType=1&SchoolType=2&SchoolType=3&SchoolType=4&SpecificSchlTypes=all&IncGrade=-1&LoGrade=-1&HiGrade=-1&ID=341011003978

National Oceanic and Atmospheric Administration NOAA (2013). Hurricane Research Division. Retrieved from http://www.aoml.noaa.gov/hrd/tcfaq/D7.html

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

National Research Council NRC (1999). *Designing mathematics or science curriculum programs: A guide for using mathematics and science education standards.* Washington, DC: National Academies Press.

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

National Research Council NRC (2001). *Classroom Assessment and the National Science Education Standards.* Washington, DC: National Academies Press.

National Research Council NRC (2012). *A Framework for K-12 Science Education : Practices, crosscutting concepts, and core ideas*. Retrieved from http://download.nap.edu/cart/download.cgi?&record_id=13165&free=1

Next Generation Science Standards NGSS (2013). Retrieved from http://www.nextgenscience.org

Next Generation Science Standards NGSS (2014). Retrieved from http://www.nextgenscience.org/three-dimensions

Noddings, N. (2005a). *The challenge to care in schools: An alternative approach to education* (2nd ed.). New York: Teachers College Press.

Noddings, N. (2005b). Caring in education, *The Encyclopedia of Informal Education.* Retrieved from http://infed.org/mobi/caring-in-education/

Northfield, J., & Loughran, J. (1997, March). The nature of knowledge development in the self-study practice. *Paper presented at the annual meeting of the American Educational Research Association, Chicago*.

Penuel, W. R., & Fishman, B. J. (2012). Large-scale science education intervention research we can use. *Journal of Research in Science Teaching*, *49*(3), pp. 281-304.

Piaget, J. (1964). Development and learning. *Journal of Research in Learning and Learning, 2*, 176-186.

Piaget, J. (1978). *The development of thought* (A. Rosin, Trans.) Oxford, UK: Basil Blackwell.

Pine, G. J. (2008). *Teacher action research: Building knowledge democracies*. Los Angeles, CA: Sage Publications, Inc.

Pinnegar, S. (1998). Methodologoicial perspectives: Introduction. In M. L. Hamilton (Ed.), *Re-conceptualizing teaching practice: Self-study in teacher education* (pp.31-33). Bristol, PA: Falmer Press

Prawat, R. S., & Floden, R. E. (1994). Philosophical perspectives on constructivist views of learning. *Educational Psychologist, 29*(1), 37-48.

Putnam, R. T., & Borko, H. (1997). Teacher learning: Implications of the new view of cognition. In B. J. Biddle, T. L. Good, & I. F. Goodson (Eds.), *The international handbook of teachers and teaching.* Dordrecht, Netherlands: Kluwer.

Queen, J. A. (2000). Block scheduling revisited. *Phi Delta Kappan*, *82*(3), 214-222.

Rearick, M., & Feldman, A. (1999). Orientations, products, reflections' framework for understanding action research. *Teaching and Teacher Education, 15*, 333-350.

Rittmayer, M. A., & Beier, M. E. (2008). *Overview : Self-efficacy in STEM: Information sheet.* Retrieved from http://www.engr.psu.edu/awe/misc/ARPs/ARP_SelfEfficacy_InfoSheet_122208.pdf

Rowe, M B. (1974). Wait time and reward as instructional variables, their influence on language, logic, and fate control: Part One – Wait time. *Journal of Research in Science Teaching, 11*(2), 74-81.

Russell, T. (2012). Chapter 12. Science teacher education, self-study of teacher education practices, and the reflective turn. In S.M. Bullock and T. Russell (eds.), *Self-Studies of Science Teacher Education Practices,* Springer. doi10.1007/978-94-007-3904-8.

Russell, T. & Bullock, S. M. (2012). In S.M. Bullock and T. Russell (eds.), *Self-Studies of Science Teacher Education Practices,* Springer. doi10.1007/978-94-007-3904-8.

Sagor, R. (2000). *Guiding school improvement with action research*. Alexandria, VA: Association of Supervision and Curriculum Development.

Samaras, A. P. & Freese, A. R. (2006). *Self-study of teaching practices*. Peter Lang Publishing, Inc., New York, NY.

Samaras, A. P. & Freese, A. R. (2009). *Looking back and looking forward: An historical overview of the self-study school.* In J. John Loughran (Ed.). Self-Study Research Methodologies for Teacher Educators Sense Publishers: Rotterdam.

Sawada, D., Pilburn, M., Judson, E., Turley, J., Falconer, K., Russell, B., & Bloom I (2002). Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol. *School Science and Mathematics*, *102,* 245–253.

Schön, D. (1983). *The Reflective Practitioner: How professionals think in action*. NY: Basic Books.

Schön, D. (1987). *Educating the reflective practitioner*. San Francisco: Jossey Bass.

Schön, D. A. (1991). *The reflective turn: Case studies in and on educational practice*. New York: Teachers College Press.

Science Technology Engineering Mathematics STEM (2013). *Facilitating change : Experiences with the reform of STEM education*. Retrieved from http://www.wmich.edu/science/facilitating-change/Products/RamaleyPresentation.pdf

Sell, C. (2009). Exit Paper. Submitted in partial fulfillment of course requirements In Advanced Research Methods in Self-Study. George Mason University, Virginia.

Shulman, L., & Sherin, M. G. (2004). "Fostering communities of teachers as learners: disciplinary perspectives." *Journal of Curriculum Studies 36*(2): 135-140.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-31.

Simon, M. (2006). *Dissertation and Scholarly Research: Recipes for Success*. Dubuque, IA: Kendall Hunt Pub Co.

Spillane, J. P., & Callahan, K. E. (2000). Implementing state standards for science education: What district policy makers make of the hoopla. *Journal of Research in Science Teaching, 37*(5), 201–225.

Stake, R.E. (2006), *Multiple case study analysis*. The Guilford Press, London.

Stern, L., & Ahlgren, A. (2002). Analysis of students' assessments in middle school curriculum materials: Aiming precisely at benchmarks and standards. *Journal of Research in Science Teaching, 39*(9), 889–910.

Stone, J. R., Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Enhancing high school students' math skills through career and technical education. *American Educational Research Journal*, *45*(3), 767–795.

Stone, J. R. (2011). *Delivering STEM education through career and technical education schools and programs*. Retrieved from http://www7.nationalacademies.org/bose/STEM_Schools_Stone_Paper_May2011.pdf

Thornburg, D. D. (2008). Why STEM topics are interrelated: The importance of interdisciplinary studies in K-12 education. *Thornburg Center for Space Exploration* (pp. 1-5). Retrieved from http://www.tcse-k12.org/pages/stem.pdf

Tobin, K. (1987). The role of wait time in higher cognitive level learning. *Review of Educational Research, 57*(1), 69-95.

UbD_stages (2014). Retrieved from http://www.rubicon.com/AtlasCurriculumMapping_Pedagogy.php?page=UbD

Valli, L. (1997). Listening to other voices: A description of teacher reflection in the United States. *Peabody Journal of Education, 72*(1), 67-68.

Wang, F., & Hannafin, M. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research & Development*, *53*(4), 5-23.

Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration : Teacher perceptions and practice. *Engineering Education*, *2*, 1-13.

Webster-Wright, A. (2009). Reframing professional development through understanding authentic professional learning. *Review of Educational Research*, *79*(2), 702-739.

Wenger, E. (1998a). *Communities of practice. Learning as a social system*. Retrieved from http://www.co-i-l.com/coil/knowledge-garden/cop/lss.shtml.

Wenger, E. (1998b). *Communities of Practice: Learning, meaning, and identity*. Cambridge: Cambridge UP.

Wiggins G. & McTighe, J. (2005). *Understanding by Design*. Expanded 2nd Ed. USA: Association for Supervision and Curriculum Development.

Williams, P. J. (2009). STEM Education: Proceed with caution. *Design and Technology Journal: An International Journal*, *16*(1), 26-35.

Wong, E. D. (1993). Challenges confronting the researcher teacher: Conflicts of purpose and conduct. Paper presented at the Annual Meeting of the *American Educational Research Association*, Atlanta, GA.

Yeh, T. K., Chang, C. Y., Hu, C. Y., Yeh, T. C., & Lin, M. Y. (2009). Association of catechol-O-methyltransferase (COMT) polymorphism and academic achievement in a Chinese cohort. *Brain and Cognition, 71*(1), 300-305.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

Zeichner, K. M., & Noffke, S. E. (2001). Practitioner research. In V. Richardson (Ed.), Handbook of research on teaching (pp. 298–332). Washington, DC: American Educational Research Association.

APPENDIX A: THE THREE DIMENSIONS OF THE FRAMEWORK

(NRC, 2012)

1 Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

2 Crosscutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

3 Disciplinary Core Ideas

Physical Sciences
PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer

Life Sciences
LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy, and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity

Earth and Space Sciences
ESS1: Earth's place in the universe
ESS2: Earth's systems
ESS3: Earth and human activity

Engineering, Technology, and Applications of Science
ETS1: Engineering design
ETS2: Links among engineering, technology, science, and society

APPENDIX B: NINE TALK MOVES

(Michaels & O'Connor, 2012)

Phase One: Statistics (Case 3)

Scoring

- 0 (no observation of activity),
- 1 (seldom activity observed 1-2 times),
- 2 (moderate activity observed 3-5 times)
- 3 (frequent activity observed greater than 5 times).

			Score
Goal One: Help individual students share, expand and clarify their own thinking			
1.	**Time to Think:** - Partner Talk - Writing as Think Time - Wait Time		1
2.	**Say More:** "Can you say more about that?" "What do you mean by that?" "Can you give an example?"		3
3.	**So, Are You Saying...?:** "So, let me see if I've got what you're saying. Are you saying...?" (always leaving space for the original student to agree or disagree and say more)		3
Goal Two: Help Students listen carefully to one another			
4.	**Who Can Rephrase or Repeat?** "Who can repeat what Javon just said or put it into their own words?" (After a partner talk) "What did your partner say?"		2
Goal Three: Help Students deepen their reasoning			
5.	**Asking for Evidence or Reasoning:** "Why do you think that?" "What's your evidence?" "How did you arrive at that conclusion?"		3
6.	**Challenge or Counterexample:** "Does it always work that way?" "How does that idea square with Sonia's example?" "What if it had been a copper cube instead?"		3
Goal Four: Help Students think with others			
7.	**Agree/Disagree and Why?:** "Do you agree/disagree? (And why?)" "What do people think about what Ian said?" "Does anyone want to respond to that idea?"		3
8.	**Add On:** "Who can add onto the idea that Jamal is building?" "Can anyone take that suggestion and push it a little further?"		2
9.	**Explaining What Someone Else Means:** "Who can explain what Aisha means when she says that?" "Who thinks they could explain why Simon came up with that answer?" "Why do you think he said that?"		3

APPENDIX C: MODELS BASED TEACHING RUBRIC

(Khan, 2011)

Instructors' actions to promote or model = Is **Students' evidence of engagement with** = Ss		Across cases Is	Across cases Ss
Generating the initial model (G)	**Access prior knowledge** • Reference to prior classes/information		
	Visualization • Draw, create a concrete model, show an image		
	Simulation • Mental or visual run of model		
	Explanations or Conceptual Models • Explain? Why? How do you know? Give me a reason…		
	Consider relationship between 2 or more variables • Have you thought of x on y?		
	Analogies (near or far)		
	Comparisons		
	Gestures (Meaningful)		
	Isolate components / factors of model • What's important? What do you need to think about? • Have you taken x into consideration?		
	Gather further information • From sources (books, internet)		
	Predictions (what if) • What will happen if x happens or changes?		
Evaluating, enriching, or changing a model (after initial model has been expressed) *(E)*	**Comparison** (of peer, teacher, computer models; comparing alternative theories or theoretical frameworks)		
	Evaluation • Logical: if I do x, then y should occur; Empirical: #s, observation, instrument; Conceptual: 2 theories that should work but don't, model holds up?		
	Visualization • Draw, create a concrete model, show an image		
	Gather further information		
	Explanations or Conceptual Models • Explain? Why? How do you know? Give me a reason…		
	Predictions (what if) • What will happen if x happens or changes? (real or not)		
	Critique of design, • Did you control for all variables; Compare evidence?		
	Simulation • Mental or visual run of model		
	Analogies (near or far)		
	Gestures (Meaningful)		
	Reduction • Reducing complexity, variables		
	Model Progression • Added variables/ factors (add w and x)		
Modifying	Initial model has changed or been enriched		
Instructors' actions to promote or model = Is **Students' evidence of engagement with** = Ss		Across cases Is	Across cases Ss
model (M)	I.e. confirmed model is presented		
Primary literature skills	**Primary sources** (Journals)		
Making the model public	**Presentations, drawing or sharing** • In class or to small groups		
Nature of modeling	Identifying assumptions, characteristics		

APPENDIX D: GUIDELINES FOR QUALITY IN SELF-STUDY

(Bullough and Pinnegar, 2001)

No	Guideline
1	Autobiographical studies should ring true and enable connection
2	Self-studies should promote insight and interpretation
3	Autobiographical self-study research must engage history forthrightly and the author must take an honest stand
4	Biographical and auto-biographical self-studies in teacher education are about the problems and issues that make someone an educator
5	Authentic voice is a necessary but not sufficient condition for the scholarly standing of a biographical self-study
6	The autobiographical self-study researcher has an ineluctable obligation to seek to improve the learning situation not only for the self but for the other
7	Powerful autobiographical studies portray character development and include dramatic action: Something genuine is at stake in the story
8	Quality autobiographical self-studies attend carefully to persons in context or setting
9	Quality autobiographical self-studies offer fresh perspectives on established truths
10	Self-studies that rely on correspondence should provide the reader with an inside look at participants' thinking and feelings
11	To be scholarship, edited conversation or correspondence must not only have coherence and structure, but that coherence and structure should provide
12	Self-studies that rely on correspondence bring with them the necessity to select, frame, arrange, and footnote the correspondence in ways that demonstrate wholeness
13	Interpretations made of self-study data should not only reveal but also interrogate the relationships, contradictions, and limits of the views presented
14	Effective correspondence self-studies contain complication or tension

APPENDIX E: FIVE VALIDITY CRITERIA

(Herr & Anderson, 2001, pp. 55-57)

1. Outcome Validity

The extent to which actions occur which lead to a resolution of the problem that led to the study.

2. Process Validity

To what extent problems are framed and solved in a manner that permits ongoing learning of the individual or system.

3. Democratic validity

The extent to which research is done in collaboration with all parties who have a stake in the problem under investigation.

4. Catalytic validity

The degree to which the research process reorients, focuses, and energizes participants toward knowing reality in order to transform it.

5. Dialogic Validity

A process of peer review where other researchers can monitor decisions and assess inferences.

APPENDIX F: RECOMMENDATIONS IN SELF-STUDY

(Feldman, 2003, pp. 27-28)

1. Provide clear and detailed description of how we collect data and make explicit what counts as data in our work. That is, either within the text itself or as an appendix, provide the details of the research methods used.
2. Provide clear and detailed descriptions of how we constructed the representation from our data. It is not always obvious how an artistic representation of research has arisen from the data. It would add to the validity of the representation if readers had some knowledge or insight into the way the researcher transformed data into an artistic representation.
3. Extend triangulation beyond multiple sources of data to include explorations of multiple ways to represent the same self-study. Because one data set can lead to a variety of representations it is important to show why one has been chosen over the others. A danger is the construction of straw men. However, multiple representations that support and challenge one another can add to our reasons to believe and trust the self-study.
4. Provide evidence of the value of the changes in our ways of being teacher educators. As I have discussed, self-study is a moral and political activity. If a self-study were to result in a change in the researcher's way of being a teacher or teacher educator, then there should be some evidence of its value (Northfield and Loughran, 1997). A presentation of this evidence can help to convince readers of the study's validity.

APPENDIX G: REASONS FOR MIXING METHODS

(Bryman, 2006)

- **Triangulation or greater validity** refers to the traditional view that quantitative and qualitative research might be combined to triangulate findings in order that they may be mutually corroborated.
- **Offset** refers to the suggestion that the research methods associated with both quantitative and qualitative research have their own strengths and weaknesses so that combining them allows the researcher to offset their weaknesses to draw on the strengths of both.
- **Completeness** refers to the notion that the researcher can bring together a more comprehensive account of the area of inquiry in which he or she is interested if both quantitative and qualitative research are employed.
- **Process** refers to when quantitative research provides an account of structures in social life but qualitative research provides sense of process.
- **Different research questions** refers to the argument that quantitative and qualitative research can each answer different research questions.
- **Explanation** refers to when one is used to help explain findings generated by the other.
- **Unexpected results** refers to the suggestion that quantitative and qualitative research can be fruitfully combined when one generates surprising results that can be understood by employing the other.
- **Instrument development** refers to contexts in which qualitative research is employed to develop questionnaire and scale items—for example, so that better wording or more comprehensive closed answers can be generated.
- **Sampling** refers to situations in which one approach is used to facilitate the sampling of respondents or cases.
- **Credibility** refers to suggestions that employing both approaches enhances the integrity of findings.
- **Context** refers to cases in which the combination is rationalized in terms of qualitative research providing contextual understanding coupled with either generalizable, externally valid findings or broad relationships among variables uncovered through a survey.

APPENDIX H: SCHOOL DEMOGRAPHIC DATA

(CCD Public school data 2011-2012 school years)

Grade Span: (grades 5 - 12)

5	6	7	8	9	10	11	12

Locale: Suburb: Large (21)

Magnet: –

Total Students: 1,443

Classroom Teachers (FTE): 85.00

Student/Teacher Ratio: 16.98

Title I School: No

Title I School-Wide Program: †

Enrollment Characteristics (2010-2011 school year)

Enrollment by Grade:

	5	9	10	11	12	Ungraded
Students	0	319	363	384	363	14

Enrollment by Race/Ethnicity:

	Amer Ind/ Alaskan	Asian/ Pacific Islander *	Black	Hispanic	White	Two or More Races
Students	2	43	21	46	1,331	0

* combined Asian and Native Hawaiian / Pacific Islander categories

Enrollment by Gender:

	Male	Female
Students	705	738

Free lunch eligible: 60

Reduced-price lunch eligible: 19

Note: Details may not add to totals.

NOTES

- [†] indicates that the data are not applicable. For example, the enrollment and staff characteristics for schools that opened in the 2011-2012 school year will not be available until the full 2011-2012 file is released.
- [–] indicates that the data are missing.
- [‡] indicates that the data do not meet NCES data quality standards.
- The directory information on school name, address, and phone number are preliminary data from initial submissions of school level data for 2011-2012.
- Data provided on student membership and staffing are from the official school level data for 2010-2011.

APPENDIX I: PHASE ONE UNIT PLANS

CHEMISTRY UNIT PLAN (CASE 1 & CASE 2)

(The Periodic Table)

UNIT SUMMARY

The Periodic Table is a tool that all scientists use. It can be used to describe and predict the nature of elements and chemical reactions. The organization of the periodic table is based on atomic arrangement which results in specific trends. This unit explores the various uses that the periodic table has in chemistry

STAGE 1: STANDARDS AND GOALS

MIDDLETOWN TARGETED STANDARDS-BASED OBJECTIVES

- **5.2.12.A.1. Use atomic models to predict the behaviors of atoms in interactions.**
- **5.2.12.A.2. Account for the differences in the physical properties of solids, liquids, and gases.**
- **5.2.12.A.3. Predict the placement of unknown elements on the Periodic Table based on their physical and chemical properties.**
- **5.2.12.B.1. Model how the outermost electrons determine the reactivity of elements and the nature of the chemical bonds they tend to form.**

NEXT GENERATION SCIENCE STANDARDS

- **HS-PS1 (b,i) - Matter and Its Interactions**

OVERARCHING ENDURING UNDERSTANDINGS

- **Chemistry, defined as the study of matter and its interactions, and is also known as the "Central Science"**
- **We can best understand chemical knowledge by observing and representing matter at multiple levels.**
- **Communicating information about chemical concepts is highly dependent upon understanding the symbolism and conventions used to represent matter and information about matter.**
- **Although we would like to be able to clearly categorize matter and change, scientific categories for all disciplines are often not clear cut.**
- **All changes in and interactions of matter are associated with changes in energy.**
- **Matter, on all levels, has predictable properties that can be related to structures of the elements that make up that matter.**
- **Chemical knowledge is, as are all of the sciences, a process and not a finished product.**

ENDURING UNDERSTANDINGS

- **The periodic table was not organized in one day, it is the compilation of many years of scientists' research.**
- **Elements in the same row and column share similar properties due to their atomic arrangement.**
- **The periodic table provides a way of mapping the elements in such a way that much useful information can be incurred about individual elements.**
- **The first 93 elements are naturally occurring, whereas the later elements are man-made.**

ESSENTIAL QUESTIONS

- **How is the periodic table organized?**
- **What is the significance of valence electrons to chemical properties?**
- **What trends are present within the periodic table?**
- **What are the properties and location of alkali metals, alkali earth metals, transition metals, halogens, and noble gases?**
- **What is significant about the noble gases?**
- **What are differences between metals, nonmetals, and metalloids?**

TARGETED KNOWLEDGE & SKILLS (What students are expected to know and do)

- **Identify the valence electrons of atoms using the periodic table.**
- **Justify why valence electrons play a role in the interaction of atoms.**
- **Trace the development of the periodic table and identify key features of the periodic table.**
- **Predict the probable electron gain or loss for elements in a specific column.**
- **Predict the characteristics of elements knowing the characteristics of another element in that family.**
- **Compare period and group trends of atomic size, reactivity, and ionization energy based on atomic structure.**
- **Explain the current organization structure of the periodic table**
- **Classify elements as metals, non-metals or metalloids on the basis of their physical and chemical properties**
- **Locate metals, non-metals and metalloids within the periodic table**
- **Predict the characteristics of elements knowing their position on the periodic table**
- **Relate uses of some elements to their physical and chemical properties**

COMMON MISCONCEPTIONS STUDENTS HAVE

- **The Periodic Table in its present form is the way the elements have always been categorized**
- **There is only one way to categorize the elements, consensus was easily achieved**
- **Science and its methods provide absolute truth rather than being tentative and evolving**
- **All that is to be known is known regarding atoms and elements**
- **Science is procedural more than creative**

STAGE 2: DETERMINING ACCEPTABLE EVIDENCE

PERFORMANCE TASKS

- **Construct dot diagrams showing the valence electrons of atoms and ions**
- **Construct trends in periodic table for atomic radii, ionization energy, atomic number and mass and explain why these trends exist**
- **Trends on PT practice sheet**
- **Practice drawing Bohr diagrams**
- **Practice classifying elements based on properties and location on periodic table**

OTHER EVIDENCE (Labs & Student Journal)

- **BEFORE LESSON: Predict. Explain why you think so.**
- **AFTER THE LESSON: Explain what actually happened.**
- **Tell me what you've learned about ….**
- **Observations-sketches, notes**
- **Planning- investigations, steps, materials**

- Questioning- student's questions
- Data Collections- charts, graphs, logs, tables, thought processes
- Analysis/Interpretation- make meaning/connections
- Reflection - responses to open-ended questioning
- Use essential questions as pre-writes
- Quizzes
- Unit Test

RESOURCES - MATERIALS

- Document Camera,
- Calculators,
- SMART Board,
- Textbook
- Textbook Labs
- Textbook Graphic Organixer
- Websites
  - http://www.funbrain.com/periodic/index.html
  - http://www.uky.edu/Projects/Chemcomics
  - http://periodictable.com/
  - http://www.chem4kids.com/
  - http://www.webelements.com/
  - Periodic Table Poster Project Webquest http://www.mcccsc.edu/~jduncan/chap10/ppp.htm

STAGE 3: LESSON ACTIVITIES

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
DAY 1 - 2	• Explain how electrons move between energy levels	• Discuss Bohr's planetary model • Lab 46 – Electrons • Chapter 10 Energy Levels • Lab 49 – Colored Flames & Electrons	• Inquiry/discussion • Generate, evaluate, modify models • Student journal entries	• Direct Instruction • Whole class discussion • Pairing of students
DAY 3 - 4	• Why are valance electrons important • Explain what a dot diagram is • Explain that an atom	• Construct Dot Diagrams	• Inquiry/discussion • Generate, evaluate, modify models • Lesson 10-5 review • Lesson 11-2 • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
	shares, gains, or loses valence electrons in a bond			
DAY 5	• What is a family and identify families • Explain the periodic repeating of properties	Lab 51 on prediction of properties	• Inquiry/discussion • Generate, evaluate, modify models • Lesson 11-1 review • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 6-7	• Comparison of atomic radii in same family, in same period	Lab 52 on atomic radii Lab 53 on Modeling a pattern	• Inquiry/discussion • Generate, evaluate, modify models • Lesson 11-3 • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 8-9	• Explain the pattern of ionization energy in terms of distance • Define electron affinity & the shielding effect	Lab 54 Ionization Energy	• Inquiry/discussion • Generate, evaluate, modify models • Lesson 11-4 • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 10-11	• Describe the properties in each family	Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Lesson 11-5 Review • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 11-12	• Unit Review	Graphic Organizer Vocab review	• Inquiry/discussion • Generate, evaluate, modify models • Chapter 11 Review • Student journal entries	•
DAY 13	• End of Unit	End of Unit	• End of Unit Test	Individual

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
	Test	Test		

<u>Assessments/Evaluation:</u>

- **Formative assessment of classroom participation/understanding: through discourse and guided practice**
- **Summative assessment of performance tasks**
- **Summative quizzes on the Periodic Table**
- **End of Unit Test**

<u>Accommodations/Adaptations *(Based on IEP Data from students in this class)*:</u>

- **Use review sheets for quizzes**
- **Use summary guides at end of Chapter 10,11**
- **Provide adequate time per IEP**

STATISTICS UNIT PLAN (CASE 3 & CASE 4)

(Hypothesis Testing)

STAGE 1: STANDARDS AND GOALS

MIDDLETOWN TARGETED STANDARDS-BASED OBJECTIVES

Unit #7: Hypothesis Testing

1. **Define Hypothesis Testing**
2. **Understand the fundamentals of hypothesis testing**
3. **Test a claim about the mean for large samples**
4. **Test a claim about the mean for small samples**
5. **Test a claim about proportions**

NEXT GENERATION SCIENCE STANDARDS

- **Science and Engineering Practices**
- **Analyzing and Interpreting Data**
- **Mathematical modeling and computational thinking**

OVERARCHING ENDURING UNDERSTANDINGS

- **Statistics is the process of collecting, organizing, analyzing, and interpreting data to make and evaluate inferences and predictions about our world.**
- **Statistics is a process by which we collect and organize data so that we can analyze information and make predictions about our world**

ENDURING UNDERSTANDINGS

- **Students will understand the underpinnings of statistical inference**
- **Tests of significance and confidence intervals drive decision making in our world**
- **Error analysis is a critical component of significance testing.**
- **Significance tests determine the likelihood of a sample.**
- **The analysis is only as good as the data.**

ESSENTIAL QUESTIONS

- **Why is data collected and analyzed?**
- **How do people use data to influence others?**
- **How can predictions be made based on data?**
- **What is inference?**
- **How can decisions be based on chance?**
- **To what extent should decisions be based on chance?**
- **What is a Hypothesis?**
- **What is the Null Hypothesis and the Alternative Hypothesis?**
- **How can we test a claim about a mean (both small &large samples), and proportions?**
- **What is a significance level?**
- **What is the test statistic?**
- **What is the critical region?**
- **To what extent are significance tests reliable?**

- **When are tests of significance and confidence intervals used?**
- **How can one prepare for errors from significance tests?**

TARGETED KNOWLEDGE (What students are expected to know)

- **Null and Alternative Hypothesis**
- **Test Statistic**
- **Critical region**
- **Significance level**
- **Critical value**
- **Type I ands Type I errors**
- **Two tail, left tail test, right tail test**

TARGETED SKILLS: (What students are expected to do)

- **Check assumptions for confidence intervals and significance tests**
- **Find confidence intervals**
- **Conduct significance tests**

COMMON MISCONCEPTIONS STUDENTS HAVE

- **Law of small numbers and sampling variability as it relates to the sample mean and the sampling distribution**
- **Misconceptions regarding the different distributions**
- **Misconceptions concerning the central limit theorem**
- **Definition of hypothesis testing**
- **Different approaches to hypothesis testing**
- **The conditional nature of significance levels**
- **Interpretation of the numerical value of the p-value**
- **Evaluation of statistical significance**
- **Confidence Interval Interpretation**

STAGE 2: DETERMINING ACCEPTABLE EVIDENCE

PERFORMANCE TASKS

- **Students will be able to carry out a test of significance for a population mean – both large and small samples based on a claim.**
- **Students will be able to carry out a test of significance for a population proportion based on a claim.**

OTHER EVIDENCE (Student Journal)

- **Tell me what you know about a hypothesis?**
- **How can we test hypothesis?**
- **BEFORE LESSON: Predict. Explain why you think so.**
- **AFTER THE LESSON: Explain what actually happened.**
- **Tell me what you've learned about ….**
- **Observations-sketches, notes**
- **Planning- investigations, steps, materials**
- **Questioning- student's questions**

- Data Collections- charts, graphs, logs, tables, thought processes
- Analysis/Interpretation- make meaning/connections
- Reflection - responses to open-ended questioning
- Use essential questions as pre-writes
- Quizzes

RESOURCES - MATERIALS

- Document Camera,
- Calculators,
- SMART Board
- Video segments

STAGE 3: LESSON ACTIVITIES

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
DAY 1	• Chapter 7-1,2 Fundamentals of Hypothesis Testing	• Activities listed in Robert Lock: Instructors Manual: unlocking the power of data.	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter 7-1,2 • Student journal entries • Homework – P340-342 Do 1,5,9,17,25,29,33	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 2	• Chapter 7-1,2 Fundamentals of Hypothesis Testing	• Activities listed in Robert Lock: Instructors Manual: unlocking the power of data.	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of 7-1,2 • Student journal entries • Homework – Page 340-342 Do 2,6,10,19.20.26,30, 34	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 3	• Chapter 7-3 Testing a claim about the mean: large samples	• Activities listed in Robert Lock: Instructors Manual: unlocking	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end	• Direct Instruction • Whole class discussion • Cooperati

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
		the power of data	of each Chapter 7-3 • Student journal entries • Homework – P357-358 Do 1,2,5,6,9,10,15,16	ve Groups of 3 to 4 students
DAY 4	• Chapter 7-3 Testing a claim about the mean: large samples	• Activities listed in Robert Lock: Instructors Manual: unlocking the power of data	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of Chapter 7-3 • Student journal entries • Homework – P357-358 Do 3,4,7,8,11,12,17,18	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 5	• Chapter 7-4 Testing a claim about the mean: small samples	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of Chapter 7-4 • Student journal entries • Homework – P367-368 Do 1,2,5,6,9,10,	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 6	• Chapter 7-4 Testing a claim about the mean: small samples	• Activities listed in Robert Lock: Instructors Manual: unlocking the power of data	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of Chapter 7-4 • Student journal entries • Homework – P367-368 Do 3,4,7,8,11,12	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 7	• Chapter 7-5 Testing a claim about a proportion	• Activities listed in Robert Lock: Instructors Manual: unlocking the power of	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter	• Direct Instruction • Whole class discussion • Cooperative

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
		data	• Student journal entries • Homework – P375-377 Do 1 through7	Groups of 3 to 4 students
DAY 8	• Chapter 7-5 Testing a claim about a proportion	• Activities listed in Robert Lock: Instructors Manual: unlocking the power of data	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of Chapter 7-5 • Student journal entries • Homework – P375-377 Do 8 through 14	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 9	• End of Unit Test	• End of Unit Test	• End of Unit Test	Individual

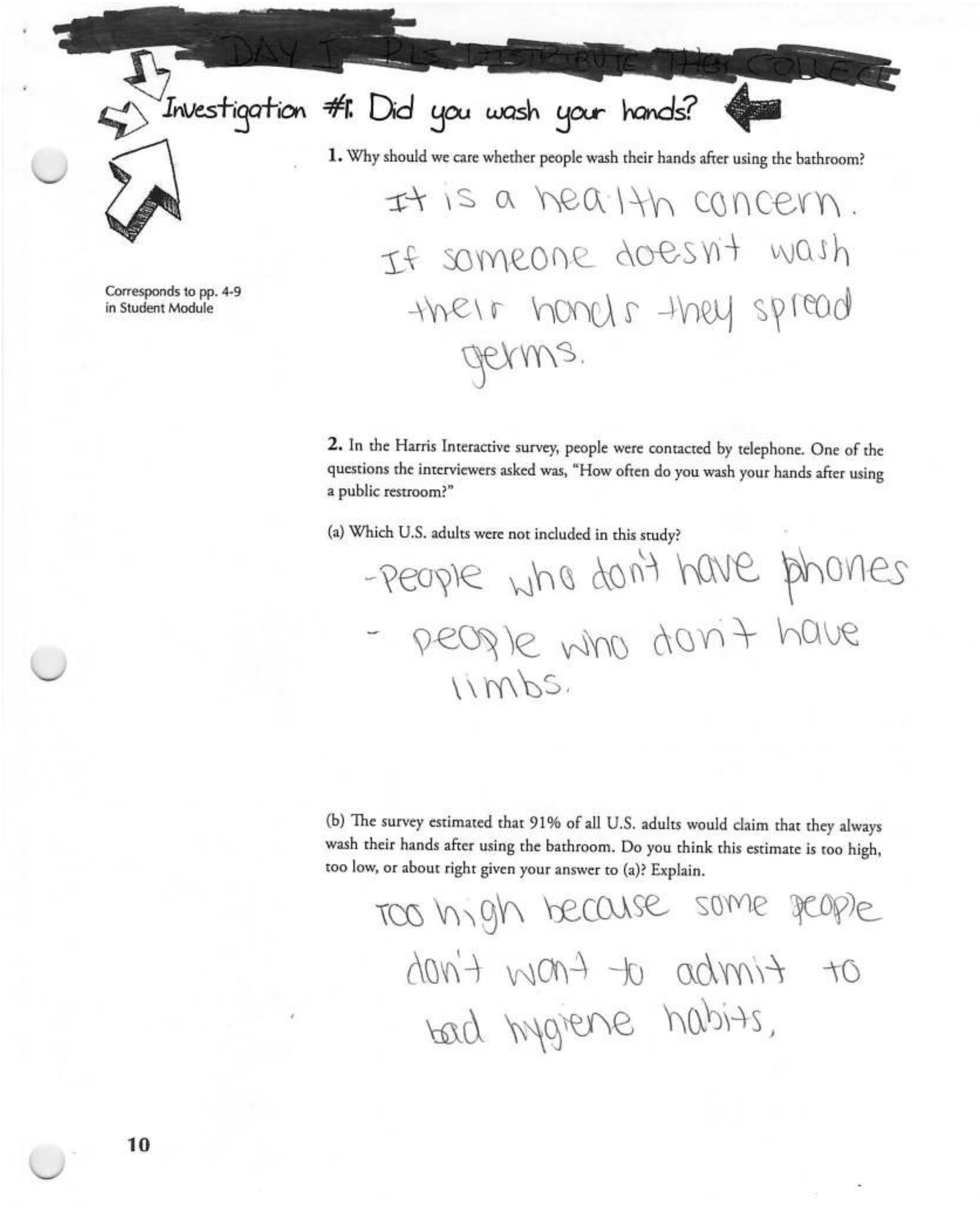
Assessments/Evaluation:

- **Formative assessment of classroom participation/understanding: through discourse and guided practice**
- **Summative assessment of performance tasks**
- **Summative quizzes on each Chapter section**
- **End of Unit Test**

Accommodations/Adaptations *(Based on IEP Data from students in this class)*:

- **Use review sheets for quizzes**
- **Use summary guides at end of each chapter**
- **Provide adequate time per IEP**

STATISTICS FORMATIVE ASSESSMENT (CASE 3 & CASE 4)



[redacted]

Investigation #1: Did you wash your hands?

Corresponds to pp. 4-9 in Student Module

1. Why should we care whether people wash their hands after using the bathroom?

It is a health concern. If someone doesn't wash their hands they spread germs.

2. In the Harris Interactive survey, people were contacted by telephone. One of the questions the interviewers asked was, "How often do you wash your hands after using a public restroom?"

(a) Which U.S. adults were not included in this study?

- People who don't have phones
- people who don't have limbs.

(b) The survey estimated that 91% of all U.S. adults would claim that they always wash their hands after using the bathroom. Do you think this estimate is too high, too low, or about right given your answer to (a)? Explain.

Too high because some people don't want to admit to bad hygiene habits,

10

1.

[redacted]

(c) Several people refused to participate in the survey. Give a reason that this might happen.

They can't talk or they don't want to admit they don't wash their hands.

(d) In any survey, it is possible that some people will not answer a question accurately or honestly. Thinking about the hand-washing survey, do you think this is likely to happen? Explain your answer.

Yes because there is a stigma attached to those who don't wash hands.

3. The observational study of hand washing was conducted at a baseball field in Atlanta, a museum and an aquarium in Chicago, a bus and train terminal in New York, and a farmers' market in San Francisco.

(a) Observers in the public bathrooms combed their hair or put on make-up at one of the available sinks while they were watching individuals' hand-washing behaviors. If the observation had been done by hidden camera instead (with no observer present), do you think the percent who washed their hands would have been greater than, less than, or about the same as 83%? Justify your answer.

Less because if they don't know someone is watching them they will feel less inclined to wash.

(b) Suppose the observational study had been conducted using hidden cameras in the homes of the same 6,336 adults. Do you think the percent of these individuals who washed their hands would have been greater than, less than, or about the same as 83%? Justify your answer.

Less because people feel more comfortable in their own home and less germy than if they were in public,

4. (a) Comment on the conclusion reached in the newspaper headline: "More People Claim to Wash Their Hands than Who Actually Do."

People may feel embarrassed to admit they don't wash their hands so they will lie.

(b) Describe a study design involving only one group of people that might help us better evaluate the validity of the quoted claim in part (a).

High school students because they come from a variety of socioeconomic backgrounds and belief systems.

5. Both studies were paid for by the American Society for Microbiology and the Soap and Detergent Association. Should you take this information into account when interpreting the results of the studies? If so, how?

Yes because they want to sell soap so they may skew the results to their favor.

6. You have been asked to help design a study to investigate how often teenagers wash their hands after using the bathroom.

(a) Define a research question for your study.

How many times a week do you wash your hands after using the bathroom?

(b) Would you recommend using a survey, an observational study, or an experiment to produce the data? Explain.

observational study because people may not tell the truth on a survey but their actions don't lie.

(c) Do you think the percent of teenagers who always wash their hands after using the bathroom is higher than, lower than, or about the same as the percent of adults who do so? Justify your answer.

The same because they learn behaviors from their parents.

7. For each of the following research questions, decide which method of data production—a survey, an experiment, or an observational study—would be most appropriate. Justify your choice of method.

(a) What percent of teenagers leave the water running while they brush their teeth?

observational study
→ people may lie

(b) Which of two drugs is more effective at preventing nausea following the onset of a migraine headache?

experiment
→ easiest to compare results.

(c) Do male teenagers or female teenagers tend to have more numbers stored in their cell phones?

survey → can give specific number

(d) What percent of drivers come to a complete stop at a stop sign near a local elementary school?

observational study → people won't lie

(e) Does printing suggested tip amounts on the bottom of a restaurant bill increase the average amount that customers leave in tips?

experiment → compere results

8. A follow-up study conducted in 2007 by Harris Interactive revealed that while 92% of adults said that they always washed their hands after using the bathroom, only 77% of the adults observed in public restrooms actually did. According to Harris Interactive's Hand Washing Fact Sheet, "The overall decline in hand washing observations is largely due to males. The percentage of males observed washing their hands fell from 75% in 2005 to 66% in 2007. Overall, the percentage of females observed washing their hands is down slightly from 90% in 2005 to 88% in 2007."

Did people's hand washing habits improve or get worse from 2005 to 2007? Justify your answer with specific evidence from the reports describing the Harris Interactive studies.

stayed the same because the habits didn't change the people were just lying.

ENGINEERING UNIT PLAN (CASE 5)

Applying Principles of Electricity to Systems Design

STAGE 1: STANDARDS AND GOALS

MIDDLETOWN TARGETED STANDARDS-BASED OBJECTIVES

Unit #2: Demonstrate use of basic engineering tools and skills

- **Apply principles of electricity to system designs (NJCCS Correlation 5.7B.1-4)**

NEXT GENERATION SCIENCE STANDARDS

- **HS-PS2 (d,e) - Forces & Interactions**
- **HS-PS3 (c,e,f) – Energy**
- **HS-PS4 (a,f) – Waves and their applications in Technologies for Information Transfer**

OVERARCHING ENDURING UNDERSTANDINGS

- **Engineering and science are methods of observation and investigation used to understand our world.**
- **Inquiry is the integration of process skills, the application of engineering, mathematics, technology, and scientific content, and critical thinking to solve problems.**

ENDURING UNDERSTANDINGS

- **Electrical circuits require a complete loop through which an electrical current passes**
- **Electricity is used to generate energy that can be transformed into other forms of energy**
- **Some materials conduct electricity and some materials do not.**
- **Electricity is essential to living in today's modern, technologically advanced world.**
- **Magnets produce a force that can move certain objects without direct contact.**
- **There are several electrical components (both electrical and electronic) that perform useful functions in products**

ESSENTIAL QUESTIONS

- **What is electricity? Where does it come from?**
- **What is the ultimate source of energy available on the Earth?**
- **Where does a generator get the energy needed to produce electric energy?**

- **Why does the battery in a flashlight eventually "lose" its energy?**
- **What is actually "flowing" when an electric current is present in a wire?**
- **How does a light bulb use electrical energy to produce light?**
- **Why is a fluorescent light bulb more efficient than an incandescent light bulb?**
- **What is the difference between a "series" circuit and a "parallel" circuit?**
- **Why is a parallel circuit the most common circuit used in homes?**
- **What factors determine how much current will flow through a circuit?**
- **What is a "voltage drop"?**
- **How does a fuse or circuit breaker protect the wires in an electrical circuit?**
- **Does an increase in the number of devices connected to a circuit in your home increase the possibility that a circuit breaker will "trip" or a fuse will "blow"?**
- **What does the "power rating" on an appliance indicate?**
- **How does the operation of switches in a parallel circuit differ from the operation of switches in a series circuit?**
- **Is current ever "lost" or "gained" in a circuit?**
- **What are you actually paying for when you pay an electric bill?**
- **Does a high wattage electrical device always use a large amount of energy?**
- **What is a "high-efficiency" appliance?**
- **If high-efficiency appliances cost more than traditional appliances, are they worth the added cost?**
- **What is an electrical schematic? What do the schematic symbols mean?**
- **What are the various electrical/electronic components and what is their function in electrical/electronic circuits?**
- **What is radio? What is AM? What is FM?**
- **How can we measure electrical signals with a laptop?**

<u>TARGETED KNOWLEDGE (What students are expected to know)</u>

- **Describe how batteries and wires can transfer energy to light (a light bulb) and/or heat.**
- **Explain the path of electricity in a circuit (open, closed, parallel, series circuit)**
- **Wire a simple electrical circuit to light a light bulb.**
- **Construct a circuit in more than one way using the same materials.**
- **Use symbols to represent the different parts of an electric circuit schematic.**
- **Classify materials as conductors of electricity and others materials as insulators based on tests using simple electrical circuits.**

- **Explain how electricity is essential to our modern world.**
- **Apply troubleshooting strategies (knowledge of electrical circuits) to complete an incomplete circuit.**
- **Investigate the properties of magnets including:**
  - **Magnets have north and south poles**
  - **Magnetic fields weaken as distance increases.**
  - **Magnets produce a force that some things respond to and some things do not.**
  - **Magnets exert a force at a distance/they can push or pull without touching.**
  - **A magnetic force can hold a limited amount of weight.**
  - **Magnets possess various degrees of strength.**
  - **Magnets can exert a force through materials.**
  - **Explore how electricity and magnetism are related (electromagnet)**
- **Explain how AM and FM radio transmissions work?**
- **List the various electrical/electronic components and what their function is in electrical/electronic circuits**

TARGETED SKILLS: (What students are expected to do)

- **Generate investigable and non-investigable questions.**
- **Observe objects and describe commonalities and differences.**
- **Classify, based on observations of properties.**
- **Predict what might happen.**
- **Design an investigation to help answer an investigable question.**
- **Conduct investigations.**
- **Employ equipment and measuring tools.**
- **Organize appropriate and accurate measurements and observations, using:**
  - **Graphic organizers**
  - **Charts and graphs**
  - **Illustrations or diagrams**
  - **Journaling**
- **Draw conclusions based on data, observations, or findings**
- **Communicate results or information in an appropriate manner, using:**
  - **Presentations**
  - **Reports**
  - **Visuals**
  - **Journaling**

COMMON MISCONCEPTIONS STUDENTS HAVE

- **Energy is lost, rather than conserved.**
- **Variables do not affect the outcome.**

- **Energy exists only when it's visible.**
- **Batteries store a certain amount of current. This current is consumed by any appliances or lights connected to it.**
- **If wires are connected to a battery and bulb, no matter where, a complete circuit is made.**
- **Electrons flow at nearly the speed of light**
- **Batteries and generators create electricity**
- **Electricity leaves one battery plate and returns to the other**
- **Are electrons negative?**
- **Electricity is made up of electrons**
- **Static electricity is the opposite of current electricity**
- **Each individual electron carries energy**
- **Electrical energy flows inside wires**

STAGE 2: DETERMINING ACCEPTABLE EVIDENCE

PERFORMANCE TASKS

- **Construct series circuits, parallel circuits, series-parallel circuits**
- **Construct schematics of circuits using batteries, lamps, and motors**
- **Determine equivalent resistance of series, parallel, and series-parallel networks**
- **Construct a logic circuit**
- **Determine equivalent capacitance of series, parallel, and series-parallel networks**
- **Construct circuits using NPN and PNP transistors**
- **Construct an oscillator circuit**
- **Construct circuit using integrated circuits**
- **Construct an AM/FM radio**
- **Construct electromagnetic, solar panel circuits**
- **Construct computer interface to measure signals in various circuits**

OTHER EVIDENCE (Student Journal)

- **Tell me what you know about electricity. List any questions you have about electricity.**
- **Describe one way you got the light bulb to light.**
- **BEFORE LESSON: Predict. Explain why you think so.**
- **AFTER THE LESSON: Explain what actually happened.**
- **Tell me what you've learned about ….**
- **Observations-sketches, notes**
- **Planning- investigations, steps, materials**
- **Questioning- student's questions**
- **Data Collections- charts, graphs, logs, tables, thought processes**
- **Analysis/Interpretation- make meaning/connections**

- **Reflection - responses to open-ended questioning**
- **Use essential questions as pre-writes**
- **Quizzes**

RESOURCES - MATERIALS

- **Document Camera,**
- **Calculators,**
- **SMART Board,**
- **ELANCO Snap Circuit Kits,**
- **Student Guide for Electronic Snap Circuits**

STAGE 3: LESSON ACTIVITIES

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
DAY 1	• Chapter 1: Basic Components and Circuits • Chapter 2: Motors and Electricity	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative • Groups of 3 to 4 students
DAY 2	• Chapter 3: Resistance • Chapter 4: Capacitors	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 3	• Chapter 5: Transistors • Chapter 6: Oscillators •	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 4	• Chapter 7: Integrated Circuits	• Activities listed in each	• Inquiry/discussion • Generate,	• Direct Instruction • Whole

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
	• Chapter 8: Electromagnetism and Radio	chapter of Student Guide for Snap Circuits	evaluate, modify models • Quiz at end of each Chapter • Student journal entries	class discussion • Cooperative Groups of 3 to 4 students
DAY 5	• Chapter 9: Meters, Transformers, and FM Radio •	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students

DAY 6	• Chapter 10: Diodes and applications Chapter 11: Electronic Switches •	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 7	• Off unit Trebuchet	• View DVD	• Inquiry, discussion	
DAY 8	• Review results from marking period exam	• Study survey	•	•
DAY 9	• Chapter 12: electromagnetism • Chapter 13: Sun Power • Robotics Setup	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative • Groups of 3 to 4 students
DAY 10	• Chapter 14: The SNAP CIRCUITS Computer Interface • Robotics Setup	• Activities listed in each chapter of Student Guide for Snap Circuits	• Inquiry/discussion • Generate, evaluate, modify models • Quiz at end of each Chapter • Student journal entries	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
	•	•	•	•

<u>Assessments/Evaluation:</u>

- **Formative assessment of classroom participation/understanding: through discourse and guided practice**
- **Formative and Summative assessment of performance tasks**
- **Summative quizzes on each Chapter in the Student Guide**
- **End of Unit Test**

<u>Accommodations/Adaptations *(Based on IEP Data from students in this class)*:</u>

- **Use review sheets for quizzes**
- **Use summary guides at end of each chapter**

Provide adequate time per IEP

-

APPENDIX J: PHASE TWO UNIT PLANS

STATISTICS UNIT PLAN (CASE 3 & CASE 4)

(Correlation)

STAGE 1: STANDARDS AND GOALS

MIDDLETOWN TARGETED STANDARDS-BASED OBJECTIVES

Unit #9: Correlation

1. **Recognize a relationship**
2. **Compare, contrast, correlate bivariate data**

NEXT GENERATION SCIENCE STANDARDS

- **Science and Engineering Practices**
- **Analyzing and Interpreting Data**
- **Mathematical modeling and computational thinking**

OVERARCHING ENDURING UNDERSTANDINGS

- **Statistics is the process of collecting, organizing, analyzing, and interpreting data to make and evaluate inferences and predictions about our world.**

ENDURING UNDERSTANDINGS

- **Students will use mathematical analysis and scientific inquiry to pose questions, seek answers, and develop solutions.**
- **Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.**

ESSENTIAL QUESTIONS

- **What does correlation mean to you?**
- **How can you tell when two variables are correlated?**
- **How can you tell when they are not correlated?**
- **How can I use a scatter plot to draw informal inferences about the correlation between two variables?**
- **What is the correlation coefficient of a scatter plot?**

TARGETED KNOWLEDGE (What students are expected to know)

- **Bivariate data**
- **Correlation**
- **Scatterplots**

- **Linear correlation coefficient**
- **Critical value**
- **Hypothesis testing for linear correlation**

TARGETED SKILLS: (What students are expected to do)

- **Common errors with using correlation**

COMMON MISCONCEPTIONS STUDENTS HAVE

- **The correlation between two variables, *X* and *Y*, never reveals anything about a possible causal relationship between the two variables. Simply stated: correlation ≠ cause**
- **Students expect correlated variables to be linked by a mathematical function such as a proportion or a power function**
- **Students perceive the association only when it is positive and they consider a negative correlation as independence**

STAGE 2: DETERMINING ACCEPTABLE EVIDENCE

PERFORMANCE TASKS

- **Use scatter plots to determine the relationship between variables**
- **Recognize that correlation is a value from -1 to +1**
- **Match correlation coefficients to appropriate scatter plots**
- **Understand that correlation does not imply causality**
- **Draw the line of best fit**
- **Use the line of best fit to make predictions**
- **Calculate the correlation coefficient by calculator**

OTHER EVIDENCE (Student Journal)

- **BEFORE LESSON: Predict. Explain why you think so.**
- **AFTER THE LESSON: Explain what actually happened.**
- **Tell me what you've learned about ….**
- **Observations-sketches, notes**
- **Planning- investigations, steps, materials**
- **Questioning- student's questions**
- **Data Collections- charts, graphs, logs, tables, thought processes**
- **Analysis/Interpretation- make meaning/connections**
- **Reflection - responses to open-ended questioning**
- **Use essential questions as pre-writes**
- **Quizzes**

RESOURCES - MATERIALS

- **Document Camera,**
- **Calculators,**
- **SMART Board**
- **Video segments**

STAGE 3: LESSON ACTIVITIES

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
DAY 1 – 2	• Chapter 9-1,2 • What is correlation? Exploring the data • Exploring and interpreting the correlation coefficient	• In pairs think of quantitative variables that are related. Think of quantitative variables that are not related. • Discuss examples that would be strong, weak, or totally uncorrelated • Develop a model to measure correlation • Calculate Pearson's using formula and table entries • Calculate Pearson r using a calculator • Construct scatter plot using calculator). •	• Inquiry /discussion • Generate, evaluate, modify models • Homework – P448 Do 3,4	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 3	• Work on research project	• Work on research project	• Work on research project	• Work on research project
DAY 4 – 5	• Chapter 9-1,2 • Formal Hypothesis Testing using test statistic t and test statistic r	• Use critical values and r squared to interpret r Use formal hypothesis testing to test a tipping example • Use Problem 7 Page 449	• Homework review • Inquiry /discussion • Generate, evaluate, modify models • Homework – P448,449 Do 5,6	• Direct Instruction • Whole class discussion • Cooperative Groups of 3 to 4 students
DAY 6	• Review homework on r squared and correlation hypothesis testing • Work on	• Students review homework problems	• Homework review • Inquiry /discussion • Generate	• Direct Instruction • Whole class discussion • Cooperative Groups of 3

	research project			to 4 students
DAY 7	• Quiz on correlation • Work on research project	• Quiz on correlation • Students collect/analyze data from surveys by going into various classrooms	• Quiz on correlation • Inquiry /discussion •	• Individual • • Cooperative Groups of 3 to 4 students

Assessments/Evaluation:

- **Formative assessment of classroom participation/understanding: through discourse and guided practice**
- **Summative assessment of performance tasks**
- **Summative quizzes on each Chapter section**

Accommodations/Adaptations *(Based on IEP Data from students in this class)*:

- **Use review sheets for quizzes**
- **Use summary guides at end of each chapter**
- **Provide adequate time per IEP**

APPENDIX K: PHASE THREE UNIT PLAN

STATISTICS UNIT PLAN (CASE 3)

(Regression)

STAGE 1: STANDARDS AND GOALS

MIDDLETOWN TARGETED STANDARDS-BASED OBJECTIVES

Unit #9: Regression

1. **Recognize a relationship**
2. **Compare, contrast, correlate bivariate data**
3. **Use regression lines and regression equations**

NEXT GENERATION SCIENCE STANDARDS

- **Science and Engineering Practices**
- **Analyzing and Interpreting Data**
- **Mathematical modeling and computational thinking**

OVERARCHING ENDURING UNDERSTANDINGS

- **Statistics is the process of collecting, organizing, analyzing, and interpreting data to make and evaluate inferences and predictions about our world.**

ENDURING UNDERSTANDINGS

- **Students will use mathematical analysis and scientific inquiry to pose questions, seek answers, and develop solutions.**
- **Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.**

ESSENTIAL QUESTIONS

- **What is a good model? Does such a thing exist?**
- **How do we distinguish between good and better? Useful and not useful?**
- **Is a simpler model preferable to a more complex model that fits the data better?**
- **What is regression?**
- **What does “regression to the mean” mean to you”**
- **What is the purpose of regression analysis?**
- **What is estimation and prediction mean?**
- **What is a predictor variable? What is the predicted variable?**
- **How does y intercept and slope relate to regression?**
- **Does the generation of a regression line tell us everything we need to know?**
- **Does a high r value necessarily mean that the data are generally linear?**
- **Does a low r value necessarily mean that the data are generally linear?**
- **How do I determine an equation for the line of best fit using a graphing calculator?**
- **What is the impact of outliers on regression analysis?**

TARGETED KNOWLEDGE (What students are expected to know)

- **Students analyze patterns in the scatterplot to determine correct function type for regression.**
- **Students will be able to transform data and perform regression to generate models from existing data.**
- **Students evaluate transformed data for linearity.**
- **Students will justify conclusions using statistically sound reasoning.**
- **Students will use R squared values and residual plots to evaluate a model's strength.**

TARGETED SKILLS: (What students are expected to do)

- **Students will be able to use stat plot to generate a scatterplot**
- **Students will analyze the shape of a scatterplot to determine what type of functional regression is appropriate.**
- **Student will scatterplot to determine linearity**

COMMON MISCONCEPTIONS STUDENTS HAVE

- **Students understand concepts better when they are posed in real life. Linear equations are not just there – they are derived from experimental observations.**
- **In regression analyses, the independent variable is the variable being predicted**

STAGE 2: DETERMINING ACCEPTABLE EVIDENCE

PERFORMANCE TASKS

- **Draw the line of best fit**
- **Use the line of best fit to make predictions**
- **Define regression equation and regression line in terms of the independent or predictor variable and dependent or response variable**
- **Use the notation for regression equations**
- **Discuss assumptions for regression methods**
- **Discuss rounding the y-intercept and the slope**
- **Use procedures for finding and applying the regression equation**
- **Use the regression equation for predictions**
- **Follow the guidelines for Using the Regression Equation**
- **Define and use:**
    - **Marginal change**
    - **Outliers**
    - **Influential points**
    - **Residual**
    - **Least-squares property**

OTHER EVIDENCE (Student Journal)

- **BEFORE LESSON: Predict. Explain why you think so.**

- **AFTER THE LESSON: Explain what actually happened.**
- **Tell me what you've learned about ….**
- **Observations-sketches, notes**
- **Planning- investigations, steps, materials**
- **Questioning- student's questions**
- **Data Collections- charts, graphs, logs, tables, thought processes**
- **Analysis/Interpretation- make meaning/connections**
- **Reflection - responses to open-ended questioning**
- **Use essential questions as pre-writes**
- **Quizzes**

RESOURCES - MATERIALS

- **Document Camera,**
- **Calculators,**
- **SMART Board**
- **Video segments**

STAGE 3: LESSON ACTIVITIES

DATE	TASKS: What STUDENTS will do . . .	HOW?	CHECK FOR UNDERSTANDING	INSTRUCTIONAL STRATEGIES
DAY 1	• Use regression lines and regression equations	• Collect data, develop scatter plots, calculate r, calculate significance of r, estimate line of best fit using data to obtain regression • Use regression equation to make a prediction	• Inquiry /discussion • Home work Page 463 Do 1,3,5	• Cooperative Groups of 3 to 4 students
DAY 2	• Review homework on regression • Work on research project	• Students collect/analyze data from surveys	• Inquiry / discussion • Home work Page 463 Do 6,7,8,9	• Cooperative Groups of 3 to 4 students
DAY 3	• Review homework on regression • Work on research	• Students review their homework solutions	• Inquiry /discussion	• Cooperative Groups of 3 to 4 students I

	project			
DAY 4	• Use variation in a variety of ways	• Discuss assumptions for variation in order to define total deviation, explained deviation, and unexplained deviation • Define and compute the coefficient of determination	• Inquiry /discussion • Home work Page 476 Do problems 1, 5, 7	• Cooperative Groups of 3 to 4 students
DAY 5	• Review homework on regression • Work on research project	• Students collect/analyze data from surveys by	• Inquiry / discussion	• Cooperative Groups of 3 to 4 students
DAY 6	• Use variation in a number of ways	• Use a prediction interval, which is the confidence interval estimate of a predicted value of y • Define and use the standard error of estimate • Discuss and use the Prediction Interval for an Individual y	• Inquiry /discussion • Home work Page 476 Do problems 8,9,10, 11	• Cooperative Groups of 3 to 4 students
DAY 7	• Test on regression • Work on research project	• Unit Test on Regression • Students collect/analyze data	• Summative • Inquiry /discussion •	• Individual • Cooperative Groups of 3 to 4 students
DAY 8	• Finalize Work on research project	• Students collect/analyze data	• Inquiry / discussion	• Cooperative Groups of 3 to 4 students

Assessments/Evaluation:

- **Formative assessment of classroom participation/understanding: through discourse and guided practice**
- **Summative assessment of performance tasks**
- **Summative quizzes on each Chapter section**

Accommodations/Adaptations *(Based on IEP Data from students in this class)*:

- **Use review sheets for quizzes**
- **Use summary guides at end of each chapter**
- **Provide adequate time per IEP**

APPENDIX L: RTOP WITH STEM RUBRIC

REFORMED TEACHING OBSERVATION PROTOCOL (RTOP) WITH ACCOMPANYING DAYTON REGIONAL STEM CENTER RUBRIC

HTTP://MATHED.ASU.EDU/INSTRUMENTS/RTOP/INDEX.SHTML

The Dayton Regional STEM Center (DRSC) is a grant funded educational foundation that has assumed the responsibility of providing educators professional opportunities for growth in collaboration with Science, Technology, Engineering and Math professionals. Educators participate in a year long professional development sequence during which they intern and tour STEM industries, participate in workshops on topics such as inquiry-based learning, a STEM Quality Rubric, and collaborative learning and finally use their newly gained knowledge to develop original STEM curriculum. In order to ensure the most effective creation and implementation of the DRSC's curriculum, strong assessment criteria is paramount.

The RTOP was created as an observational tool to be used in measuring "reformed" teaching, based upon the theory of constructivism. It was developed by the Arizona Collaborative for Excellence in the Preparation of Teachers, and allows for the assessment of a specific instructional segment. The authors of the RTOP share, "Acknowledging this variety (current conceptions of constructivism), perhaps a beginning definition of a constructivist classroom would be one in which people are working together to learn. This has been called a "knowledge-building community" (Bereiter & Scardamalia, 1993, pg. 210-216). The RTOP provides an assessment of constructivist teaching, but lacks feedback for improvement in creation and delivery of the curriculum. The DRSC strongly supports the utilization of the RTOP's criteria, and has made strides to provide feedback and development suggestions on the curricular design demanded by a constructivist approach. Dr. James Rowley of the University of Dayton has developed a STEM Quality Rubric which examines principles that are unique to STEM curriculum. It specifically identifies the uniquities of constructivist (STEM) education, and sets standards for successful development. Utilizing both of the assessment pieces, the DRSC is able to provide educators with immense scaffolding for planning and instructional growth.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 2

Section 1: Background Information

Name of teacher ____

Announced Observation? (yes, no, or explain)

____

Location of class (district, school, room)

Years of Teaching __

Teaching Certification (K-8 or 7-12)

Subject observed Grade level ________________________________

Observer Date of observation ________________________________

Start time __________

End time __________

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 3

Section 2: Contextual Background and Activities

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

Record here events that may help in documenting the ratings.

Time	Description of Events

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 4

Section 3: LESSON DESIGN AND IMPLEMENTATION

1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent herein

A cornerstone of reformed teaching is taking into consideration the prior knowledge that students bring with them. The term "respected" is pivotal in this item. It suggests an attitude of curiosity on the teacher's part, an active solicitation of student ideas, and an understanding that much of what a student brings to the mathematics or science classroom is strongly shaped and conditioned by their everyday experiences.

4	The students write or draw a diagram of their hypothesis, estimation or prediction and discuss it in a small group or large group setting, prior to exploration and teacher instruction.
3	The students write, draw or discuss their hypothesis, estimation or prediction prior to exploration and teacher instruction.
2	The teacher solicits information from students concerning prior knowledge of phenomenon.
1	The teacher refers to previous student experiences or relates previous learning. (no respect aspect)
0	The teacher makes no reference to prior knowledge.

2. The lesson was designed to engage students as members of a learning community.

Much knowledge is socially constructed. The setting within which this occurs has been called a "learning community." The use of the term community in the phrase "the scientific community" (a "self-governing" body) is similar to the way it is intended in this item. Students participate actively; their participation is integral to the actions of the community, and knowledge is negotiated within the community. It is important to remember that a group of learners does not necessarily constitute a "learning community."

4	All students in the small group contribute to the construction of ideas and theory building.
3	Some students in the small group contribute to the construction of ideas and theory building.
2	There is some student-to-student interaction and discussion but little or no construction of ideas or theory building.
1	The lesson employs only large group discussion with little evidence of community. Primarily the teacher addresses the class and some students respond.
0	This lesson is completely teacher-centered, lecture only.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 5

3. In this lesson, student exploration preceded formal presentation.

Reformed teaching allows students to build complex abstract knowledge from simpler, more concrete experience. This suggests that any formal presentation of content should be preceded by student exploration. This does not imply the converse...that all exploration should be followed by a formal presentation.

4	The teacher presents no formal content prior to student exploration.
3	The teacher introduces formal content prior to student investigation.
2	The teacher presents the results of the student investigation prior to student exploration.
1	The teacher instruction of formal content occurs prior to student investigation.
0	No student exploration is seen.

4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.

Divergent thinking is an important part of mathematical and scientific reasoning. A lesson that meets this criterion would not insist on only one method of experimentation or one approach to solving a problem. A teacher who valued alternative modes of thinking would respect and actively solicit a variety of approaches, and understand that there may be more than one answer to a question.

4	The teacher solicits multiple approaches to solve the problem and has students present the approaches to the large group.
3	The teacher solicits multiple approaches to solve the problem.
2	The students utilize multiple approaches to solve the problem.
1	The student investigation is teacher directed.
0	The students do no investigation or problem solving.

5. The focus and direction of the lesson was often determined by ideas originating with students.

If students are members of a true learning community, and if divergence of thinking is valued, then the direction that a lesson takes cannot always be predicted in advance. Thus, planning and executing a lesson may include contingencies for building upon the unexpected. A lesson that met this criterion might not end up where it appeared to be heading at the beginning.

4	Students generate ideas and questions. Students develop
3	Students generate ideas and questions. Students have input in designing the investigation. –or- Teacher presents problem
2	The students generate ideas and/or investigation.
1	The student investigation is teacher directed.
0	The lesson is teacher demonstration.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 6

Section 4: CONTENT (PROPOSITIONAL & PROCEDURAL KNOWLEDGE

Knowledge can be thought of as having two forms: knowledge of what is (Propositional Knowledge), and knowledge of how to (Procedural Knowledge). Both are types of content. The RTOP was designed to evaluate mathematics or science lessons in terms of both.This section focuses on the level of significance and abstraction of the content, the teacher's understanding of it, and the connections made with other disciplines and with real life.

6. The lesson involved fundamental concepts of the subject

The emphasis on "fundamental" concepts indicates that there were some significant scientific or mathematical ideas at the heart of the lesson. For example, a lesson on the multiplication algorithm can be anchored in the distributive property. A lesson on energy could focus on the distinction between heat and temperature.

4	The lesson is driven by a fundamental scientific or mathematical content concept.
3	The lesson includes a fundamental scientific or mathematical concept to average depth.
2	The lesson includes a fundamental scientific or mathematical content concept with little or no depth.
1	The lesson is based on a procedural algorithm, not a fundamental scientific or mathematical concept.
0	The lesson has no scientific or mathematical concept at its heart.

7. The lesson promoted strongly coherent conceptual understanding.

The word "coherent" is used to emphasize the strong inter-relatedness of mathematical and/or scientific thinking. Concepts do not stand on their own two feet. They are increasingly more meaningful as they become integrally related to and constitutive of other concepts.

4	The teacher directs the large group discussion/concept building to center on the major math or science concepts of the unit.
3	The teacher solicits a description of the phenomena from the students; but there is little concept building.
2	The students have no opportunity for whole group discussion.
1	The lesson follows a logical progression, but no effort is made to make students aware of the progression or to allow students to organize the structure themselves.
0	The concepts have no interrelatedness; each is isolated from the others.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 7

8. The teacher had a solid grasp of the subject matter content inherent in the lesson

This indicates that a teacher could sense the potential significance of ideas as they occurred in the lesson, even when articulated vaguely by students. A solid grasp would be indicated by an eagerness to pursue student's thoughts even if seemingly unrelated at the moment. The grade-level at which the lesson was directed should be taken into consideration when evaluating this item.

4	The teacher solicits student input, builds on that input and helps students make sense of the concept.
3	The teacher solicits student input.
2	The teacher does not solicit student input or ideas.
1	The teacher makes a factual error.
0	The teacher makes a factual error in content that when pointed out s/he

9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.

Conceptual understanding can be facilitated when relationships or patterns are represented in abstract or symbolic ways. Not moving toward abstraction can leave students overwhelmed with trees when a forest might help them locate themselves.

4	The students represent the phenomenon in a symbolic way, and students develop theory through discussion.
3	The students represent the phenomenon in a symbolic way, and teacher develops theory through discussion.
2	The students represent the phenomenon in a symbolic way, or teacher develops theory through discussion.
1	The teacher represents the phenomenon in a symbolic way or teacher explains the theory.
0	No abstract or symbolic representations of the phenomenon are demonstrated and no real theory is developed.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 8

10. Connections with other content disciplines and/or real world phenomena were explored and valued.

Connecting mathematical and scientific content across the disciplines and with real world applications tends to generalize it and make it more coherent. A physics lesson on electricity might connect with the role of electricity in biological systems, or with the wiring systems of a house. A mathematics lesson on proportionality might connect with the nature of light, and refer to the relationship between the height of an object and the length of its shadow.

4	The lesson is connected to a familiar context, and a real world example, application or connection to another discipline is valued with a whole class
3	The lesson is connected to a familiar context, and a real world example,
2	The lesson is connected to a familiar context, and a real world example,
1	The lesson is connected to a familiar context, but no application or connection to another discipline is mentioned
0	The lesson is not connected to a familiar context.

Procedural Knowledge

This section focuses on the kinds of processes that students are asked to use to manipulate information, arrive at conclusions, and evaluate knowledge claims. It most closely resembles what is often referred to as mathematical thinking or scientific reasoning.

11. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulatives, etc.) to represent phenomena.

Multiple forms of representation allow students to use a variety of mental processes to articulate their ideas, analyze information and to critique their ideas. A "variety" implies that at least two different means were used. Variety also occurs within a given means. For example, several different kinds of graphs could be used, not just one kind.

4	The students represent the phenomenon in at least 2 different ways, at least one of which is student choice.
3	The students represent the phenomenon in at least 2 different
2	The students represent the phenomenon.
1	The teacher represents the phenomenon.
0	There is no representation of the phenomenon.

APPENDIX L: RTOP WITH STEP RUBRIC PAGE 9

12. Students made predictions, estimations and/or hypotheses and devised a means for testing them.

This item does not distinguish among predictions, hypotheses and estimations. All three terms are used so that the RTOP can be descriptive of both mathematical thinking and scientific reasoning. Another word that might be used in this context is "conjectures". The idea is that students explicitly state what they think is going to happen before collecting data.

4	The students explicitly make, write down or depict, and explain their prediction, estimation and/or hypothesis. Students devise a means for testing their prediction,
3	The students explicitly make and explain their prediction, estimation and/or hypothesis. Students or teacher devise a means for testing their prediction, estimation and/or hypothesis.
2	The students make a prediction, estimation and/or hypothesis. Students or teacher devise a means for testing the student's prediction, estimation and/or
1	A prediction, estimation or hypothesis is only done in a large
0	The students do not make a prediction, estimation or hypothesis.

13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.

This item implies that students were not only actively doing things, but that they were also actively thinking about how what they were doing could clarify the next steps in their investigation.

4	The teacher asks the students to reflect upon the procedure. Students critically assess the validity of their procedure.
3	The teacher asks the students to reflect upon the procedure, but no ideas are shared with their group.
2	The students are actively engaged in a thought-provoking activity, but do not assess the validity of the procedure, or how it could be improved.
1	The students are actively engaged, but the activity is not thought- provoking and students do not assess their procedures.
0	The students are passively engaged in the lesson.

APPENDIX L: RTOP WITH STEP RUBRIC PAGE 10

14. Students were reflective about their learning.

Active reflection is a meta-cognitive activity that facilitates learning. It is sometimes referred to as "thinking about thinking." Teachers can facilitate reflection by providing time

and suggesting strategies for students to evaluate their thoughts throughout a lesson. A review conducted by the teacher may not be reflective if it does not induce students to re-examine or re-assess their thinking.

4	The students discuss questions such as "How do we know this?" "How can we be sure?" "What does this tell us about what we know?" within their small and
3	The students discuss questions such as "How do we know this?" "How can we be sure?" "What does this tell us about what we know?" only within their small group or large group.
2	There is evidence that some students are thinking about
1	The teacher asks a question to prompt students to consider how they think
0	There is no evidence of student reflection.

15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued.

At the heart of mathematical and scientific endeavors is rigorous debate. In a lesson, this would be achieved by allowing a variety of ideas to be presented, but insisting that challenge and negotiation also occur. Achieving intellectual rigor by following a narrow, often prescribed path of reasoning, to the exclusion of alternatives, would result in a low score on this item. Accepting a variety of proposals without accompanying evidence and argument would also result in a low score.

4	There is critical discussion of the ideas within the small groups and cross-group or
3	There is critical discussion of the ideas within the small groups
2	The students articulate more than one idea.
1	The students articulate one idea, but no competing ideas are
0	The students articulate no ideas related to the activity.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 11

Section 5: CLASSROOM CULTURE (COMMUNICATIVE & STUDENT/TEACHER RELATIONSHIPS

This section addresses a separate aspect of a lesson, and completing these items should be done independently of any judgments on preceding sections. Specifically the design of the lesson or the quality of the content should not influence ratings in this section. Classroom culture has been conceptualized in the RTOP as consisting of: (1) Communicative Interactions, and (2) Student/Teacher Relationships. These are not mutually exclusive categories because all communicative interactions presuppose some kind of relationship among communicants.

Communicative Interactions

Communicative interactions in a classroom are an important window into the culture of that classroom. Lessons where teachers characteristically speak and students listen are not reformed. It is important that students be heard, and often, and that they communicate with one another, as well as with the teacher. The nature of the communication captures the dynamics of knowledge construction in that community. Recall that communication and community have the same root.

16. Students were involved in the communication of their ideas to others using a variety of means and media.

The intent of this item is to reflect the communicative richness of a lesson that encouraged students to contribute to the discourse and to do so in more than a single mode (making presentations, brainstorming, critiquing, listening, making videos, group work, etc.). Notice the difference between this item and item 11. Item 11 refers to representations. This item refers to active communication.

4	The students share their ideas with their classmates using more than one mode of communication.
3	The students share their ideas with their classmates in a small group discussion.
2	The students share their ideas with their classmates in a large group discussion.
1	The students share procedural information but not ideas.
0	The students do not communicate with each other.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 12

17. The teacher's questions triggered divergent modes of thinking.

This item suggests that teacher questions should help to open up conceptual space rather than confining it within predetermined boundaries. In its simplest form, teacher questioning triggers divergent modes of thinking by framing problems for which there

may be more than one correct answer or framing phenomena that can have more than one valid interpretation.

4	The teacher asks open-ended questions and offers multiple explanations or explores connected areas to the large group and to small groups.
3	The teacher asks open-ended questions and offers multiple explanations or
2	The teacher asks at least one open-ended or divergent question.
1	The teacher asks at least one open-ended question, but it is clear the teacher

18. There was a high proportion of student talk and a significant amount of it occurred between and among students.

A lesson where a teacher does most of the talking is not reformed. This item reflects the need to increase both the amount of student talk and of talk among students. A "high proportion" means that at any point in time it was as likely that a student would be talking as that the teacher would be. A "significant amount" suggests that critical portions of the lesson were developed through discourse among students.

4	This lesson is mostly student talk with critical portions of the lesson developed
3	A larger portion of the talk is student-to-student; however critical portions of
2	The proportion of student-to-student talk to teacher-to-student talk is about equal.
1	There is minimal student-to-student dialog.
0	There is no talk amongst students. Student-instructor dialog (answering questions) is not scored for this item.

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19. Student questions and comments often determined the focus and direction of classroom discourse.

This item implies not only that the flow of the lesson was often influenced or shaped by student contributions, but that once a direction was in place, students were crucial in sustaining and enhancing the momentum.

4	The students discuss in their groups, between groups, with the teacher and with the large group. This discourse is central to the development of the description and development of understanding of the phenomenon.
3	The students discuss in their groups and with the teacher. This discourse is central to the development of the description of the phenomenon.
2	The students discuss in their small groups, but the discourse is not central to the development of the description of the phenomenon.
1	The students discuss with the teacher, however student input only slightly influences the focus or direction of the discourse.
0	The teacher determines the direction of the lesson with no student input.

20. There was a climate of respect for what others had to say.

Respecting what others have to say is more than listening politely. Respect also indicates that what others had to say was actually heard and carefully considered. A reformed lesson would encourage and allow every member of the community to present their ideas and express their opinions without fear of censure or ridicule.

4	All students are comfortable representing their ideas and expressing their opinions without fear of censure or ridicule. All teacher interactions encourage student exploration and/or discussion.
3	All students are comfortable representing their ideas and expressing their opinions without fear of censure or ridicule. Teacher interactions usually encourage student exploration and/or discussion.
2	Some students are comfortable representing their ideas and expressing their opinions without fear of censure or ridicule. Teacher interactions seldom encourage student exploration and/or discussion.
1	There is some student interaction. Teacher interaction does not encourage student exploration and/or discussion.
0	There is little or no student interaction. If the students interact, negative comments may occur.

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Student/Teacher Relationships

21. Active participation of students was encouraged and valued.

This implies more than just a classroom full of active students. It also connotes their having a voice in how that activity is to occur. Simply following directions in an active manner does not meet the intent of this item. Active participation implies agenda-setting as well as “minds- on” and “hands-on”.

4	The students describe the phenomenon and play a significant role in constructing and validating the final explanation of the phenomenon.
3	The students describe the phenomenon but do not play an adequate role in constructing and validating the final explanation.(Some building of explanation)
2	The students describe the phenomenon but do not participate in constructing or validating the final explanation of the phenomenon. (No building of explanation)
1	The teacher’s questioning strategy involves student participation, but is not closely tied to concept building.
0	Student participation was not encouraged and valued.

22. Students were encouraged to generate conjectures, alternative solution strategies, and/or different ways of interpreting evidence.

Reformed teaching shifts the balance of responsibility for mathematical of scientific thought from the teacher to the students. A reformed teacher actively encourages this transition. For example, in a mathematics lesson, the teacher might encourage students to find more than one way to solve a problem. This encouragement would be highly rated if the whole lesson was devoted to discussing and critiquing these alternate solution strategies.

4	This is valued within groups and is discussed with the large group.
3	This is valued within groups; it is not discussed with the large group.
2	The teacher accepts multiple strategies, conjectures or ways of interpreting evidence but makes no effort to solicit multiple ways.
1	The teacher has only one path to the correct answer that is acceptable.
0	The teacher provides all conjectures, solution strategies and ways of interpreting evidence.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 15

23. In general the teacher was patient with students.

Patience is not the same thing as tolerating unexpected or unwanted student behavior. Rather there is anticipation that, when given a chance to play itself out, unanticipated behavior can lead to rich learning opportunities. A long "wait time" is a necessary but not sufficient condition for rating highly on this item.

4	The teacher provides sufficient wait time and ample opportunity for students to explore on their own terms.
3	The teacher provides sufficient wait time, but does not capitalize on all opportunities to allow students to explore on their own terms.
2	The teacher provides sufficient wait time before accepting student responses.
1	The teacher sometimes provides sufficient wait time before accepting student responses.
0	The teacher provides no wait time.

24. The teacher acted as a resource person, working to support and enhance student investigations.

A reformed teacher is not there to tell students what to do and how to do it. Much of the initiative is to come from students, and because students have different ideas, the teacher's support is carefully crafted to the idiosyncrasies of student thinking. The metaphor, "guide on the side" is in accord with this item.

	The teacher uses student investigations or questions to direct the inquiry process.
	The teacher answers questions instead of directing inquiry.
	The student investigations are teacher prescribed.
	The teacher demonstrates the phenomenon followed by large group discussion.
	The class is lecture based.

APPENDIX L: RTOP WITH STEM RUBRIC PAGE 16

25. The metaphor "teacher as listener" was very characteristic of this classroom.

This metaphor describes a teacher who is often found helping students use what they know to construct further understanding. The teacher may indeed talk a lot, but such talk is carefully crafted around understandings reached by actively listening to what students are saying. "Teacher as listener" would be fully in place if "student as listener" was reciprocally engendered.

4	The teacher listens to the students and does not dominate group interactions. The teacher asks questions to help the student construct their own understanding.
3	The teacher listens to the students, the students listens to the teacher (reciprocity) but the teacher was too directive. The teacher gives too many answers instead of asking questions to help the student construct their own understanding.
2	Some attempts are made by the teacher to check initial student knowledge, incorporate student ideas into the lesson, and assess final student understanding of the material.
1	At least one attempt is made by the teacher to check initial student knowledge, or incorporate student ideas into the lesson, or to assess final student understanding of the material.
0	There is no attempt by the teacher to check initial student knowledge, or incorporate student ideas into the lesson, or to assess final student understanding of the material.

The RTOP was developed by Arizona Collaborative for Excellence in the Preparation of Teachers.Dayton Regional STEM Center has authored the imbedded rubrics for the 25 established categories. For more information on the RTOP please visit: http://mathed.asu.edu/instruments/RTOP/index.shtml or http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/.

APPENDIX M: QUESTIONING CYCLE CHECKLIST

(Fusco, 2012, p. 121)

Phase One: Statistics (Case 3)

Scoring

- 0 (no observation of activity),
- 1 (seldom activity observed 1-2 times),
- 2 (moderate activity observed 3-5 times)
- 3 (frequent activity observed greater than 5 times).

Questions	Never 0%	Seldom 1-25%	Moderate 26-50%	Frequent 51-75%	Always 100%
Did my questions build conversations with my students?	0	**1**	2	3	4
Did my questions recognize students' knowledge and background?	0	1	2	**3**	4
Did I focus my questions to relate to the essential questions in my lessons?	0	1	2	3	**4**
Did I use a range of types of questions?	0	1	2	**3**	4
Did I recognize and equally engage all students?	0	**1**	2	3	4
Did I call on one group of students more than another?	0	**1**	2	3	4
Did I allow for students' questions?	0	1	2	3	**4**
Did I allow for students-to-student interactions?	0	1	**2**	3	4
Did I use questions as a discipline method?	0	**1**	2	3	4

APPENDIX N: CRITICAL FRIEND OBSERVATIONAL RECORD

STATISTICS (CASE 3)

Art,

Here are my observations

1. Areas for Improvement
    a. Better organize your exploitation of correlation.
        i. Introduce with a table, have them draw conclusions
        ii. Follow up with scatter plot, ditto
        iii. Have them brainstorm examples of positive and negative, weak and strong correlations
        iv. Remember that they have covered scatter plots and regression (sort of) in Algebra
        v. Better explanation of r as a measure of correlation
        vi. The tie/no tie was a good idea but it was a bit out of place
    b. Another idea: Case study
        i. Hypothesis: "I think short people like big cars. In fact I'll bet you that if you tell me how tall someone is, I can predict the size of their car."
        ii. Explore with this case study
    c. Call on people more often
    d. Reduce your physical wandering
    e. Introduce the concept of correlation vs. causation
2. Strengths
    a. Asked to explain definitions
    b. Hypothesis metaphor
    c. Manual calculate 'r' in groups
    d. Explored the meaning of the correlation coefficient
    e. Divide and conquer
    f. Visit every group

APPENDIX O: COLES STUDENT SURVEY

(Aldridge, Fraser, Bell, & Dorman, 2012)

Curtin University of Technology

Student Questionnaire

INSTRUCTIONS:

- Use a blue/black pen or 2B pencil
- Do not use red pen or felt tip pen
- Do not fold or bend

BLUE OR BLACK PEN

2B PENCIL

Please MARK LIKE THIS ONLY:

SECTION 1. Background

What is your ID Number?

Example:

Please write in boxes here, then mark oval corresponding to the number in each column. → 7 3 4 0 2 5 0 1

Subject:

School:

Grade Level: ○ 8 ○ 9 ○ 10 ○ 11 ○ 12

Gender: ○ Male ○ Female

What level of education would you like to achieve? *(Fill in ONE oval only)*

- ○ Finish secondary school.
- ○ Finish secondary school plus a vocational qualification.
- ○ Complete an apprenticeship/trade qualification.
- ○ At least some university.
- ○ Graduate from university with a degree such as a BA or BSc.
- ○ Graduate from university with a postgraduate qualification such as a Master's or Doctoral degree.

SECTION 2. Learning Environment

Directions:

This section of the questionnaire contains statements about practices that could take place in your class. The 'Actual' column is to be used to describe how often each practice actually takes place in this class. The 'Preferred' column is to be used to describe how often you would like each practice to take place (a wish list).

Fill in the oval

- ① if this happens (actual) or you would like it to happen (preferred) **Almost Never**
- ② if this happens (actual) or you would like it to happen (preferred) **Seldom**
- ③ if this happens (actual) or you would like it to happen (preferred) **Sometimes**
- ④ if this happens (actual) or you would like it to happen (preferred) **Often**
- ⑤ if this happens (actual) or you would like it to happen (preferred) **Almost Always**

Be sure to give an answer for all questions. There are no 'right' or 'wrong' answers. Your opinion is what is wanted. Your responses will be confidential.

APPENDIX O: PAGE 2 - COLES STUDENT SURVEY

(Aldridge, Fraser, Bell, & Dorman, 2012)

SECTION 2.
Learning Environment Continued

Student Friendship	ACTUAL: Almost Never	Seldom	Some-times	Often	Almost Always	PREFERRED: Almost Never	Seldom	Some-times	Often	Almost Always
1. I make friends among students in this class.	1	2	3	4	5	1	2	3	4	5
2. I know other students in this class.	1	2	3	4	5	1	2	3	4	5
3. I am friendly to members of this class.	1	2	3	4	5	1	2	3	4	5
4. Members of the class are my friends.	1	2	3	4	5	1	2	3	4	5
5. I work well with other class members.	1	2	3	4	5	1	2	3	4	5
6. I help other class members who are having trouble with their work.	1	2	3	4	5	1	2	3	4	5
7. Students in this class like me.	1	2	3	4	5	1	2	3	4	5
8. In this class, I get help from other students.	1	2	3	4	5	1	2	3	4	5

Teacher Support	Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
9. The teacher is interested in my problems.	1	2	3	4	5	1	2	3	4	5
10. The teacher goes out of his/her way to help me.	1	2	3	4	5	1	2	3	4	5
11. The teacher considers my feelings.	1	2	3	4	5	1	2	3	4	5
12. The teacher helps me when I have trouble with the work.	1	2	3	4	5	1	2	3	4	5
13. The teacher talks with me.	1	2	3	4	5	1	2	3	4	5
14. The teacher takes an interest in my progress.	1	2	3	4	5	1	2	3	4	5
15. The teacher moves about the class to talk with me.	1	2	3	4	5	1	2	3	4	5
16. The teacher's questions help me to understand.	1	2	3	4	5	1	2	3	4	5

Involvement	Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
17. I discuss ideas in class.	1	2	3	4	5	1	2	3	4	5
18. I give my opinions during class discussions.	1	2	3	4	5	1	2	3	4	5
19. The teacher asks me questions.	1	2	3	4	5	1	2	3	4	5
20. My ideas and suggestions are used during classroom discussions.	1	2	3	4	5	1	2	3	4	5
21. I ask the teacher questions.	1	2	3	4	5	1	2	3	4	5
22. I explain my ideas to other students.	1	2	3	4	5	1	2	3	4	5
23. Students discuss with me how to go about solving problems.	1	2	3	4	5	1	2	3	4	5
24. I am asked to explain how I solve problems.	1	2	3	4	5	1	2	3	4	5

Task Focus	Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
25. Getting a certain amount of work done is important to me.	1	2	3	4	5	1	2	3	4	5
26. I know what I am required to do when completing a task.	1	2	3	4	5	1	2	3	4	5
27. I know the goals for this class.	1	2	3	4	5	1	2	3	4	5
28. I am ready to start this class on time.	1	2	3	4	5	1	2	3	4	5
29. I set my own goals for this class.	1	2	3	4	5	1	2	3	4	5
30. I pay attention during this class.	1	2	3	4	5	1	2	3	4	5
31. I try to understand the work in this class.	1	2	3	4	5	1	2	3	4	5
32. I know how much work I have to do.	1	2	3	4	5	1	2	3	4	5

Personal Relevance	Almost Never	Seldom	Some-times	Often	Almost Always	Almost Never	Seldom	Some-times	Often	Almost Always
33. I relate what I learn in this class to life outside school.	1	2	3	4	5	1	2	3	4	5
34. I draw on past experiences to help me in this class.	1	2	3	4	5	1	2	3	4	5
35. What I learn in this class is relevant to my everyday life.	1	2	3	4	5	1	2	3	4	5
36. I apply my everyday experiences in this class.	1	2	3	4	5	1	2	3	4	5
37. This class is relevant to my life outside of school.	1	2	3	4	5	1	2	3	4	5
38. I link my class work to my life outside of this class.	1	2	3	4	5	1	2	3	4	5
39. In this class, I get an understanding of life outside school.	1	2	3	4	5	1	2	3	4	5
40. I apply my past experience to the work in this class.	1	2	3	4	5	1	2	3	4	5

APPENDIX O: PAGE 3 - COLES STUDENT SURVEY

(Aldridge, Fraser, Bell, & Dorman, 2012)

SECTION 2.
Learning Environment Continued

Cooperation

	ACTUAL Almost Never	ACTUAL Seldom	ACTUAL Sometimes	ACTUAL Often	ACTUAL Almost Always	PREFERRED Almost Never	PREFERRED Seldom	PREFERRED Sometimes	PREFERRED Often	PREFERRED Almost Always
41. I cooperate with other students when doing assignment work.	1	2	3	4	5	1	2	3	4	5
42. I share my books and resources with other students when doing assignments.	1	2	3	4	5	1	2	3	4	5
43. When I work in groups in this class, there is teamwork.	1	2	3	4	5	1	2	3	4	5
44. I work with other students on projects in this class.	1	2	3	4	5	1	2	3	4	5
45. I learn from other students in this class.	1	2	3	4	5	1	2	3	4	5
46. I work with other students in this class.	1	2	3	4	5	1	2	3	4	5
47. I cooperate with other students on class activities.	1	2	3	4	5	1	2	3	4	5
48. Students work with me to achieve class goals.	1	2	3	4	5	1	2	3	4	5

Equity

	ACTUAL Almost Never	ACTUAL Seldom	ACTUAL Sometimes	ACTUAL Often	ACTUAL Almost Always	PREFERRED Almost Never	PREFERRED Seldom	PREFERRED Sometimes	PREFERRED Often	PREFERRED Almost Always
49. The teacher gives as much attention to my questions as to other students' questions.	1	2	3	4	5	1	2	3	4	5
50. I get the same amount of help from the teacher as do other students.	1	2	3	4	5	1	2	3	4	5
51. I have the same amount of say in this class as other students.	1	2	3	4	5	1	2	3	4	5
52. I am treated the same as other students in this class.	1	2	3	4	5	1	2	3	4	5
53. I receive the same encouragement from the teacher as other students do.	1	2	3	4	5	1	2	3	4	5
54. I get the same opportunity to contribute to class discussions as other students.	1	2	3	4	5	1	2	3	4	5
55. My work receives as much praise as other students' work.	1	2	3	4	5	1	2	3	4	5
56. I get the same opportunity to answer questions as other students.	1	2	3	4	5	1	2	3	4	5

Individualisation

	ACTUAL Almost Never	ACTUAL Seldom	ACTUAL Sometimes	ACTUAL Often	ACTUAL Almost Always	PREFERRED Almost Never	PREFERRED Seldom	PREFERRED Sometimes	PREFERRED Often	PREFERRED Almost Always
57. I work at the speed which suits my ability.	1	2	3	4	5	1	2	3	4	5
58. Students who work faster than me can move on to the next topic.	1	2	3	4	5	1	2	3	4	5
59. I can choose topics I wish to study.	1	2	3	4	5	1	2	3	4	5
60. Tasks are suited to my interests.	1	2	3	4	5	1	2	3	4	5
61. Tasks are suited to my ability.	1	2	3	4	5	1	2	3	4	5
62. I use different materials from those used by other students.	1	2	3	4	5	1	2	3	4	5
63. I use different assessment methods from other students.	1	2	3	4	5	1	2	3	4	5
64. I do work that is different from other students' work.	1	2	3	4	5	1	2	3	4	5

Young Adult Ethos

	ACTUAL Almost Never	ACTUAL Seldom	ACTUAL Sometimes	ACTUAL Often	ACTUAL Almost Always	PREFERRED Almost Never	PREFERRED Seldom	PREFERRED Sometimes	PREFERRED Often	PREFERRED Almost Always
65. I am treated like a young adult.	1	2	3	4	5	1	2	3	4	5
66. I am given responsibility.	1	2	3	4	5	1	2	3	4	5
67. I am expected to think for myself.	1	2	3	4	5	1	2	3	4	5
68. I am dealt with as a grown up.	1	2	3	4	5	1	2	3	4	5
69. I am regarded as reliable.	1	2	3	4	5	1	2	3	4	5
70. I am considered mature.	1	2	3	4	5	1	2	3	4	5
71. I am given the opportunity to be independent.	1	2	3	4	5	1	2	3	4	5
72. I am encouraged to take control of my own learning.	1	2	3	4	5	1	2	3	4	5

Formative Assessment

	ACTUAL Almost Never	ACTUAL Seldom	ACTUAL Sometimes	ACTUAL Often	ACTUAL Almost Always	PREFERRED Almost Never	PREFERRED Seldom	PREFERRED Sometimes	PREFERRED Often	PREFERRED Almost Always
73. I use feedback from assessment tasks to improve my learning.	1	2	3	4	5	1	2	3	4	5
74. Assessment tasks help me to understand the topic.	1	2	3	4	5	1	2	3	4	5
75. There is a link between classroom activities and my assessment tasks.	1	2	3	4	5	1	2	3	4	5
76. Assessment tasks help my understanding.	1	2	3	4	5	1	2	3	4	5

APPENDIX O: PAGE 4 - COLES STUDENT SURVEY

(Aldridge, Fraser, Bell, & Dorman, 2012)

SECTION 2.
Learning Environment Continued

Formative Assessment Continued

Item	Actual: Almost Never	Actual: Seldom	Actual: Sometimes	Actual: Often	Actual: Almost Always	Preferred: Almost Never	Preferred: Seldom	Preferred: Sometimes	Preferred: Often	Preferred: Almost Always
77. Assessment tasks are an important part of my learning.	1	2	3	4	5	1	2	3	4	5
78. Assessment tasks help me to recognise weaknesses in my understanding.	1	2	3	4	5	1	2	3	4	5
79. Assessment tasks help me to monitor my own learning.	1	2	3	4	5	1	2	3	4	5
80. I find the assessment tasks meaningful.	1	2	3	4	5	1	2	3	4	5

Clarity of Assessment Criteria

Item	Actual: Almost Never	Actual: Seldom	Actual: Sometimes	Actual: Often	Actual: Almost Always	Preferred: Almost Never	Preferred: Seldom	Preferred: Sometimes	Preferred: Often	Preferred: Almost Always
81. I am aware of which activities and tasks are used to assess my performance.	1	2	3	4	5	1	2	3	4	5
82. I know what types of information I need to complete an assessment task.	1	2	3	4	5	1	2	3	4	5
83. The instructions for assessment tasks are clear to me.	1	2	3	4	5	1	2	3	4	5
84. The requirements for the assessment tasks are clear to me.	1	2	3	4	5	1	2	3	4	5
85. I understand how to complete assessment tasks successfully.	1	2	3	4	5	1	2	3	4	5
86. The assessment criteria are clear to me.	1	2	3	4	5	1	2	3	4	5
87. I understand how the teacher judges my work.	1	2	3	4	5	1	2	3	4	5
88. I know how to complete different assessment tasks.	1	2	3	4	5	1	2	3	4	5

SECTION 3. Feelings about the Subject

Directions:

This questionnaire contains statements about how you feel about this Subject.

Fill in the oval

- ① if you feel this way **Almost Never**
- ② if you feel this way **Seldom**
- ③ if you feel this way **Sometimes**
- ④ if you feel this way **Often**
- ⑤ if you feel this way **Almost Always**

Your responses will be confidential.

Attitude to Subject

Item	Almost Never	Seldom	Sometimes	Often	Almost Always
89. I look forward to lessons in this Subject.	1	2	3	4	5
90. Lessons in this Subject are fun.	1	2	3	4	5
91. This Subject is one of my favourite school Subjects.	1	2	3	4	5
92. Lessons in this Subject interest me.	1	2	3	4	5
93. There should be more lessons in this Subject.	1	2	3	4	5
94. I enjoy lessons in this Subject.	1	2	3	4	5
95. I enjoy the activities that we do in this Subject.	1	2	3	4	5
96. These lessons make me interested in this Subject.	1	2	3	4	5

Academic Efficacy

Item	Almost Never	Seldom	Sometimes	Often	Almost Always
97. I find it easy to get good grades in this Subject.	1	2	3	4	5
98. I am good at this Subject.	1	2	3	4	5
99. My friends ask me for help in this Subject.	1	2	3	4	5
100. I find this Subject easy.	1	2	3	4	5
101. I outdo most of my classmates in this Subject.	1	2	3	4	5
102. I feel that I will pass this Subject with ease.	1	2	3	4	5
103. I feel that I am an intelligent student.	1	2	3	4	5
104. I help my friends with their homework in this Subject.	1	2	3	4	5

Thank you for your assistance in completing this questionnaire.