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By William S. Walker, III

Entitled

FACTORS INFLUENCING TEACHER INSTRUCTIONAL PRACTICE IN MATHEMATICS WHEN PARTICIPATING IN PROFESSIONAL DEVELOPMENT

For the degree of Doctor of Philosophy

Is approved by the final examining committee:

Dr. Signe Kastberg
Chair

Dr. John Staver

Dr. Rachael Kenney

Dr. Catherine Brown

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Approved by Major Professor(s): Dr. Signe Kastberg

Approved by: Dr. Janet Alsup 11/3/2016

Head of the Departmental Graduate Program Date

FACTORS INFLUENCING TEACHER INSTRUCTIONAL PRACTICE IN MATHEMATICS WHEN PARTICIPATING IN PROFESSIONAL DEVELOPMENT

A Dissertation

Submitted to the Faculty

of

Purdue University

by

William S. Walker, III

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

December 2016

Purdue University

West Lafayette, Indiana

I dedicate this work to Teresa, Maggie, Molly, Sam, Charlie, my parents, and the rest of my family. I could not have done this without your love, support, encouragement, and patience.

ACKNOWLEDGEMENTS

There are many people I want to thank for their help and support in completing my graduate work and the research for this dissertation. First, thank you to the four teacher participants. I appreciate each of you allowing me to visit your classrooms, learn about your teaching, and use the information to learn more about the impact of professional development. Second, thank you to the TAPS facilitators for allowing me to work with your program to do this research. Third, thank you to my committee: Dr. Signe Kastberg, Dr. John Staver, Dr. Cathy Brown, and Dr. Rachael Kenney. You were wonderful mentors and supportive throughout this long process. Fourth, thank you to Dr. Andrew Tyminski for getting me off to a great start. Finally, I would like to thank Dr. Brandon Sorge. I appreciate your help with the reliability of the interview and observation data. More importantly, you have been a life-long friend who has inspired me.

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ABSTRACT

Walker III, William S. Ph.D., Purdue University, December 2016. Factors Influencing Teacher Instructional Practice in Mathematics when Participating in Professional Development. Major Professor: Signe Kastberg.

In this research, I investigated teachers' interpretations of the goals of professional development and factors that contributed to enacted instructional practices. A multiple-case study design was used to examine the interpretations of four high school teachers participating in a year-long professional development program with a standards-based framework for mathematics education. Data collection included information about the professional development program, the intended and enacted curriculum (Stein et al., 2007), the teachers' interpretations of the professional development goals, and context factors that influenced instructional planning and implementation. The data were used to create a description of the professional development, a case study of each teacher that included a description of the enacted curriculum and a description of context factors that influenced the instructional practices. Additional examination included a cross-case analysis to identify common themes between the teachers.

Each teacher provided an interpretation of the goals of the professional development that was consistent with the professional development, but often focused on a narrower objective for each of the goals. The teachers' interpretations of the goals influenced their use of ideas from the professional development in their classrooms. Four additional context factors were identified as influences on enacted instruction: perception of classroom control, attitude towards standards-based instruction, usefulness of professional development activities in relationship to grade levels or courses taught, and concerns about student success due to a lack of experience with standards-based instruction. The findings of this research have implications for providers of professional development for K-12 teachers of mathematics. First, professional development providers need to spend time learning about teachers' interpretations of the goals of the professional development. Second, professional development providers should use a framework of content to be learned that is aligned with the goals of a professional development program. Finally, learning activities and sample lessons during the professional development should be grade level or course appropriate.

CHAPTER 1. BACKGROUND, RATIONALE, AND RESEARCH QUESTIONS

1.1 Background

In the United States, national standards and national reports from groups such as the Mathematical Sciences Education Board (1990), the National Council of Teachers of Mathematics (NCTM) (1989, 2000), the National Governors Association Center for Best Practices and the Council of Chief State School Officers (NGACBP and CCSSO) (2010), and the National Research Council (NRC) (2001) promote visions for standards-based instruction in K-12 mathematics education. These visions contain goals for students that include reasoning, modeling, communicating, connecting, constructing arguments, and supporting conclusions (NCTM, 2000; NGACBP & CCSSO, 2010). At the same time, research has documented that mathematics instruction in the US is not consistent with the standards-based visions (e.g. Hiebert et al., 2003; Mullis, Martin, Gonzalez, & Chrostowski, 2004).

Implementing standards-based instruction in mathematics includes many challenges for teachers, administrators, and schools. For example, teachers must learn new content, gain experience with different instructional techniques, and implement new assessment methods (Reys, Reys, Lapan, Holliday, & Wasman, 2003). Administrators need to align policies such as teacher evaluation procedures and resources such as time to encourage standards-based practices (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Schools need to support an environment of investigation where students work with teachers on significant mathematical tasks (Loucks-Horsley et al., 2010). Research-based professional development is needed for mathematics teachers, administrators, and school communities so that standards-based instruction can occur and be sustained (Lappan, 1997; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Loucks-Horsley et al., 2010).

1.2 Introduction

Supovitz and Turner (2000) used the model in Figure 1.1 to demonstrate how teacher participation in professional development could lead to improved student achievement such that, "… high quality professional development will produce superior teaching in classrooms, which will, in turn, translate into higher levels of student achievement" (Supovitz & Turner, 2000, p. 965). This model is important not only because it represents the progression from professional development to student achievement, but also because it represents the educational environment as a factor that influences the design of professional development, the implementation of inquiry-based (or standards-based) instructional practices, and improved student achievement.

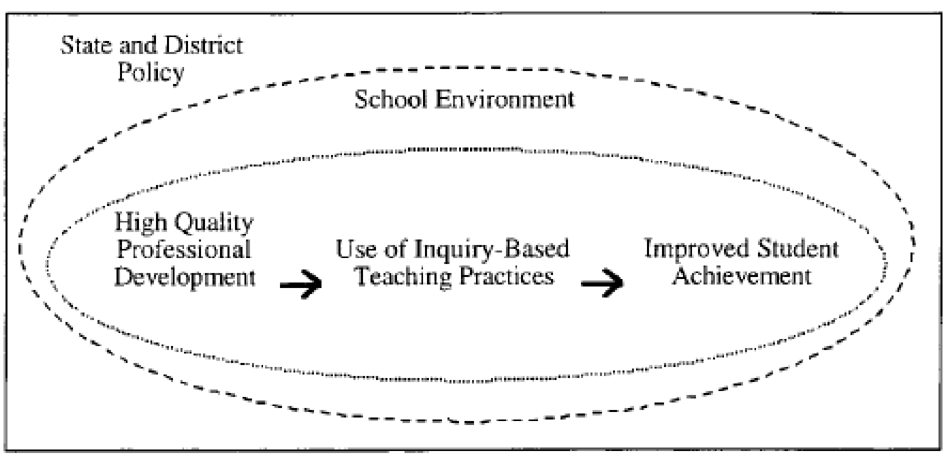

Figure 1.1 Model of Theoretical Relationship between Professional Development and Student Achievement (Supovitz & Turner, 2000, p. 965)

Stein et al. (2007) provide a model of the *Temporal Phases of Curriculum Use* to represent the influence of curriculum on student learning (see Figure 1.2). This model represents context factors described as explanations for transformations that influence curriculum enactment and student learning. Context factors can be understood as features that are distinct to local schools or populations that can influence the outcomes of professional development (Loucks-Horsley et al., 2010; Sztajn, 2011) and instruction as it is planned by the teacher and enacted in the classroom.

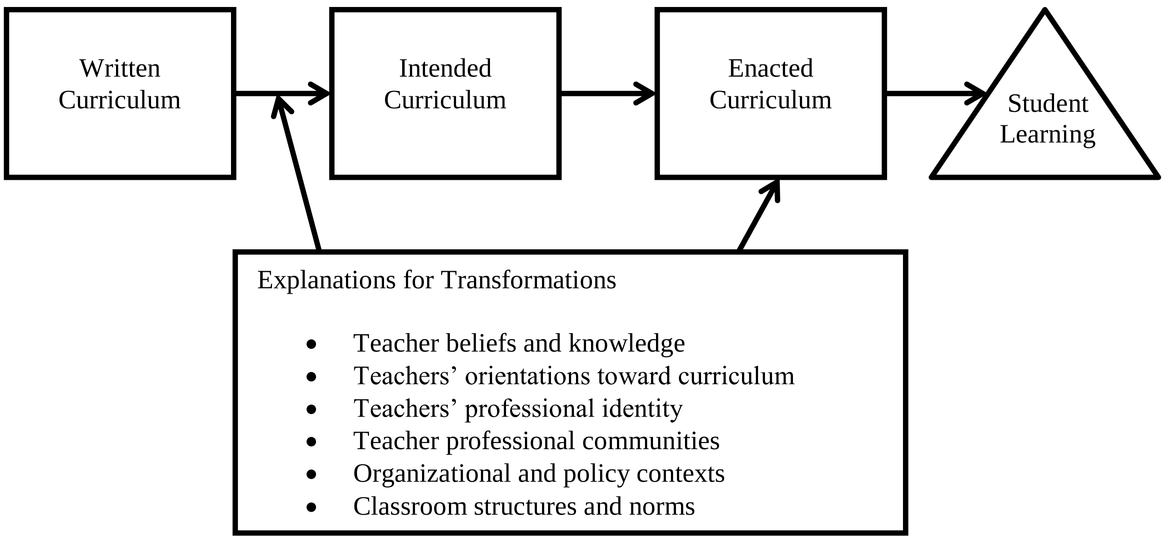

Figure 1.2 *Temporal Phases of Curriculum Use* (Stein et al., 2007, p. 322)

This model demonstrates that the priorities of the written curriculum, teachers' interpretations and use of the written curriculum, and factors that influence classroom practice all impact student learning. In the *Temporal Phases* model, the teacher's plan is the intended curriculum and the implementation of his or her teaching practices results in the enacted curriculum. Factors such as a teacher's beliefs and knowledge, educational policies, and classroom norms influence the enacted curriculum such that it may be different from the written curriculum and intended curriculum (Stein et al., 2007).

These two models are merged in Figure 1.3 so that the *Temporal Phases of Curriculum Use* model adds depth to the Supovitz and Turner (2000) model. The merged model represents transitions from both research-based professional development and written curriculum to the intended curriculum. Arrows with solid lines are used to represent transitions between phases of curriculum and arrows with dotted lines are used to represent places where context factors may influence the curriculum phases. For example, there is a transition from the enacted curriculum to student learning denoted by an arrow with a solid line, but the influence of the context factors on the enacted curriculum is denoted by an arrow with a dotted line.

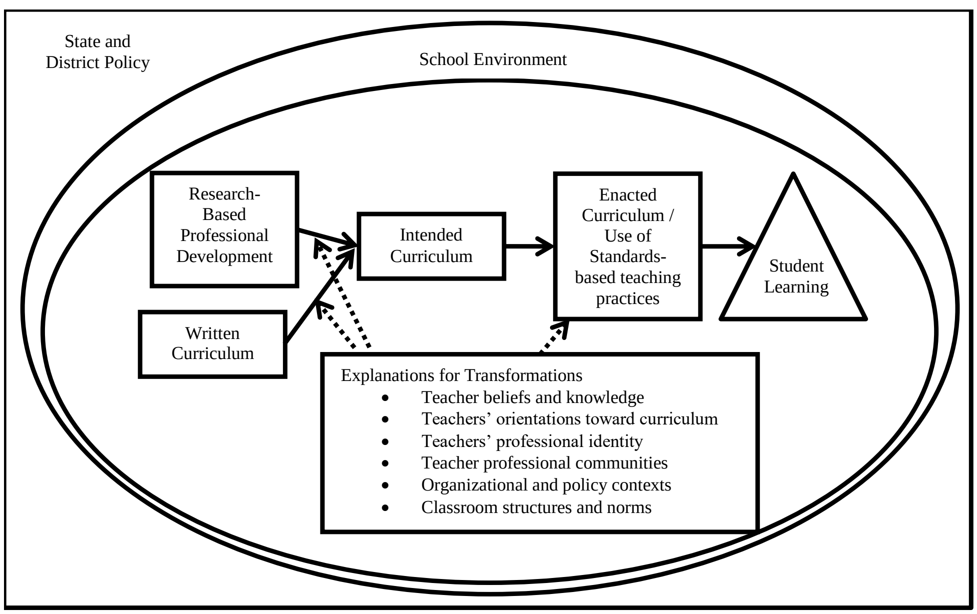

Figure 1.3 Model of Theoretical Relationship between Professional Development and Student Learning Incorporating the *Temporal Phases of Curriculum Use*

Research-based professional development provides teachers with opportunities to learn content, theories of learning, and pedagogy. The teacher learning experiences are altered by the teachers based on context factors including the school environment (e.g. Borko, 2004; Drake, Spillane, & Hufferd-Ackles, 2001; Stein et al., 2007). Teachers' knowledge, orientations, and professional identity, along with school environment factors such as educational policy and classroom structures, can influence the intended curriculum and the enacted curriculum (Henningsen & Stein, 1997).

Models depicting the relationships that influence student learning are a helpful tool for interpreting the connections and transitions between professional development for teachers of mathematics, curriculum use, and student learning. The goals and strategies of professional development can influence how teachers make sense of the written curriculum and a teacher's work on the intended curriculum. Additional factors such as teacher prior knowledge and educational policies can influence the intended and enacted curriculum. Since the environment that surrounds instruction in mathematics is complex, research is needed to understand the factors that influence the intended and enacted curriculum when teachers participate in professional development.

1.2.1 Further Justification

Several studies and reports indicate the need for research on the impact of teacher professional development programs in K-12 mathematics (e.g. Loucks-Horsley et al., 2010; Sowder, 2007; Stein et al., 2007; Tarr et al., 2008). Research has shown that evaluation of change in teacher practice does not match teachers' interpretations of change from self-reports (Cohen, 1990; Lee, Hart, Cuevas, & Enders, 2004). Some teachers are able to teach in a manner consistent with the goals of the professional development that is focused on standards-based instruction, some teachers' instruction reflects portions of the goals (Cook, Walker, Sorge, & Weaver, 2015), and other teachers struggle with using the reform concepts in their classroom.

Given the need for more information about the impact of professional development and the differences that occur when teachers enact standards-based teaching, it is important to further examine factors that influence how professional development goals are enacted during instruction. Moreover, it is important to learn more about the interpretations that teachers form as a result of the professional development experiences. Studying the purpose, characteristics, factors that influence change, interpretations developed by teachers, and results of research-based professional development will help promote effective professional development programs.

1.3 Research Questions

This research investigated four high school teachers participating in a year-long professional development program with a standards-based framework for mathematics education. In particular, the research focused on teachers' interpretations of the goals of professional development and factors that contributed to enacted instructional practices.

The research questions investigated in this study were:

1. What are the teachers' interpretations of the goals of a K-12 professional development program for mathematics?
2. How do context factors and interpretations of professional development goals influence the intended curriculum and enacted curriculum of mathematics lessons when the intent is to incorporate goals from the professional development program?

CHAPTER 2. PERSPECTIVES UNDERLYING ACADEMIC STANDARDS AND PROFESSIONAL DEVELOPMENT STANDARDS FOR MATHEMATICS EDUCATION

This research examined instructional practices of teachers who participated in professional development focused on standards-based mathematics instruction, teachers' interpretations of professional development goals, and context factors that influenced teacher's practice. In order to investigate professional development for standards-based mathematics instruction, key elements of standards-based mathematics and principles of effective professional development needed to be elucidated.

2.1 Standards-Based Mathematics Instructional Practices

Conceptions of standards-based mathematical activity in US classrooms have developed over the years. The NCTM (1989) published research-informed process standards that included problem solving, communication, reasoning, and connections as process standards for K-12 mathematics. These process standards were revised to problem solving, reasoning and proof, communication, connections, and representation by the NCTM (2000). After 2000, national standards focused more on proficiencies and expertise. The NRC (2001) identified conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition as five strands of mathematical proficiency for successful mathematics learning.

Most recently, standards-documents were released to describe student proficiencies and teacher practices to support mathematical literacy for all students. The NGACBP and CCSSO (2010) identified eight standards for mathematical practice (SMPs) that “describe varieties of expertise that mathematics educators at all levels should seek to develop in their students” (p. 6). The SMPs include (1) making sense of problems and persevering in solving them, (2) reasoning abstractly and quantitatively, (3) constructing viable arguments and critiquing the reasoning of others, (4) modeling with mathematics, (5) using appropriate tools strategically, (6) attending to precision, (7) looking for and making use of structure, and (8) looking for and expressing regularity in repeated reasoning. The NCTM (2014) provided eight mathematics teaching practices (MTPs) that “provide a framework for strengthening the teaching and learning of mathematics” (p. 9). The MTPs include (1) establishing mathematics goals to focus learning, (2) implementing tasks that promote reasoning and problem solving, (3) using and connecting mathematical representations, (4) facilitating meaningful mathematical discourse, (5) posing purposeful questions, (6) building procedural fluency from conceptual knowledge, (7) supporting productive struggle in learning mathematics, and (8) eliciting and using evidence of student thinking.

Standards-based mathematics classrooms can be described as educational settings where teachers and students work together to develop proficiencies or expertise in mathematics content.

> [R]esearchers seem to agree in principle that classrooms that support mathematical proficiency would be places where students are encouraged to be curious about mathematical ideas, where they can develop their mathematical

> intuition and analytic capabilities, where they learn to talk about and with mathematical expertise. (Franke, Kazemi, & Battey, 2007, p. 229)

Research and the standards documents describe important aspects of standards-based instructional practices for mathematics which include classroom norms and classroom discourse, teachers' and students' roles, standards-based curriculum, and assessment.

2.1.1 Classroom Norms and Classroom Discourse

The environment in which students learn affects their views of what mathematics is, how someone learns it, and their views of themselves as learners of mathematics (Boaler, 2002; Lappan, 1997). In a standards-based mathematics classroom students should engage in an empirical study of mathematics by expressing understandings, questioning conjectures, and participating in mathematical discourse.

Classroom norms influence the social context of a classroom and afford and constrain what is learned and how it is learned (Yackel & Cobb, 1996). Norms are taken-as-shared understandings that are interactively negotiated by teachers and students through classroom social development (Cobb, Yackel, & Wood, 1992; Franke et al., 2007; Yackel, Cobb, & Wood, 1991). Classroom norms include social norms such as the nature of discourse; expectations for individual, small group, and whole class work; and expectations for written communication. Additionally, classroom norms include sociomathematical norms such as making mathematical claims, perceptions of what constitutes mathematical work, and acceptable ways to mathematically disagree (Franke et al., 2007; Lampert, 2001; Yackel & Cobb, 1996). Normative participation is part of the routine of a class and can help identify standards-based mathematics classrooms.

The nature of discourse in a mathematics classroom is such that learners exchange points of view, negotiate meanings, resolve conflicts, and develop consensual domains for mathematical concepts and mathematical reasoning (Cobb, Wood, & Yackel, 1990). "How teachers and students talk with one another in the social context of the classroom is critical to what students learn about mathematics and about themselves as doers of mathematics" (Franke et al., 2007, p. 230). Teachers can support student learning in a standards-based class by promoting mathematical discourse and allowing students to express their ideas, explore possibilities, and develop understandings (Fennema, Franke, Carpenter, & Carey, 1993; NCTM, 2000; NGACBP & CCSSO, 2010; Walker, 1998).

2.1.2 Teacher and Student Roles in Standards-Based Mathematics Classrooms

Teachers and students in K-12 standards-based mathematics classrooms have roles that are different from traditional mathematics classrooms. One of the main responsibilities of a teacher in a standards-based mathematics classroom is to plan, establish, and sustain the mathematical learning environment.

Teachers are responsible for creating an environment where students can actively build mathematical understandings and share concepts (Confrey, 1990; NCTM, 2000). In these classrooms teachers set expectations for students to work independently and in groups on worthwhile mathematical tasks with a goal of creating autonomous mathematical learners (Cobb et al., 1991; McClain & Cobb, 2001; NCTM, 2000; NRC, 2001; Yackel & Cobb, 1996). A teacher in a standards-based classroom is able to use his or her knowledge of mathematical content and pedagogy to "understand the big ideas of mathematics and be able to represent mathematics as a coherent and connected enterprise" (NCTM, 2000, p. 17). Teachers also use their knowledge of mathematics to ask questions that are mathematically relevant and engage in mathematical investigations that will stimulate higher-order thinking and deeper comprehension (Fennema et al., 1993; Grouws, 2004; Maher & Davis, 1990; NCTM, 2000).

Students have important roles in standards-based mathematics classrooms that are negotiated and developed through their participation over time (McClain & Cobb, 2001; Yackel & Cobb, 1996). For example, students are expected to do mathematical work independently and collaboratively (Lampert, 2001; NCTM, 2000). Students are also expected to make conjectures and share mathematical thinking verbally and in writing (Boaler, 2002; Grouws, 2004). Some additional types of normative roles for students in standards-based classrooms include using mathematical differences and mistakes as opportunities for learning, using reasoning to explain solutions processes to all members of the class, justifying mathematical claims, persevering in solving mathematical problems, and using mathematics to model experiences (Boaler, 1999, 2002; NGACBP & CCSSO, 2010; Walker, 1998).

2.1.3 Standards-Based Curriculum and Curriculum Use

A school mathematics curriculum can be broadly understood as the learning trajectories for students along with the supporting components such as instructional materials and pedagogical practices that influence student learning. Articulated learning trajectories and supporting components play an important role in how students view and learn mathematics. The NCTM (2000) describes characteristics of effective school mathematics curriculum, which include coherence within and among important mathematical concepts, focusing classroom work on the foundational ideas of mathematics, and having clear articulation across the grades to help students develop sophisticated mathematical understandings.

2.1.3.1 Intended and Enacted Curriculum

Stein et al. (2007) provide a model for phases of curriculum use that identifies distinctions between the written curriculum, intended curriculum, and enacted curriculum (see Figure 1.2). This model reflects research evidence that curriculum is enacted in a variety of different ways and student learning is influenced by the enacted curriculum and context factors. Studies have found that, when a curriculum is used with varying degrees of fidelity, then differences in student learning and achievement can exist (e.g., Balfanz, Mac Iver, & Byrnes, 2006; Huntley, Rasmussen, Villarubi, Sangtong, & Fey, 2000; Tarr et al., 2008). In other words, different enactments result in different learning opportunities for students and in differences in student achievement in mathematics.

The written curriculum represents the design of the curriculum materials and accompanying teaching resources. The written curriculum itself influences the opportunity for mathematical learning due to the context and solution strategies afforded and constrained. The intended curriculum represents the curriculum that the teacher interprets and intends to enact. "[T]he process of reading and using curriculum materials necessarily involves interpretation and meaning making on the part of the teacher. In this way teachers do not merely read and follow written curriculum" (Stein et al., 2007, p. 340). The differences between the written curriculum and the intended curriculum exist due to interpretations that teachers use to transform the curriculum and by factors that influence intended curriculum. The enacted curriculum refers to what actually occurs as curricular materials are utilized in a classroom during instructional practice. Variations that take place during the enactment of a mathematics lesson exist due to teacher characteristics, student characteristics, teacher and student interpretations, normative classroom practices, and the context of teaching (Stein et al., 2007). The phases of curriculum use ultimately influence student learning.

2.1.3.2 Mathematical Tasks

Curriculum materials are an important consideration because many teachers of mathematics rely on these curricular materials as the principal tool for teaching mathematics (Grouws, Smith, & Sztajn, 2004). Within the research on how curricular materials influence student learning is research on mathematical tasks. Mathematical tasks are a set of activities or a single complex activity designed to focus students' attention on a particular mathematical idea (Stein, Grover, & Henningsen, 1996; Stein, Smith, Henningsen, & Silver, 2000).

The selection of mathematical tasks influences students' opportunities to learn mathematics through the topics that are covered and how mathematics is presented (Lappan, 1997; Stein et al., 1996; Stein et al., 2007). To select appropriate mathematical tasks, the teacher must make judgments about how well the task represents the embedded mathematical concepts, how likely the students are to develop mathematical skill, and how well the tasks represent doing mathematics (Lappan, 1997). The tasks should allow for different solution methods, give the teacher a chance to examine student thinking, and provide opportunities to generalize mathematical processes and understandings (Lappan, 1997; Stein et al., 1996).

Selection of mathematical tasks alone is not sufficient to change instructional practice in classrooms (Bouck, Keusch, & Fitzgerald, 1996; Tarr et al., 2008). In addition to selecting mathematical tasks, teachers must create a learning environment and implement pedagogy that compliments the tasks in such a way that the cognitive demand of a task can be maintained while students learn to use mathematics to make sense of the problems they encounter (Henningsen & Stein, 1997; Stein et al., 2007; Tarr et al., 2008).

2.1.3.3 Assessment

In a standards-based classroom, each day must include evidence-gathering that provides information about students' current mathematical understandings and allow teachers to make informed decisions about mathematical tasks, instructional techniques, and the learning environment (NCTM, 2000; Wiliam, 2007, 2011). Standards-based instruction requires teachers to gather data and use assessment methods including creating, using, and interpreting rubrics for performance tasks (Garet, Porter, Desimone, Birman, & Yoon, 2001; Lappan, 1997; Reys et al., 2003; Wiliam, 2007).

2.1.4 Discussion of Mathematics Instructional Practices

One of the largest challenges facing the change to standards-based instruction in K-12 mathematics classes is the complex social environment surrounding the classroom that includes multiple factors influencing how instruction is enacted. A framework that considers the complex environment of a school is needed to analyze the enactment of standards-based mathematics instructional practice. The model that merged the *Temporal Phases of Curriculum Use* with the Supovitz and Turner model (see Figure 1.3) helps place instruction in the context of the school environment, identify the transformations that happen within and between the different phases of curriculum use, and context factors that influence the transformations.

Along with accounting for the systemic environment, there are considerable challenges for teachers to enact standards-based instruction in mathematics. Strong content knowledge and addressing student learning needs are necessary for the selection of mathematical tasks. Teachers must learn new roles to sustain a learning environment that sets expectations for standards-based student roles. These roles present a challenge for teachers who are inexperienced in situations where reasoning, explanation, argument, and decisions based on evidence are central parts of the mathematics learning experience (Lappan, 1997). Additional challenges for teachers include building an environment that encourages taking intellectual risks and is continually evaluated based on evidence. The merged model includes research-based professional development which can help teachers learn mathematics content, theories of student learning, pedagogical strategies, and implementation of these skills into classrooms.

2.2 Principles of Effective Professional Development in K-12 Mathematics

This research focused on professional development aligned with standards-based visions for mathematics classrooms. Principles of effective professional development for K-12 teachers of mathematics and standards for reporting mathematics professional development in research studies (Sztajn, 2011) were used to describe the professional development program.

2.2.1 Principle One: Systemic Approach

A systemic approach involves integrating professional development on standards-based instructional practices with the school vision for mathematics education and with existing school or district culture. Such an approach helps support sustained change for a school or school district. National, state, and local standards should be used as a framework for professional development to provide clear objectives and support systemic change (Garet et al., 2001; Little, 1993; Loucks-Horsley et al., 2010; NCTM, 2000). A systemic approach also requires school and/or district policies to be aligned with the vision for standards-based instruction. For example, if student performance assessments or teacher evaluations do not align with the vision for standards-based mathematics instruction, then any changes will likely be short-lived.

2.2.2 Principle Two: Involving Participants in Decision Making

Involving teachers, administrators, and professional development providers in the data analysis, goal setting, and design of a professional development program increases the relevance of a program (Ball, 1996; Borko & Putnam, 1995; Hawley & Valli, 1999; Little, 1993). Participants will be motivated to learn, empowered to assume new responsibilities, and able to build an improvement-oriented school culture if they are involved in the decision making process (Hawley & Valli, 1999; Pink, 1992). Offering opportunities for analysis of differences and alternative strategies as part of the decision making process promotes productive analysis rather than resistance (Little, 1993). If teachers and administrators are denied input, they are likely to become detached and indifferent towards school improvement efforts.

2.2.3 Principle Three: Theory of Learning:

A well-defined theory of learning plays an important role in the goal setting and planning of professional development (Ball, 1996; Hawley & Valli, 1999; Loucks-Horsley et al., 2010). Professional development activities should allow teachers to experience learning from the perspective of a student and incorporate theories of learning into planning. Important concepts such as prior knowledge, learning as personal construction, and learning that is enabled by social and cultural features should be taught during professional development (Loucks-Horsley et al., 2010) and integrated into the work of the teachers and the school during enactment.

The theory of learning also influences professional development activities for adult learning. Professional development activities should reflect teachers' specialized content knowledge (Ball, 1996; Lappan, 1997; Shulman, 1986). Research has found that including content knowledge as a focal point for professional development has a positive influence on improving teacher skills and student achievement (Ball, 1996; Garet et al., 2001; Hill & Ball, 2004; Hill, Sleep, Lewis, & Ball, 2007).

2.2.4 Principle Four: Accounting for the Contexts of Teaching

In order to be systemic, professional development in K-12 mathematics must take into account the context in which instruction takes place. The idea of context highlights features that are distinct to local schools or populations that can influence the design and outcomes of professional development (Loucks-Horsley et al., 2010; Sztajn, 2011). Seven context features to consider when planning professional development are: (1) students and their learning needs; (2) teachers and their learning needs; (3) curriculum, instruction, assessment practices, and learning environment; (4) organizational culture and professional learning communities; (5) national, state, and local policies; (6) available resources; and (7) families and communities (Loucks-Horsley et al., 2010).

The first two context factors are learning needs for students and teachers. A clear picture of students' and teachers' current situations and their needs is critical for designers (Ball, 1996; Loucks-Horsley et al., 1998; Loucks-Horsley et al., 2010). Professional development should include a clear vision for student learning and assessment aligned with this vision to investigate student growth. Designers also need knowledge about the teachers participating in professional development. Teachers have different levels of experience and different types of educational attainment. Also, teachers at different instructional levels have different learning needs.

Curriculum, instructional practices, assessment practices, and learning environment constitute the core of education that influences mathematics learning (Loucks-Horsley et al., 2010). Knowledge of the current state of the educational core in relationship to national, state, and local standards will help create a plan for improving mathematics instruction (Little, 1993; Tetley, 1998). Determining the current state of these areas with respect to standards-based visions for mathematics learning will help identify realistic goals for professional development work.

Organizational culture refers to the culture of the school, community, and beyond that supports or inhibits teaching and learning. Leadership that provides a clear vision for mathematics education and follows up with aligned feedback and decision making can support successful professional development. A school that includes professional learning communities can support standards-based changes through professional development (Garet et al., 2001; Little, 1993). Professional developers need to address existing cultures and leadership structures that may or may not support professional growth.

Professional development activities need to reflect state and federal education regulations, employment contracts, and school calendars. Educators "often face an unfriendly policy environment in which professional development is undervalued, underfunded, or narrowly defined as workshops or courses" (Loucks-Horsley et al., 2010, p. 103). Professional development providers should work with school district leaders to align visions for mathematics education with regulations and policies.

Resources of time, materials, and expertise are needed to support teacher improvement in teaching mathematics. Sufficient time must be available for teachers to learn about standards-based instruction (Ball, 1996; Garet et al., 2001; Supovitz & Turner, 2000). Teachers need time away from students to work with colleagues and experts, collect and analyze data, and reflect on practice as part of the regular work routine (Loucks-Horsley et al., 2010). Other resources such as appropriate curricular materials and access to technology are important considerations (Ball, 1996). Educators need access to curricular materials and technology to learn how they will support student learning in mathematics.

Public support for systemic change is important for professional development to succeed. As schools participate in professional development, learning expectations may change and teachers may be out of classrooms attending meetings. Information about how the professional development will address the mathematical needs of the students can help create public support (Loucks-Horsley et al., 1998). Professional development outcomes can be influenced by plans for families to get involved in school decision making, building trusting relationships with school staff, and participating in the learning of their children (Loucks-Horsley et al., 2010).

2.2.5 Principle Five: Educational Leadership

District and school leaders are a critical part of systemic change because they set the vision for effective instruction, control the availability of resources, set time schedules, oversee assessment and accountability measures, and manage community support (Loucks-Horsley et al., 2010). Developing teachers as educational leaders and supporting them to serve in leadership roles creates a valuable resource for systemic school improvement that promotes sustainability over time. Teacher leadership includes learning roles such as coaching, mentoring, facilitating professional development, acting as an instructional specialist, or chairing a department (Loucks-Horsley et al., 2010; Silva, Gimbert, & Nolan, 2000). Educational leaders benefit student learning by implementing reforms in classrooms, growing collaborative cultures, and sustaining professional growth within a school district.

2.2.6 Principle Six: Continuous and Ongoing Support

Professional development should be ongoing over long periods of time to allow teachers to learn and enact standards-based mathematics instruction (Ball, 1996; Hawley & Valli, 1999; Lappan, 1997; Supovitz & Turner, 2000). Teachers need time to learn about theories of student learning for mathematics, understand the content they will be teaching, and become proficient in the use of pedagogy that is consistent with standards-based instruction. They also need time to discuss and work with colleagues and experts who are involved in implementing the changes to make adjustments on an ongoing basis (e.g., Jacobs, Franke, Carpenter, Levi, & Battey, 2007).

2.2.7 Formative and Summative Assessment

Evaluation of a professional development program should reflect the desired outcomes and determine to what extent they have been met (Guskey, 2000; Guskey & Sparks, 1991). Summative evaluation provides information about the outcomes of professional development. Formative evaluation provides opportunities for ongoing adjustments to the program so that final results can be maximized. Data sources aligned to the program outcomes such as teacher content assessments, classroom observation protocols, and guided interviews provide essential information. Data from classroom experiences such as student work, student assessment results, and teacher reflection journals can be used to support improvements.

2.2.8 Strategies for Effective Professional Development

Identifying strategies that address the principles for effective professional development is important for designing a program for K-12 teachers of mathematics. Strategies are learning experiences with identifiable characteristics (Loucks-Horsley et al., 2010). Each strategy has strengths and weaknesses that should be considered in relationship to program goals. Strategy selection requires matching the strengths of the strategy with the goals of professional development and the needs of the participants. Some strategies include immersion in content, standards, and research; examining teaching and learning; aligning and implementing curriculum; and study groups (Hawley & Valli, 2000; Loucks-Horsley et al., 2010).

2.2.9 Reflection on Professional Development for K-12 Teachers of Mathematics

Research on professional development programs provides evidence about characteristics of effective professional development that need further investigation. For example, Garet et al. (2001) identified three features of professional development that have positive effects on teachers’ knowledge and classroom practice. Analysis of teachers’ self-report survey data identified the three features as focusing on content, opportunities for active learning, and coherence with other learning activities. Supovitz and Turner (2000) used survey data and found statistically significant correlations between inquiry-based teaching practices with hours of professional development, students on free or reduced lunch, type of community, school size, gender, minority or non-minority teachers, years of experience, attitude, content preparedness, principal support, classroom resource availability, and school resource availability.

The use of survey results and self-reporting by teachers about the effectiveness of research-based professional development programs has some limitations. For example, in the evaluation of a reform-based science education professional development program, Lee et al. (2004) noted that teachers reported enhanced knowledge of science content and stronger beliefs about the importance of inquiry-based science instruction, although the actual practices of the teachers did not change significantly based upon observation data. Cohen (1990) examined one teacher who believed she had revolutionized her mathematics instruction in relationship to a reform vision, but her self-reporting of significant changes was not consistent with classroom observations.

While there is some consensus regarding principles or essential characteristics of effective professional development (e.g., Garet et al., 2001; Hawley & Valli, 1999; Supovitz & Turner, 2000), consistent criteria for understanding the effectiveness of professional development and researched-based evidence supporting the characteristics is rare (Guskey, 2003; Sztajn, 2011). This research will investigate context factors that influence the transition from professional development focused on standards-based mathematics instruction and the enacted curriculum.

CHAPTER 3. METHODOLOGY

In this research, I examined four teachers participating in a year-long professional development program. The research questions focused on how context factors influenced the phenomena of the intended and enacted curriculum. I used a multiple-case study design because it allowed for the analysis of "complex social units consisting of multiple variables of potential importance in understanding the phenomenon" (Merriam, 2009, p. 50). The case study design also allowed me to investigate the intimate knowledge of each teacher's activities in and interpretations of the professional development and teaching mathematics. The model depicting a theoretical relationship between professional development and student learning was the central framework for data collection and analysis (see Figure 3.1). Consistent with other research (e.g., Darling-Hammond, 1999; Mullis, Martin, Foy, & Arora, 2012; Tarr, Chávez, & Reys, 2006; Tarr et al., 2008), the model demonstrates that student learning is influenced by curriculum use and transforming factors. This research concentrated on the phases that lead to student learning and the factors that influence these phases.

Data collection included information that would describe the professional development experience, the intended curriculum, the enacted curriculum, the teachers' interpretations of the professional development goals, and context factors that influenced instructional planning and implementation. This data was used to create a description of the professional development, a case study (Merriam, 2009) of each teacher that included the teacher's interpretation of the goals of professional development, the teacher's perspectives about the intended and enacted curriculum, a description of the enacted curriculum in relationship to standards-based mathematics instruction, and a description of context factors that influenced the intended and enacted curriculum. Additional examination included a cross-case analysis to identify common themes between the teachers. The case studies and the common themes were used to add detail to the model.

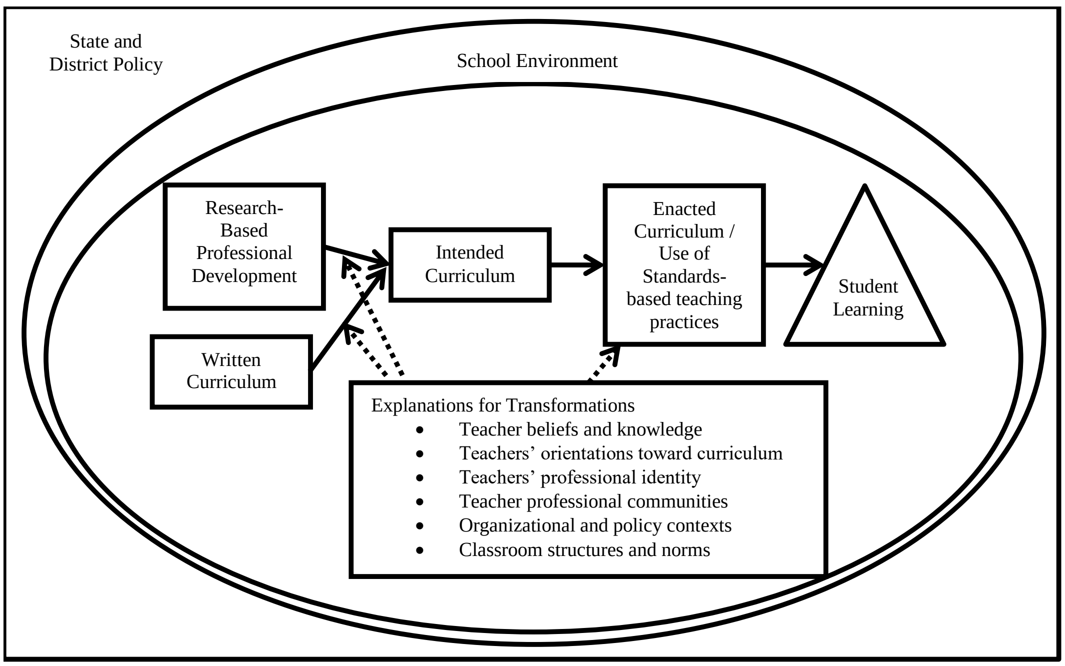

Figure 3.1 Model of Theoretical Relationship between Professional Development and Student Learning Incorporating the *Temporal Phases of Curriculum Use*

3.1 Professional Development and Participant Selection

The professional development program was identified by asking university faculty and state department of education personnel for recommendations of year-long mathematics professional development programs for K-12 teachers. The programs needed to be research-based with goals for teachers to implement standards-based mathematics instruction. Additionally, it was desirable for the professional development programs to include a multi-day summer institute and academic-year follow-up meetings. The professional development program in this research was called Teaching Algebra with Practice Standards (TAPS). TAPS was a three-year program focused on standards-based mathematics instruction with a ten-day summer institute and school-year follow-up sessions. Permission to conduct the research was obtained from the professional development leaders and the school district.

Fifteen middle and high school mathematics teachers volunteered to participate in TAPS. All fifteen of the teachers received continuing education units and stipends for work done outside of school time. At the beginning of the TAPS summer institute teachers were recruited by the researcher to participate in this research. Teachers were informed that participating in the research would require them to complete surveys, interviews, and permit the researcher to conduct classroom observations. As an incentive, teachers participating in this research were credited with ten hours of independent work required by TAPS. Four high school teachers from the same school volunteered to participate in the research. Pseudonyms are used for the city, school district, school, professional development program, and teachers.

3.2 Role of the Researcher

My role was observer as participant (Merriam, 2009). I was not involved in the design or execution of any parts of the professional development or any mathematics lesson taught. Being disconnected from design and execution helped reduce researcher bias. I am a former K-12 teacher of mathematics, have participated in research on standards-based mathematics instruction, and have created professional development opportunities for K-12 teachers of mathematics and science. My prior experience with standards-based teaching and professional development influenced data that were prioritized during observations and analyses such as student discourse about mathematics and using incorrect solutions as learning opportunities.

3.3 Data Collection

In order to investigate teacher interpretations and context factors that influence the intended and enacted curriculum, data were collected on the professional development, the school district, the school, teachers' interpretations, and the intended and enacted curriculum. The data consisted of surveys with short answer, Likert scale, and open ended items; audiotaped and transcribed interviews; field notes; videotaped classroom observations; and classifications of instruction using an observation protocol. Data were collected between June 2015 and May 2016 (see Table 3.1).

3.3.1 Professional Development Data

Data were collected to create a description of the professional development that included articulated goals, alignment with the seven common principles of effective professional development, and strategies for effective professional development using the *Professional Development Data Collection Guide* (see Appendix A). Data sources included the professional development written proposal, field notes from professional development sessions, email interview responses from the professional development providers, and artifacts from the sessions. I interviewed the professional development providers via email in the summer of 2015 and the summer of 2016. Interview questions focused on the professional development goals and the areas highlighted in the

Professional Development Data Collection Guide. I took field notes during the summer institute sessions in 2015 and the academic-year follow up sessions in fall 2015 and spring 2016. The notes included descriptions of professional development activities and teacher and facilitator comments during the activities. Times were recorded between each of the activities. For example, the teachers started the professional development at 1:00 working on a reflection question, discussed the reflection question at 1:30, and worked in small groups on a mathematical task at 2:00.

Table 3.1 Data Collection Timeline

Time	Activity
Summer 2015	- *Professional Development Data Collection Guide* (goals, critical issues, etc.) - *District Profile* - *School Profile* - *Teacher Background and Experience* survey - *Teacher Professional Opportunities* survey - *Teacher School Context and Attitude Towards Standards-Based Instruction* survey (1)
Fall 2015	- *Teacher Interpretation of Professional Development Goals and Intended Curriculum* interview - *Teacher School Context and Attitude Towards Standards-Based Instruction* survey (2) - *Teacher Planning and Intended Curriculum* interview (1) - Teacher Observation (1) - *Teacher Post-Observation and Enacted Curriculum* interview (1)
Spring 2016	- *Teacher Planning and Intended Curriculum* interview (2) - Teacher Observation (2) - *Teacher Planning and Intended Curriculum* interview (2) - *Teacher School Context and Attitude Towards Standards-Based Instruction* survey (3)
- Parentheses indicate occurrence when a tool is used more than once - Italics represent the titles of data collection tools (see next section)	

3.3.2 Background and Context Data for the School District, School, and Teachers

Background information was collected for the school district and school where the four participating teachers worked. A *District Profile* survey adapted from Shafer, Davis, and Wagner (1997a) which included questions about the school district, schools, students, teachers, and mathematics program (see Appendix B) was completed by reviewing online data and interviewing a school district representative. A *School Profile* survey adapted from Shafer, Davis, and Wagner (1997d), which included context information about the school, students, teachers, and mathematics program (see Appendix C) was completed by reviewing online data and interviewing a school representative. This provided background information about the school environment and allowed for triangulation with data from teacher interviews regarding how context factors influenced the intended and enacted curriculum.

Three surveys were given to the four teachers participating in the research to gather baseline data on background, teaching experience, prior professional development experience, attitudes towards standards-based instruction, and school context. The first survey was *Teacher Background and Experience* and was adapted from Shafer, Wagner, and Davis (1997a) (see Appendix D). This survey provided data on education and teaching experience. The second survey was *Teacher Professional Opportunities* and was adapted from Shafer, Davis, and Wagner (1997b) (see Appendix E). This survey provided data about the frequency, content, and support for each teacher's prior professional development experience. Participants were asked to complete these two surveys before they participated in the professional development experience.

The third survey was *Teacher School Context and Attitude Towards Standards-Based Instruction* (see Appendix F). This survey was adapted from Shafer, Davis, and Wagner (1997c) and Supovitz and Turner (2000). It was administered three times: before the teachers participated in the professional development, in the fall after they completed the summer institute, and at the end of the spring semester. The three completion times helped identify if the teachers' interpretations of the school context and attitudes towards standards-based instruction changed after participation in the professional development summer institute or after enacting mathematics lessons consistent with the professional development. The survey contained Likert scale items about teacher influence over school policy, classroom control, the school as a workplace, the school support environment, the school professional development climate, and attitude towards standards-based aspects of mathematics teaching and learning. Items were used to triangulate data from teacher interviews and classroom observations regarding how context factors influenced the intended curriculum and enacted curriculum of mathematics lessons.

3.3.3 Teacher Interviews: Professional Development Goals and Intended Curriculum

Teachers were interviewed to learn about their interpretations of the professional development, how they planed mathematics lessons, and context factors that influenced the intended curriculum. After the summer institute, each participating teacher was interviewed regarding his or her interpretations of the professional development. An interview protocol *Teacher Interpretation of Professional Development Goals and Intended Curriculum* was adapted from Shafer, Davis, and Wagner (1998) and used to collect data about each teacher's interpretations of the professional development goals and how they anticipated using the professional development during the upcoming school year (see Appendix G). The questions also provided opportunities for the teachers to identify context factors that may support or limit their ability to use aspects of the professional development during mathematics instruction.

A second type of interview was completed with each teacher two times during the school year. An interview protocol *Teacher Planning and Intended Curriculum* was used (see Appendix H). It was adapted from Shafer et al. (1998) and Shafer, Davis, and Wagner (1997e). These interviews took place before each teacher taught a lesson that was aligned to the goals of the professional development. Data from these interviews provided information about the intended curriculum and how each teacher planned to incorporate ideas from the professional development in instruction. The interviews also provided opportunities for each teacher to share his or her thoughts about context factors that influenced planning or that may influence the enacted curriculum.

3.3.4 Classroom Observations and Teacher Interviews: Enacted Curriculum

The enacted curriculum of each participating teacher was observed and videotaped two times during the school year. The participating teachers identified two lessons for the researcher to observe that they felt were consistent with the professional development. For three of the four teachers the first observation took place early in the school year, and the second observation took place later in the school year. The observations of the fourth teacher took place within a few weeks of each other, per the teacher's request. In most cases more than one video file was needed to tape the entire lesson. Tape numbers are noted when referencing the data. The observations provided evidence of standards-based mathematics instruction aligned to the professional development goals. Videotaping allowed for review of the data after the observation and for checking of reliability of the classifications.

An adapted version of an observation tool from the Wisconsin Longitudinal Study (Romberg & Shafer, 2003; Shafer, Wagner, & Davis, 1997b) was used. The tool was titled *Standards-Based Mathematics Instruction Observation Tool* (see Appendix I) and allowed the researcher to describe and classify the classroom learning environment, student actions, and teacher actions. Data were collected before the lesson, during the lesson, and after the lesson. The observation tool was adapted to include the sixteen practice standards: eight descriptors aligned with the SMPs (NGACBP & CCSSO, 2010) and eight descriptors aligned with the MTPs (NCTM, 2014).

Before each observed lesson, a phone interview was done with the teacher to identify intended features of the lesson such as the purpose, aspects of the professional development that the teacher planned to enact, expectations for the students, and planned assessments. During the lesson, detailed notes were made at least every five minutes describing the classroom activities. These notes were used for completion of the descriptors after the observation. After the lesson, I summarized the main activities that occurred during the class period, completed questions on the primary emphasis of the lesson, and described the degree to which classroom events aligned with descriptors of instructional practices aligned to the sixteen practice standards.

3.3.5 Post-Observation Teacher Interviews: Understandings of Enacted Curriculum

Each teacher participated in a post-observation interview within two weeks of the observed lesson. I completed the *Standards-Based Mathematics Instruction Observation Tool* before the interviews so clarifying questions about the lessons could be added. An interview protocol called *Teacher Post-Observation and Enacted Curriculum* was adapted from Shafer, Wagner, and Davis (1997c) and used for the post-observation interviews (see Appendix J). During the interview, teachers were asked to describe the lesson focusing on teacher participation, student participation, content emphasized, and changes that may have occurred in comparison to the intended curriculum. The second part of the interview focused on how the enacted lesson compared with the goals for professional development and context factors that may have influenced the lesson. Finally, the interview included questions about specific portions of the lesson in relationship to the *Standards-Based Mathematics Instruction Observation Tool*.

3.4 Data Analysis

3.4.1 School District, School, and Professional Development

The *District Profile* and the *School Profile* surveys were summarized to provide a description of the context of the school district and the school. They were reviewed for factors that may influence intended curriculum and enacted curriculum, focusing on the seven context features identified in Chapter 2. For example, the high school where the four participating teachers worked had a high percentage of students eligible for free or reduced lunch fees. These data were used to triangulate other context data.

Data about the professional development were used to create a description of the program goals, strategies for a systemic approach, participants' voice in decision making, theory of learning basis, contexts of teaching, educational leadership, continuous and ongoing support, and use of formative and summative assessment (Loucks-Horsley et al., 2010; Sztajn, 2011). Other important features of the professional development included content focus on mathematics, student thinking, or curriculum materials; strategies to address the learning of K-12 mathematics teachers; time (duration, span, and organization); activities used during the professional development; specific mathematics content topics addressed; ethical decisions; and costs (Sztajn, 2011). Data from the collection guide, interviews, and observations were compared to teacher interviews about professional development goals to identify consistencies and inconsistencies.

3.4.2 Teacher Surveys

The *Teacher Background and Experience* and the *Teacher Professional Opportunities* surveys were administered to learn about the teaching background and professional development experience of each teacher. The surveys provided information about the circumstances of each teacher before he or she participated in the professional development to account for existing influences on standards-based mathematics instruction during classroom observations and to triangulate findings and gain insight into the impact of the professional development as interpreted by the teachers.

An additional survey on *Teacher School Context and Attitude towards Standards-Based Instruction* was administered and analyzed to provide a description of each teacher on these topics and for consistency or variance after completing the professional development experience and the school year. If the responses to a Likert-scale item stayed the same for all three survey completions or if the responses only changed by one level (e.g., disagree to strongly disagree), then it was determined that the teacher was relatively consistent with his or her perception for that item. The response used to describe a teacher's perception about an item was the one that appeared most frequently. For example, if a teacher agreed on the first survey, agreed on the second survey, and had no opinion on the third survey then it would be reported that he or she agreed with this statement. If the responses to an item had a difference of more than one level (e.g., strongly agree to no opinion or disagree to agree), then it was determined that the teacher varied his or her perception. For example, if a teacher stated that he or she had no classroom control when selecting teaching methods on the first survey, little classroom control on the second survey, and complete classroom control on the third survey then it was determined that his or her perception varied for that item. The perception was described at each of the three different times to see if there was a trend (e.g., towards more classroom control) or if the responses to the item were inconsistent (e.g., agree, then disagree, and then no opinion).

Additional analysis was done with the attitude towards standards-based instruction items to report if the teachers were consistent or inconsistent with these statements. First, the items were classified as consistent with or inconsistent with standards-based mathematics instruction based on a comparison with the SMPs and MTPs. Statements such as “students learn mathematics best in classes where they are able to work in small groups” or “teachers should encourage children to find their own strategies to solve problems even if the strategies are inefficient” were identified as being consistent with the practice standards. Statements such as “if students use calculators, they won’t learn the mathematics they need to know” were identified as inconsistent with the practice standards. In total, thirteen statements were classified as consistent and five statements were classified as inconsistent with the practice standards.

To report the consistency of a teacher’s attitude with standards-based instruction, the number of times a teacher agreed with consistent statements and was added to the number of times he or she disagreed with inconsistent statements. For example, if a teacher agreed with eight statements consistent with the standard-based instruction and disagreed with two statements inconsistent with standards-based instruction, then it would be reported that this teacher was consistent with the practice standards on ten of the eighteen statements. When a teacher's responses varied, an end of the school-year report was given to show if the teacher changed toward more or fewer statements consistent with standards-based instruction. For example, suppose the teacher in the example had responses that varied on one item during the three administrations of the survey. On the final survey this teacher agreed with the statement that was also consistent with standards-based instruction. It would be reported that this teacher agreed with eleven statements consistent with the standards-based instruction at the end of the school year.

3.4.3 Teacher Interviews

The teacher interviews were transcribed nearly word for word. Repeated words and "ums" were left out to help with the readability of the statements. NVivo 11 (QSR International, 2015) was used to organize the analysis of and look for patterns in the transcripts. Segments were organized in NVivo based on interview questions. A new segment was started with the next interview question when a teacher completed the answer to a question. An inductive approach of comparative pattern analysis was used to create a category coding system for the transcripts (Merriam, 2009; Patton, 2002). The model depicting a theoretical relationship between professional development and student learning, concepts of standards-based mathematics instructional practices, and context factors of teaching mathematics provided a comparative framework for the coding system. The transcripts were further examined to group segments into sub-categories (Lincoln & Guba, 1985). For example, one of the coding categories for the transcribed interviews was *Teacher Role*. Sub-categories for *Teacher Role* included *monitor or listener*, *source of mathematical knowledge*, *ensurer of correctness,* and *facilitator*.

The reliability of the coding system was checked by calculating a percent of agreement with an experienced education researcher. Dr. Brandon Sorge, assistant professor of STEM education research at IUPUI, was trained on the coding system and reviewed the coding of one interview with the researcher. Dr. Sorge coded a different interview independently and his coding was compared with the researchers coding. Dr. Sorge and the researcher agreed on 90% of the codes. Dr. Sorge and I reviewed the differences and concluded that the coding was consistent with the descriptions in the *Common Core State Standards for Mathematics* (NGACBP & CCSSO, 2010) and *Principles to Actions* (NCTM, 2014).

The survey and interview data were used to create a description of each teacher and his or her interpretations of the professional development experience. The teacher survey data were used to triangulate data on context influences with the intended and enacted curriculum. The survey data were also used to make adjustments in teacher interviews to further investigate patterns or clarify differences. For example, the *Teacher School Context and Attitude Towards Standards-Based Instruction* survey included questions about instructional support by other teachers. If a teacher agreed that other teachers were helpful with instructional support, then this would be compared to interview responses and classroom observations to see if the evidence was consistent.

3.4.4 Classroom Observations

Classroom observation data from the *Standards-Based Mathematics Instruction Observation Tool* were used to describe the degree to which each teacher’s enacted instruction aligned with the SMPs and the MTPs. The concept of normative participation (Yackel & Cobb, 1996) was used to help identify aspects of a mathematics classroom that were consistent with standards-based instruction. After an observation, a lesson was classified as *no evidence, sometimes,* or *yes* for each of the sixteen practice standards. *No evidence* was used when there were no classroom events or only one classroom event that aligned with a practice standard descriptor. *Sometimes* was used when there were two or three classroom events that aligned with a descriptor. *Yes* was used when there were more than three classroom events that aligned with a descriptor. A final summary was created for each observed lesson describing the extent to which the teacher utilized standards-based instructional practices aligned with the sixteen practice standards. In Chapter 4: Descriptions and Cases, italics are used to identify the observed practice standards.

The reliability of the observation analysis was checked by calculating Krippendorff's alpha to measure agreement for the ordinal data while accounting for agreement by chance (Krippendorff, 2004). Dr. Brandon Sorge was trained on the observation protocol and used the protocol to classify the videotape of one observed lesson with the researcher. Dr. Sorge classified a different videotaped lesson independently and his coding was compared with the researchers coding. The alpha value was calculated to be 0.8223, which is considered a good reliability test (De Swert, 2012).

The analysis of the data resulted in a description of the school district and school, a description of the professional development, and case studies for each teacher. Additionally, analysis across the case studies presented common themes adding insight to the relationship between professional development and enacted curriculum.

3.4.5 Creating the Teacher Cases

Teacher cases were created from the survey, interview, and observation data. Each case started with a summary of the teacher surveys. Each teacher case included background information, a summary of his or her perceptions of the school context, and a summary of his or her attitude towards standards-based mathematics instruction. The surveys were used to provide background information for each teacher, to identify context features that influenced their instructional practice, and changes in interpretations or attitude. The summaries focused on groups of answers where a teacher agreed or disagreed. For example, part of the case would include that the teacher felt that the school administration supported standards-based instructional practices if a teacher agreed with several items related to this idea. Similarly, the case would include examples where a teacher's attitude changed. For example, the summary would include information about a teacher not valuing small group instruction before participating in the professional development, but valuing it by the end of the school-year.

Teacher interpretations of the professional development were summarized from the *Teacher Interpretation of Professional Development Goals and Intended Curriculum* and *Teacher Post-Observation and Enacted Curriculum* interviews. Themes were identified and reported in comparison to standards-based instruction and research-based professional development. Special attention was given to teacher ideas about the goals of the professional development program.

The *Standards-Based Mathematics Instruction Observation Tool* was used to organize classroom observations around standards-based mathematics instructional themes. Evidence from the field notes and the videotapes was used to support the conclusions about the presence or absence of standards-based instructional practices. Summaries were written about the mathematics instructional activities using the field notes. The summaries included examples of standards-based episodes from the classes.

An overall summary for each case was created comparing the survey data, the interview data, and classroom observations. Relationships were explained in the summaries. For example, the summary would include a description about small group work if a teacher stated that he or she attended the professional development to learn more about using small groups during instruction, responded to small group prompts in a positive way in the surveys, and used small groups during the observed lessons.

3.4.6 Referencing the Data Sources

A system was created to help readers connect reported examples with the data sources. The primary reference for the system was the name of the data source. Following the data source, dates, times, page numbers, segment numbers, or videotape numbers were provided. For example, data examples from the *Teacher School Context and Attitude towards Standards-Based Instruction* survey were referenced in parentheses with the shorthand of "Teacher School Context and Attitude SB." An example from a videotape was referenced in parentheses by the teacher's initials and lesson number, the date in the format YEARMONTHDAY, the number of minutes into the videotape that the example took place, and the tape number. For example, DC Video Lesson One, 20150918, 1:30 to 2:30, Tape 3, was the first observed lesson of Doug Collins on September, 18, 2015. The referenced segment occurred between one minute and thirty seconds and two minutes and thirty seconds on the third tape used during this lesson. Table 3.2 summarizes the referencing system.

Table 3.2 Data Referencing System

Format	Details
(TAPS Proposal, p. 10)	Document name and page number
(PD Facilitator Email, 20150701)	Email interview with professional development facilitators and interview date
(PD Field Notes, 20150609, 1:00)	Researcher field notes from professional development, date, and time of day
(Teacher Background Experience)	*Teacher Background and Experience* survey
(Teacher Professional Opportunities)	*Teacher Professional Opportunities* survey
(Teacher School Context and Attitude SB)	*Teacher School Context and Attitude towards Standards-Based Instruction* survey
(DC PD Interview, 20150915, Segment 2)	Teacher initials, *Teacher Interpretation of Professional Development Goals* interview, date, and segment from NVivo
(DC Planning Interview, 20150915, Segment 4)	Teacher initials, *Teacher Planning and Intended Curriculum* interview, date, and segment from NVivo
(DC Post Lesson Interview, 20150915, Segment 4)	Teacher initials, *Teacher Post Observation and Enacted Curriculum* interview, date, and segment from NVivo
(DC Observation One, 20150918, 1:30 to 2:30, Page 3)	Teacher initials, *Standards-Based Mathematics Instruction Observation Tool*, date, minutes into lesson, and observation page number
(DC Video Lesson One, 20150918, 1:30 to 2:30, Tape 3)	Teacher initials, observed lesson number, date, minutes into lesson, and tape number

CHAPTER 4. COMMUNITY, SCHOOL, AND PROFESSIONAL DEVELOPMENT

4.1 Community and School District

Springfield School Corporation (SSC) was a public school district that served students in Springfield and surrounding areas. Springfield was a city with a population over 16,000 since 2000. Although located in a rural area, Springfield had significant employment in manufacturing at 37%; education, health and social services at 11%; and retail trade at 10%. Springfield and the SSC had experienced student population and student economic change over the past ten years. In the 2005-2006 school year the student population for the SSC included a 71% White population, a 26% Hispanic population, and 56% of students participating in Free or Reduced Price Meals. In 2014-2015 the student demographics for the SSC included a 52% White population, a 46% Hispanic population, and 75% of students participating in Free or Reduced Price Meals.

SSC included three elementary schools serving students in grades pre-Kindergarten through five, one middle school serving students in grades six through eight, and one high school serving students in grades nine through twelve. Each of the elementary schools was categorized as Title I School-Wide Programs. The middle school was categorized as a Title I Targeted Assistance Program where qualifying students received supplemental services for reading and mathematics. In 2014-2015 the total district enrollment was 3,195 students. The student population included 52% White students, 46% Hispanic students, 1.5% Multiracial students, and 1% American Indian, Asian, Black, and Native Hawaiian or Other Pacific Islander students. Table 4.1 compares students in SSC to the state's public student population for the 2014-2015 school year. The large rate of English language learners (ELL) and Free/Reduced Price Meal participation were notable for this school district.

Table 4.1 SSC Student Population Compared to the State Student Population in Key Categories

Category	SSC	State (Public)
ELL	32.2%	5.5%
Free/reduced price meal	75.2%	49.2%
Special education	12.0%	14.9%
Intra-district mobility	0.8%	0.5%
Inter-district mobility	6.8%	11.5%

Table 4.2 compares students in SSC to the state's public student population in key academic areas in 2014-2015. Attendance rates and graduation rates for SSC were comparable to state rates. The passing rates for SSC students on state academic measurement tests were typically 10% to 25% below the state passing rate in grades three through eight. The average difference in mathematics in these grades was 17.8% less than the state passing rate and the average difference in English/Language Arts (ELA) was 15.6% less than the state passing rate. The 10.3% difference below the state rate on a grade three reading accountability test and the high rate of ELL is evidence that the SSC faced challenges in addressing the ELA learning needs of attending students. Notably, the passing rates of students on End of Course Exams in Algebra 1 were 16.3% above the state average and English 10 was 8.3% below the state average.

Table 4.2 SSC Student Rates Compared to State Student Rates in Academic Measurement Areas

State Academic Measurement Area 2014-2015	SSC	State (Public)	Difference
Attendance rate	95.6	95.8	-0.2
Graduation rate	89.6	88.7	0.9
Grade 3 Reading Accountability – passing	82.1	92.4	-10.3
Grade 3 Mathematics – passing	54.9	62.6	-7.7
Grade 3 ELA – passing	58.4	73.2	-14.8
Grade 3 Both – passing	46.2	57.5	-11.3
Grade 4 Mathematics – passing	50.0	65.2	-15.2
Grade 4 ELA – passing	51.6	70.4	-18.8
Grade 4 Both – passing	37.6	57.6	-20.0
Grade 5 Mathematics – passing	56.8	68.4	-11.6
Grade 5 ELA – passing	54.1	65.2	-11.1
Grade 5 Both – passing	43.4	56.1	-12.7
Grade 6 Mathematics – passing	35.7	61.9	-26.2
Grade 6 ELA – passing	57.3	65.8	-8.5
Grade 6 Both – passing	33.8	53.3	-19.5
Grade 7 Mathematics – passing	30.2	54.1	-23.9
Grade 7 ELA – passing	42.4	65.7	-23.3
Grade 7 Both – passing	23.2	48.6	-25.4
Grade 8 Mathematics – passing	31.9	54.2	-22.3
Grade 8 ELA – passing	46.5	63.7	-17.2
Grade 8 Both – passing	24.2	48.0	-23.8
End of Course Exam – Algebra 1	86.0	69.7	16.3
End of Course Exam – English 10	70.4	78.7	-8.3
End of Course Exam – Both Algebra 1 and English 10	63.8	65.4	-1.6

4.2 Springfield High School

In 2014-2015 the Springfield High School (SHS) enrollment was 831 students. Student ethnicity was 58% White, 38.4% Hispanic, 2.8% multiracial, and 0.8% Asian and Black. Table 4.3 compares students in SHS to the state's public school student population for grades 9 through 12 in key areas for the 2014-2015 school year. As noted earlier, the passing rates of SHS students in 2014-2015 on the End of Course Exams in Algebra 1 were 16.3% above the state average and on the End of Course Exams in English 10 were

8.3% below the state average. Given that the average difference in mathematics in grades 3 through 8 was 17.8% less than the state passing rate and the average difference in ELA in grades 3 through 8 was 15.6% less than the state passing rate, SHS showed signs of success with students on state exams.

Table 4.3 SHS Student Population Compared to the State Student Population in Key Categories

Category	SSC	State (Public)
ELL	19.7%	3.5%
Free/reduced price meal	64.7%	42.3%
Special education	13.0%	13.7%

4.3 Professional Development Program

TAPS was the professional development program in this research. It was a three-year program funded by a mathematics partnership grant. TAPS included partnerships between four Midwestern universities and four school districts, all from the same state. Faculty and graduate students specializing in mathematics education from all four university partners worked together in the planning of the professional development activities. Each university was paired with a neighboring school district for the delivery of the activities. This study focused on the SSC, which was one of the four partner school districts. There were fifteen SSC teachers attending the first year of TAPS. Each of the fifteen teachers taught mathematics in grades six through twelve. This research was a multiple-case study of four high school teachers amongst the fifteen attending teachers.

The TAPS proposal identified two goals for the program (TAPS Proposal, p. 3, adapted for readability). The first goal was to enrich teachers' knowledge and skills for teaching algebra. Objectives for the first goal included:

(1) engaging in solving rich algebra tasks to enhance algebraic understanding and habits of mind (e.g., abstracting from computation, doing and undoing, and building rules to represent functions); (2) collaborating to locate and develop algebra activities, including modifying textbook tasks to increase cognitive demand, relate algebra to STEM and other real-world contexts, and address SMPs; (3) enacting research-based pedagogical strategies (e.g., productive discourse, multiple representations) within a system of structured reflection and feedback from critical friends; and (4) participating in a collaborative action-research project in which teachers identify their own focus for enhancing their classroom practice.

The second goal was to improve students' algebraic knowledge, algebraic skills, and disposition toward algebra. Objectives for the second goal included:

(1) assessing and building upon students' prior knowledge of algebraic concepts; (2) engaging students in solving rich algebra tasks to enhance algebraic understanding and habits of mind (e.g., abstracting from computation, doing and undoing, and building rules to represent functions); (3) providing opportunities for students to make meaning of algebra, including its conceptualization beyond symbolic manipulation and value as a tool for inquiry in STEM and other real-world contexts; and (4) improving students' performance on standardized and class-level assessments and motivation to engage with algebraic concepts.

Two sets of practice standards for mathematics were shared with the teachers as a framework for the professional development. The first were the eight SMPs from the *Common Core State Standards for Mathematics* (CCSSM) (NGACBP & CCSSO, 2010).

The SMPs were described to the teachers as descriptors of what students have an opportunity to do when learning mathematics (PD Field Notes, 20150609, 1:00). The second practice standards were the eight MTPs from *Principles to Actions: Ensuring Mathematical Success for All* (NCTM, 2014). The MTPs were described to the teachers as descriptors for what teachers have an opportunity to do when teaching mathematics (PD Field Notes, 20150609, 1:00).

In addition, the professional development focused on the use of mathematical tasks with higher-level demands (Stein et al., 2000). Teachers participated in mathematical tasks provided by the facilitators (see example in Appendix K), participated in discussions about the characteristics of mathematical tasks, worked in small groups to create three tasks that would be used in their classrooms during the upcoming school year, and presented tasks to each other (e.g. PD Field Notes, 20150608, 3:00).

4.3.1 Recruitment and Context of Teaching Considerations

An information meeting and needs assessment took place prior to the SSC deciding to participate in TAPS. The professional development facilitators met with the middle school and high school mathematics department heads to gauge their interest in professional development focused on research-based pedagogical strategies for teaching algebra and collaborative action-research projects. The department heads were interested in the program, felt that other teachers in the school would be interested, and agreed to help recruit teachers to participate. The professional development facilitators also met with SSC administrators who agreed that the program could be offered to teachers in the school district. A recruiting meeting between the facilitators and the SSC mathematics teachers took place where details about the professional development were shared (PD Facilitator Email, 20150701).

A needs assessment conducted by the professional development facilitators identified two common areas of concern. First, teachers noted that they needed to learn more about the new state-level college and career readiness standards for mathematics that were created in 2014. These standards had some alignment with the CCSSM, but were not identical. For example, the state standards included the CCSSM mathematical practices, but some of the learning progressions were different. Second, due to the adoption of new standards, the schools were transitioning to new accountability testing in grades 3 through 10. Uncertainty about the testing aligned to new standards was a significant concern for the SSC teachers.

Three additional influences on the context of teaching came up during the needs assessment that professional development facilitators took into consideration. First, the district ELL rate was seven times greater than the state average, and the SSC schools were struggling to meet the mathematics learning needs of the ELL students. Second, there was concern because the Middle School received a low rating from the state for school accountability, but the High School received a high rating. The Middle School's low rating was due to a low percentage of students passing state assessments. The High School received a high rating for school accountability due to passing rates on state assessments in mathematics that were above the state average. Many of the teachers did not understand the difference in student performance between the middle school and the high school. Third, teachers noted a lack of support for professional growth and collaboration. One reason for the lack of professional growth was the inability to go to professional development during school hours due to lack of substitute teachers.

4.3.2 Strategies, Leadership, and Other Considerations

In year one, the professional development focused on the teachers creating algebraic mathematical tasks and implementing the tasks with pedagogical strategies aligned to the practice standards. The professional development facilitators provided active learning opportunities for participating teachers (Desimone, 2009; Loucks-Horsley et al., 2010) on mathematical tasks and the practice standards. Teacher active learning opportunities included journal responses, small group discussions, large group discussions, observations of other teachers, lesson study of videos, student-like participation in mathematical tasks, and presentation of mathematical tasks with feedback from the group. One desired outcome of the active learning experiences was to transition the teachers from learners who were participating in mathematical tasks to implementers of the mathematical tasks with students. A second desired outcome was to model mathematical tasks and pedagogical strategies so that teachers could modify existing materials and strategies to better align with the practice standards (TAPS Proposal, p. 10).

There was little active participation from school or district administrators in the first year of the professional development. The professional development facilitators noted that this was not ideal, but it gave the mathematics teachers an opportunity to come together as a professional community (PD Facilitator Email, 20150701). The professional development activities included opportunities for the teachers to grow as leaders through participation in state meetings for K-12 mathematics education. Teachers were invited to attend and encouraged to submit proposals to present at these meetings (PD Facilitator

Email, 20160713). To address possible school district obstacles, the professional development program included funding that could pay for conference registrations and substitute teachers. In the first year, two teachers attended and presented at the state meeting for mathematics teachers. According to the professional development providers, thirteen teachers were planning to attend the state meeting for mathematics teachers in the second year (PD Facilitator Email, 20160713).

4.3.3 Professional Development Content, Time, and Activities

An algebraic content theme was identified for each of the three years for the professional development. This research took place in year-one, when the theme was patterns, relationships, and generalizations of patterns.

The professional development was a year-round program that started with a ten-day summer institute in June, 2015. The summer institute ran in conjunction with the SSC summer school program. This allowed the participating teachers to practice using mathematical tasks from the professional development with the summer school students. It also provided an opportunity for the teachers to observe each other using mathematical tasks with students and to discuss the observations. The morning summer school sessions lasted approximately three hours. The summer institute work sessions took place in the afternoon for three hours.

Three two-hour after school follow-up sessions took place during the school year. The meetings took place in October, February, and April. The follow-up meetings provided opportunities for the teachers to share the use of mathematical tasks in their classrooms and for additional learning of the concepts from the summer institute. In addition to the organized professional development meeting times, each teacher was expected to teach lessons based on the practice standards, complete two observations of another teacher teaching a lesson from the professional development, and provide data for research being conducted by the professional development facilitators. Each participating teacher had an opportunity to participate in eighty-six hours of professional development by completing all of the related work.

4.3.3.1 Professional Development Summer Institute

Summer institute sessions ran for three hours each day in the afternoon following the SSC summer school. On the first day the facilitators discussed the goals of the professional development with the teachers. The facilitators reviewed the SMPs and the MTPs with the participating teachers and shared that they would focus on developing and implementing activities aligned to these practices. The professional development facilitators summarized the goals for the teachers as knowing more about algebra, teaching algebra, and ways to improve teaching algebra (PD Field Notes, 20150608, 2:00). These discussions were consistent with the program goals, but did not describe the goals with the same detail as the TAPS proposal. There was a brief whole group discussion about the expectations about participating in the professional development program that concluded with all participants agreeing to: (1) engage actively in all activities; (2) work together to achieve the program goals; (3) approach each experience with a positive and open mind; (4) be aware of other participants and be inclusive; (5) treat each other with respect; (6) bring up any areas of tension/conflict in productive ways; (7) respond to correspondence within two business days whenever possible; (8)

upload items (to an online collaboration site) in a timely manner; and (9) have no more than thirty minutes of work each night (PD Field Notes, 20150608, 2:00).

Most of the institute days included a reflection question that the teachers would react to by writing in their reflection journals. The prompts included questions such as: “What do you see as the major challenges in teaching algebra?” and “What connections are there between algebra topics, between algebra and other math, and between algebra and other non-math topics?” (PD Field Notes, 20150608, 1:00; PD Field Notes, 20150612, 1:00). After the personal reflective writing the teachers would discuss the questions in small groups and as a whole group.

In addition to the reflective prompts, a significant amount of time was spent on understanding mathematical tasks. The tasks provided by the facilitators related to the algebraic content theme of patterns, relationships, and generalizations of patterns. Teachers reviewed examples of mathematical tasks, sorted them as higher-level or lower-level, and developed characteristics of tasks that could be used as identifiers. For example, the teachers described higher-level mathematical tasks as having multiple steps, requiring justification, and allowing the opportunity for more than one correct answer. They described lower-level mathematical tasks as requiring only basic computation, having few steps, and being limited to the use of a formula or memorization (PD Field Notes, 20150608, 3:00).

Teachers were asked to develop and present a task to the group during the summer professional development time, to use at least one task with secondary students during summer school, and to work in small groups to create three tasks that could be used during mathematics instruction with students in the upcoming school year (PD Field

Notes, 20150609,1:45). They were encouraged to modify existing activities into higher level mathematical tasks as well as create new mathematical task activities.

An important feature of the professional development was the time devoted to discussing and understanding the SMPs and the MTPs through reflection questions and facilitator's actions. For example, on the seventh workshop day the reflection question was: "Which MTPs do you feel most competent implementing in your classroom? Which do you wish you were better at?" Teachers responded during the whole group discussion:

> Teacher 1: I would like to be better with productive struggle and questioning.
>
> Teacher 2: I would like to get better with struggle without losing them, allow kids to struggle without stepping in.
>
> Teacher 3: I need to improve not jumping in to help.
>
> Teacher 4: It takes mistakes to learn. (PD Field Notes, 20150616, 2:45)

When teachers had time to work on the mathematical tasks for their classroom, the facilitators regularly asked the teachers to reflect on which practice standards were aligned with the activity and to find ways to include more of the practice standards (e.g. PD Field Notes, 20150609, 2:00; PD Field Notes, 20150611, 2:00; PD Field Notes, 20150615, 1:00).

4.3.3.2 Follow-Up Sessions

The three follow-up sessions were two-hour meetings after school in the fall, winter, and spring. Eleven teachers attended the fall and winter meetings, only six attended the spring meeting. Most of the absences were due to other teaching duties such as coaching or meeting with student clubs. Each of the follow-up sessions included a reflection question that teachers wrote about and discussed, a reading from *Making Sense of Algebra* (Goldenberg et al., 2015) or a mathematics education journal article that was discussed, a sample mathematical task for the teachers led by the facilitators, and time for teachers to work on mathematical tasks for use in their classrooms.

The reflection questions, group discussions, and mathematical tasks provided an opportunity for the teachers to learn more about the SMPs and MTPs. For example, during the February meeting one of the professional development facilitators shared how he selected and modified the presented mathematical task to align with the practices:

> Facilitator: Here is how I thought about the [practice] standards when I designed the task; the task included persevere because the scaling was not given to you; we had to reason abstractly because you had to go between context and numbers and solve the inequality; and you had to look for structure using shapes within shapes. (PD Field Notes, 20160202, 5:15)

Teachers were also asked to share their experience if they had taught a lesson that included a mathematical task. The teachers made comments that indicated that the professional development was having a positive impact on their students. For example,

> Teacher 1: It has been a change of mindset. My students were able to discover the exponent rules.
>
> Teacher 2: My group [of students] is not afraid to make mistakes. (PD Field Notes, 20151027, 4:10)

4.3.4 Ethical Decisions, Costs, and Professional Development Evaluation

When designing the TAPS project, the participating faculty and professional development designers from the four universities interviewed teachers from the four partnering school districts to learn about their needs. The collected information shaped decisions such as content focus and reflection questions. Specific to SSC, the professional development facilitators noted some reluctance to participate in the program. Some of this reluctance was due to skepticism about a new teaching style negatively impacting student performance on state accountability testing or teacher performance on evaluation systems (PD Facilitator Email, 20160719). In addition, the professional development facilitators noted that many of the middle and high school mathematics teachers had never met each other and had never had the opportunity to work together. The SSC professional development team decided to focus on building personal relationships with and among the teachers (PD Facilitator Email, 20160719).

The cost of the professional development program totaled approximately $156,000 for the first year. A mathematics partnership grant was awarded to the school districts which provided about $108,000 for teacher stipends, professional development supplies, and travel to conferences. Contributions from the professional development providers on curriculum development, data collection for research, and workshop facilitation totaled approximately $48,000 (PD Facilitator Email, 20160719).

The evaluation of TAPS was aligned to the project objectives. Teacher data included the *Knowledge of Algebra for Teaching* survey (McCrory, Floden, Ferrini-Mundy, Reckase, & Senk, 2012), completed lesson plans and professional development reflection sheets, lesson reflection forms, critical friend conversation forms, and comparing created lessons to existing teacher evaluation instruments. These tools respectively measured engagement in solving rich algebra tasks, collaborating to develop algebra activities, enacting research-based pedagogical strategies, and participating in a collaborative action-research project. Student data included a pre/post algebraic concept test, student work from the lesson plan implementations, lesson plans created by the teachers, and state accountability testing scores. These data sources respectively measured students' knowledge of algebraic concepts, engaging students in solving rich algebraic tasks to enhance algebraic understanding and habits of mind, providing opportunities for students to make meaning of algebra, and improving students' performance on standardized assessments (TAPS Proposal, p. 17-18).

The professional development facilitators used the discussions and teachers' written reflections to make adjustments to the professional development during the first year. For example, teachers were very interested in the practice standard about productive struggle. The facilitators included reading and discussion of a journal article about productive struggle in the April follow-up meeting (PD Field Notes, 20160427, 4:30). The facilitators also met with the other university professional development providers to review the year-one data to make adjustments to planning for the year-two summer institute (PD Facilitator Email, 20160713).

4.3.5 Context Factors and Considerations

During small group and whole class discussions about the reflection questions or about the practice standards, teachers made remarks about difficulties with teaching or difficulties with using the practice standards in a mathematics class due to perceptions of students' abilities. For example, on the first day of the summer institute the teachers discussed the questions, "What do you see as the major challenges in teaching algebra? How have you tackled some of those challenges in your classroom?" Teacher responses during the whole group discussion included:

Teacher 1: Retention.

Teacher 2: Arithmetic, the students can't do 4 + 3.

Teacher 3: Students can learn algebra, but they can't do arithmetic.

Teacher 4: They need to know basic facts.

Teacher 5: Story problems, students have a give-up attitude.

Teacher 6: They have a lack of confidence, not willing to try. (PD Field Notes, 20150608, 1:15)

The teachers' comments are about challenges that they attribute to the students' inabilities to know basic arithmetic or their inabilities to persevere. Teachers' comments about the students' lack of knowledge and give-up attitudes were evident on other days.

Teacher 1: Students won't get the algebraic equation without us telling them. (PD Field Notes, 20150609, 1:00)

Teacher 2: My kids want to give up if they don't get it right away, they don't want to fail. (PD Field Notes, 20150610, 1:15)

Teacher 3: Some of the students would not keep working, they lack perseverance. (PD Field Notes, 20150611, 1:30)

Teacher 4: When students get to us, they do not know their factors. (PD Field Notes, 20150616, 1:30)

The comments about limitations due to students' mathematical abilities was a context factor that influenced the outcome of the professional development because these perceptions reinforced unproductive beliefs about teaching and learning mathematics (NCTM, 2014). The unproductive beliefs can provide rationalizations for teachers to not provide standards-based instruction.

Another context factor was the emergent teacher understandings of mathematical tasks. Early in the year-one summer institute, the teachers learned about the characteristics of mathematical tasks. The first mathematical task presented by the facilitators was the Poison Game. The Poison Game was a strategy game with two opponents. They start with ten cubes. An opponent can take one or two cubes on his or her turn. The person who takes the last cube loses the Poison Game (Burns, 2007).

Some of the mathematical tasks that the teachers shared during the summer were strategy games with similar characteristics to Poison or had low cognitive demand. For example, one group presented a variation of the Game of Nim with 3, 5, and 7 marks in rows (see Figure 4.1). Two opponents take turns removing as many marks from one row as they like. Whoever takes the last mark loses (PD Field Notes, 20150615, 2:45). A different task was described as a mathematical scavenger hunt. A series of questions was placed on the walls around a classroom. Students could individually or in small groups go to one of the problems and find a solution. The problems could include any content, but in this case they were algebraic equations and the students were asked to find a value for the unknown ‘x’ in each problem. When students found a true value for ‘x’ it would tell them which problem they should solve next. If they made a mistake, the student or student group would need to redo the problem (PD Field Notes, 20150615, 1:00).

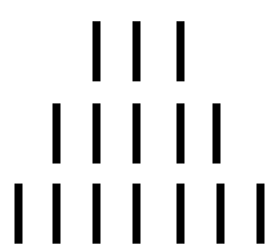

Figure 4.1 Mathematical Task, Variation of *Game of Nim*

The teachers had an emergent understanding of characteristics of a mathematical task throughout the first year of the professional development, and the teachers mirrored their tasks after the mathematical tasks shared by the professional development facilitators. In some cases, the teachers reused the tasks shared by the facilitators during the school year. An emergent understanding of the goals or main ideas of the professional development was a factor that influenced the outcomes of the professional development.

CHAPTER 5. TEACHER CASE STUDIES

5.1 Doug Collins

Doug Collins was a Caucasian male high school teacher with thirteen years of teaching experience. This was his second year at SHS, and he taught Algebra 1 and Geometry during the 2015-2016 school year. He had also taught Pre-Algebra, Algebra 2, Pre-Calculus, and Business Math. Mr. Collins's bachelor's degree was in mathematics and he took more than ten mathematics courses to finish this degree. He was working on a master's degree in mathematics education and had taken five additional mathematics courses for this degree (Teacher Background Experience).

Mr. Collins participated in other professional development workshops on core ideas of mathematics, direct instruction, using ongoing assessment to guide instruction, and basing instructional practices on student knowledge during the past eighteen months. He felt that these workshops probably led to changes in his teaching of mathematics. Mr. Collins also attended more than ten meetings on the school's mathematics curriculum and more than five meetings on mathematics teaching techniques, assessing student learning in mathematics, and evaluating the school's mathematics program. He had read the school district curriculum guide, the state mathematics academic standards, the *Principles and Standards for School Mathematics* published by the NCTM in 2000, and the CCSSM published by the NGACBP and CCSSO in 2010 (Teacher Professional Opportunities).

5.1.1 Perception of School Context

Mr. Collins felt that he had very little or no influence on making important educational decisions, setting discipline policy, determining the content of professional development, and deciding how the school budget would be spent. In comparison, he felt that he had control over many areas of his classroom, including selecting instructional materials, selecting teaching methods, determining the amount of work to be assigned, and evaluating students (Teacher School Context and Attitude SB).

Mr. Collins's perception of the school administration was positive throughout the school year. He agreed that the school administration let staff members know what was expected of them, was supportive and encouraging to the staff, and had a clear vision for the school. Mr. Collins felt that he was encouraged by administrators to try out new ideas, select instructional strategies that addressed individual students' learning, focus on covering the mathematics content and implementing practices in the current state mathematics standards, and make connections across disciplines (Teacher School Context and Attitude SB). His perception of the school staff was also positive. Mr. Collins agreed that there was a great deal of cooperative effort among the staff members of the school, the staff members maintained high standards of performance, and the teachers exhibited a focused commitment to student learning in mathematics (Teacher School Context and Attitude SB).

5.1.2 Attitude towards Standards-Based Mathematics Instruction

Mr. Collins agreed with seven of the thirteen items on the attitude towards standards-based instruction survey that were consistent with standards-based mathematics instruction (Teacher School Context and Attitude SB). Most of the items he agreed with involved using thematic units, making connections, and applying mathematics learning to contexts. He also agreed with some student-centered ideas for teaching mathematics such as having students write about solving problems and planning instruction based on teachers' knowledge of students' understandings. He was neutral on items that described teaching fewer topics in greater depth and learning by discussing mathematical ideas. Mr. Collins agreed with three of the five items that were inconsistent with standards-based mathematics instruction (Teacher School Context and Attitude SB). The items he agreed with all described the need for students to master basic facts and skills before they can be expected to analyze, compare, and generalize.

In general Mr. Collins's attitude towards standards-based instruction in mathematics was mixed. His responses were consistent on seven items, no opinion on five items, inconsistent with standards-based instruction on four items, and varied on two items. At the end of the year he was consistent with seven items, no opinion on six items, and inconsistent with five items.

5.1.3 Interpretations of Professional Development

Mr. Collins described the goals of the professional development, "To try to help improve the algebra one end-of-course exam scores at [SHS]" (DC PD Interview, 20150915, Segment 2). He interpreted the goal and related activities of the professional development as a means to help students pass a state accountability and graduation test.

During the interviews with Mr. Collins, he made twenty-three comments about positive outcomes for use of professional development. Five of the comments were about the professional development providing activities for his class. For example, he was asked what part of the professional development was most useful and why? He responded: “For me I think it was really kind of learning, getting some of the different activities and things that you can do” (DC PD InterviewFP0120150915). Mr. Collins stated that learning and getting different activities to use in class were the most useful parts of the professional development. Consistent with this comment, he used one of the activities from the professional development for his lesson observation.

> WW: Where did [the observed] lesson come from?
>
> DC: From the summer. It was one of the [TAPS] activities that we did this past summer.
>
> WW: Great. Did you pick it because it basically aligned with the content you are working on with your students?
>
> Doug Collins: Yes. (DC Planning Interview, 20160425, Segment 8)

Mr. Collins also made five positive comments about the professional development helping to engage his students. For example, after his first lesson he was asked:

> WW: Was there any part of the lesson from your perspective that went extremely well?
>
> DC: The middle part of the lesson [students working on problems in groups] I think went the best. With the exception of checking a lot of their answers, I think just the middle part. You know, I kept expecting to look up and have to tell at least a couple different students to get to work, but I didn’t have to do that at all. It was all very much, they were very into it, they were very motivated. I think that was the best part of the lesson, was the student engagement. (DC Post Lesson Interview, 20150929, Segment 16)

Following his lesson in April, 2016 he made similar comments.

WW: What parts of the lesson were successful in comparison to how you planned?

DC: I thought I did a pretty good job of estimating the amount of time for them to actually do the activity, with the exception of one bridge length or the width of the bridge and the length of the bridge. The number of pennies that I picked was pretty much spot on. The students thoroughly enjoyed it, fully engaged, really liking the activity so that, I had that pretty well pegged. (DC Post Lesson Interview, 20160502, Segment 8)

Mr. Collins described his students as "engaged" during both activities. He expected to tell students to stay on task, but the activities he used that were aligned to the professional development kept his students motivated and working on the mathematical tasks.

A third area with four positive comments was about students working together in small groups. For example, Mr. Collins was asked:

WW: Do you anticipate that teaching using the professional development will be different than the way you have taught in the past?

DC: Yeah, at least a little bit. Just because I plan on doing more activities, more hands-on stuff, more formalized group work. Most of my groups are usually very informally formed and based. Whereas this year I am planning to go much more formal; me setting up the groups, or letting the students set up the groups, but in a structured sense. (DC PD Interview, 20150915, Segment 12)

Using formalized group work influenced Mr. Collins' intended curriculum. He planned lessons to use ideas from the professional development.

Mr. Collins also made four positive comments about students learning content better based on the use of the professional development. Before his first lesson, Mr. Collins was asked if there would be any advantages for his students by using the professional development. He replied, “I’m really hoping it is for the students. That is the end all be all; is that this entire thing winds up helping them to learn algebra one better” (DC PD Interview, 20150915, Segment 13). The idea of helping students learn first-year algebra better is consistent with his interpretation that the goal of the professional development was to help improve student scores on state accountability tests.

Mr. Collins made nine comments about challenges with using the ideas from the professional development. He referred to three different challenges twice. One challenge was that the content of the professional development focused on a different grade level or course, For example:

> WW: What part of the [professional development] was least useful and why?
>
> DC: Probably the observations in the classrooms. Although they were great to get an idea for different projects I can use, there were very few aimed at the high school level. (DC PD Interview, 20150915, Segment 5).

Mr. Collins noted that observations of other teachers provided ideas for different projects, but they were the least useful part of the professional development because the activities were not appropriate for the course he was teaching.

A second challenge was students not being able to participate in class due to their inexperience with ideas from the professional development.

> WW: Was there any piece of this that was particularly difficult for the students?

> DC: The initial newness of it all. Of, “Okay, what are we doing? Is this really going to be just get up and roam around the room?” It is math class and they are very used to, “Okay, we are sitting here and we’ll work with people around us, but we are not actually up and moving and walking around and lots of math chaos and noise.” (DC Post Lesson Interview, 20150929, Segment 18)

Mr. Collins noted that the students struggled participating in his class when using ideas from the professional development such as working in small groups because it was new to them and atypical from the routine they were accustomed to in mathematics class.

The third challenge was time constraints.

> WW: If you were planning to do this lesson again or this type of activity again, is there any part of it you would do the same way?
>
> DC: I’m going to do the two colors again. I am planning on doing this with inequalities here next week or the week after, I forget which it is off the top of my head. But I am planning on doing the activity again. I am going to keep the same colors. I think I am going to shorten it down. Instead of trying to get them to do ten, I think I am going to try to get them to do seven, six or seven of solving the inequalities. (DC Post Lesson Interview, 20150929, Segment 13).

Simply put, Mr. Collins planned on using a learning activity like his first lesson, but the lesson took too long. In the future he would plan for the students to do fewer problems so the task could be done within the given class time.

5.1.4 Classroom Lessons and Use of Professional Development

5.1.4.1 Lesson One: Intended Curriculum

Mr. Collins planned to teach his first lesson aligned with the professional development in September, 2015 with an Algebra 1 class. The topic for the lesson would be writing and solving multi-step equations. He described the academic standards for the lesson as following order of operations, solving equations, and checking solutions as reasonable. Mr. Collins felt that the lesson would be aligned to the professional development because the activity was designed to be a mathematical task and the students were going to work with a partner (DC Planning Interview, 20150915, Line 39).

For the planned learning activities, each student would have a paper with an algebraic expression. They would find a partner with a different algebraic expression, set the two algebraic expressions equal to each other, and find a value for the unknown that would make the equation true. The students would then find a different partner and repeat the process (DC Planning Interview, 20150915, Line 40). Mr. Collins hoped this activity would improve students writing out their work and build their confidence with solving algebraic equations (DC Planning Interview, 20150915, Line 41). He would assess the students by monitoring their work and by checking the solutions to the equations after the activity was complete (DC Planning Interview, 20150915, Line 42). This lesson would be taught at the end of the algebraic expression unit and could be understood as a reinforcement activity (DC Planning Interview, 20150915, Line 43). This would be the first time that he taught this lesson (DC Planning Interview, 20150915, Line 44).

5.1.4.2 Lesson One: Enacted Curriculum

The lesson took place during a seventy-minute class period. It was introduced by Mr. Collins after the students completed a homework check. Each student was given an algebraic expression on either a gold or green piece of paper. Mr. Collins explained that a student with a gold sheet should find a student with a green sheet. They would set their algebraic expressions equal to each other and then find a value for the unknown that would make the equation true. Mr. Collins told the students that they should work together, show all of their work, and check to see if the solution made the equation true. He also stated that they should complete at least five equations with five different partners (DC Observation One, 20150918, 23:00 to 28:00, Page 1).

The students worked in pairs on this activity for thirty-five minutes. They checked answers with each other, explained methods used to find an answer, explained situations where there could be infinitely many or no solutions, and used calculators to check answers. Students asked questions such as, “Can you do that?” and “Do you understand why I added seven?” (DC Observation One, 20150918, 56:00 to 60:00, Page 2).

Mr. Collins moved around the room checking work done by students and helping students find new partners. He made comments to encourage the students to work together such as, “If you don’t agree you will need to check with your partner” (DC Observation One, 20150918, 53:00 to 55:00, Page 2). Many of his interactions with the students involved explaining procedures to get answers such as, “You have a mistake, you need negative twelve here” (DC Video Lesson One, 20150918, 43:00 to 45:00, Tape 1). With about five minutes remaining in the class Mr. Collins asked the students to return to their seats, collected their work, and told the students that they would do an activity like this again (DC Observation One, 20150918, 63:00 to 67:00, Page 2). He explained that the next time they would need to agree with their partner before they could move on to another partner.

5.1.4.3 Lesson One: Summary and Alignment to Professional Development

Mr. Collins's first lesson included some elements of standards-based instruction emphasized by the professional development. In comparison to the CCSSM SMPs, evidence was seen of *students making sense of problems and persevering to solve them*. During the partner work, the students worked together to find and check solutions to algebraic equations (DC Observation One, 20150918, 30:00 to 32:00, Page 1). There was also evidence of students *constructing viable arguments and critiquing the reasoning of others*. This occurred as the students worked with different partners and explained how they found the solutions. The students *used appropriate tools* and *attended to precision* sometimes during the lesson. Following the directions given by Mr. Collins, the students substituted solutions back into the algebraic equations to see if they were true and at times used calculators to do this work.

In comparison to the NCTM MTPs, there was evidence of the teacher *promoting reasoning and problem solving*, *building procedural fluency from conceptual knowledge*, and *supporting productive struggle in learning mathematics*. The teacher *promoted reasoning and problem solving* by providing challenging problems and having the students work in pairs to find the solutions. The key to promoting reasoning was the expectation that students should explain their work to each other and check the answers to see if they made the algebra equation true. By providing a task with algebraic equations that had non-integer solutions and dedicating time for the students to check answers, the students had opportunities to *build procedural fluency* and *struggle in a productive manner*. *Facilitating meaningful mathematical discourse* was observed sometimes during the pair work. The teacher asked the students to talk with their partners to work through questions or challenges related to the mathematics. A few students explained topics that were challenging other students such as the possibility of no solutions or infinitely many solutions to an algebraic equation.

5.1.4.4 Lesson Two: Intended Curriculum

Mr. Collins planned to teach his second lesson aligned with the professional development in April, 2016 in an Algebra 1 class. The planned topic for the lesson was using data to determine if relationships were linear or quadratic (DC Planning Interview, 20160425, Segment 1). The academic standards that would be addressed in this lesson were recognizing different types of equations, graphing ordered pairs, writing equations, and interpreting data and graphs (DC Planning Interview, 20160425, Segment 2). The parts of the professional development that he planned to use during the lesson included collaborative learning, working on a hands-on mathematical activity, and engaging students in a mathematical investigation (DC Planning Interview, 20160425, Segment 3).

Mr. Collins described what the students would be doing during the lesson.

> DC: The planned activity is they are going to be given strips of paper where they are going to fold up the edges to create a bridge that they are going to put in between two books of the same thickness or height. And then they are going to put pennies on them to see where the breaking point of the bridge is. So they kind

> of get an idea of like, this is something that actual architects and engineers have to worry about in the real world as well. Then they are going to look at how the thickness of the bridge changes how strong the bridge is, and then they are going to see if it is, they are going to compare the different thicknesses, they are going to interpret the data and try to find different values. Extrapolate and figure out, what if it was eighteen pieces of paper thick or two and a half pieces of paper thick or something like that. (DC Planning Interview, 20160425, Segment 4)

Similar to the first lesson, Mr. Collins planned on assessing the students by monitoring them while they were working in groups and checking worksheets when the lesson was complete (DC Planning Interview, 20160425, Segment 6). This lesson would be at the end of a unit on quadratic equations. He stated that this would be an opportunity for his students to apply mathematics to a task before they were tested on quadratic equations (DC Planning Interview, 20160425, Segment 7). Mr. Collins had not taught this lesson before. It was a lesson that was presented during the professional development summer institute. He chose to use this task in his class because it aligned with the content he was teaching (DC Planning Interview, 20160425, Segment 8).

5.1.4.5 Lesson Two: Enacted Curriculum

The second lesson was a modified version of *Bridge Strength* from *Thinking with Mathematical Models* (Lappan, 2005). It took place during one seventy-minute class period. At the beginning of the lesson, Mr. Collins asked the students to find a partner and to come to the front of the room and gather the materials that they would need for the activity (DC Observation Two, 20160427, 1:30 to 3:00, Page 1). The materials included a cup of pennies, three strips of four different-length strips of paper (twelve strips of paper total), and books that would be used to suspend the strips of paper and create a bridge. Mr. Collins passed out a work packet to each student and told them that they would need to read the packet so they would know how to do the activity for the day. Students were instructed to run through all of the experiments first and collect all of the resulting data (DC Observation Two, 20160427, 2:00, Page 1). After all data were collected, the packet had fourteen questions for the students to answer about the experiment.

The students worked in pairs on this activity for sixty minutes. They suspended paper bridges between two books, placed a cup on the bridge, placed pennies in the cup until the bridge collapsed, and recorded the number of pennies required to collapse the bridge. After a bridge collapsed, the students increased the thickness of the bridge and repeated the process. The students also did the experiment using different paper lengths. Early in the lesson, Mr. Collins went around the room observing students (DC Observation Two, 20160427, 6:00 to 7:00, Page 1). Most of the teacher-to-student interactions involved clarifying how to set up the bridges or how to collect the data (DC Observation Two, 20160427, 11:00 to 12:30, Page 1). The student-to-student interactions included discussing the procedure for collecting the data and clarifying methods to collect and represent the data (DC Observation Two, 20160427, 15:30 to 17:30, Page 1).

When data collection was complete, the students continued to work in pairs to make graphs and answer questions on the worksheet about the activity. Some questions required short answers such as, “What is the independent variable on your graph?” Other questions required justification such as, “Does the relationship between the number of layers and the breaking weight seem to be linear, quadratic, exponential, or something else? How does the graph support your answer?" There were also questions that required predictions such as, "Predict the breaking weight for a bridge that is six layers thick." Students clarified mathematical terms with their partners when working on the questions. This included questions such as, "Does this make sense?" and "Which is the independent variable?" Students also related the data tables to the graphs and considered linear and non-linear relationships.

With about two minutes remaining in the class, Mr. Collins told the students that they need to stop, put materials away, and put the desks back into rows (DC Observation Two, 20160427, 6:00 to 9:00, Page 3). He collected the packets that contained the work done by the students at the end of the class.

5.1.4.6 Lesson Two: Summary and Alignment to Professional Development

Mr. Collins's second observed lesson included more of the practice standards emphasized by the professional development than the first observed lesson. In comparison to the CCSSM SMPs, evidence was seen of students *making sense of problems and persevering to solve them*. This occurred during the small group work. Students were given a higher-level mathematical task and worked in small groups to make sense of the problem and answer related questions. The students also *modeled with mathematics* when they organized their data into tables and used the data to make graphs of the relationship between length or thickness and the weight of collapse. The lesson provided opportunities for the students to *attend to precision*. Students collected data and used it to examine the relationship between bridge length or thickness and the weight needed to collapse the bridge. The students discussed appropriate ways to display the data and made graphs.

There was some evidence of students *reasoning abstractly and quantitatively, constructing viable arguments and critiquing the reasoning of others,* and *looking for and expressing regularity in repeated reasoning*. The students *reasoned abstractly and quantitatively* when they worked together and with the teacher to graph the bridge collapse data and contextualized the situations by interpreting the graphs. *Constructing arguments and critiquing others* was observed sometimes during the small group work. This occurred when they asked questions such as, “How do we know when it has collapsed?” or “Why is this an exponential relationship?” (DC Video Lesson Two, 20160427, 10:00 to 11:00, Tape 1). Students had opportunities to *express regularity* when they made predictions for additional bridge collapse weights using their data and graphs.

In comparison to the NCTM’s MTPs, evidence was seen of Mr. Collins *promoting reasoning and problem solving*. This occurred through the use of a higher-level mathematical task from the professional development. The task and instructional practices encouraged students to make sense of the problem, explain mathematical reasoning, and make predictions using the collected data. There was also evidence of *facilitating meaningful mathematical discourse* by having the students work in small groups where they clarified terminology with each other and explained reasoning about the graphed relationships. Mr. Collins supported *productive struggle* by having the students make sense of the problem, explain mathematical reasoning, and find ways to display and interpret the collected data.

Using and connecting mathematical representations was evident sometimes when the students made and interpreted the graphs. *Posing purposeful questions* was observed sometimes when Mr. Collins interacted with the students in small groups asking questions such as, “At what point can we say the bridge has collapsed?” and “Why is that your prediction?” Students were sometimes observed *building procedural fluency* as they created graphs from the data and described the relationships represented by the graphs. Mr. Collins *elicited and used evidence of student thinking* a few times during the lesson when he monitored the work done by the groups and clarified procedures.

5.1.5 Summary, Doug Collins

Mr. Collins was an experienced teacher in his third year at SHS. He participated in a variety of professional development experiences before TAPS that led to some changes in his teaching. He was familiar with state academic standards, the *Principles and Standards for School Mathematics*, and the CCSSM. Mr. Collins’s attitude towards standards-based mathematics instruction was mixed with some agreement and some disagreement. He perceived that he had control over many areas of his classroom including selecting instructional materials and selecting teaching methods. He also felt that he was supported by administrators to try out new ideas in teaching mathematics.

Mr. Collins interpreted the goals of the professional development to be a means to help students pass a state accountability and graduation test. There were four ideas from the professional development that he described as useful for his class: providing activities for his class; ideas for engaging students; students working together in small groups; and students learning content better. He also felt that using the professional development would be challenging because the activities from the summer institute focused on a different grade level, his students would struggle in class due to inexperience with practice standards, and there were time constraints.

The number of practice standards that were used in Mr. Collins' lessons increased. Five practice standards were observed throughout the first lesson and three of the practice standards were observed sometimes. The second lesson included six of the practice standards throughout and seven additional practice standards sometimes. The practice standards that were observed throughout both lessons included *making sense of problems and persevering in solving them, implementing tasks that promote reasoning and problem solving,* and *supporting productive struggle in learning mathematics*.

The instructional practices Mr. Collins used that supported the use of practice standards included providing challenging problems, having the students work in pairs, and encouraging students to explain their solutions. His use of a mathematical task in the second lesson helped increase the number of observed practice standards.

Factors that most likely influenced Mr. Collins's use of ideas from the professional development included the elements he perceived to be helpful from the professional development, his mixed attitude towards standards-based mathematics instruction, his perception of control over most aspects of his classroom, and his interpretation that the goal of the professional development was to improve student scores on state accountability exams. His lessons contained all of the helpful elements including a mathematical task from the summer institute, engaging students by using an engineering context, and students working in small groups. He made moderate use of the sixteen practice standards, which is consistent with his mixed attitude towards standards-based instruction. His perception of control over most of the instructional decisions in his class supported his ability to use ideas from the professional development without concerns about consequences. Finally, both of the observed lessons were reinforcement or extension activities. Mr. Collins used the professional development to help his students reflect on and apply content learned before upcoming unit tests. This was consistent with his goal to use the professional development to improve student test scores.

5.2 Kathy Gibson

Kathy Gibson was a Caucasian female with eleven years of high school teaching experience, ten of the years were at SHS. At the time of this research, she taught Pre-Calculus and was the mathematics department chair. In the past she had also taught Pre-Algebra, Algebra 1, Geometry, and Algebra Remediation. Her bachelor's degree was in mathematics education and included completing more than ten mathematics courses. She was working on a master's degree in mathematics education which included completing one additional mathematics course (Teacher Background Experience).

Within the eighteen months prior to this research, Ms. Gibson had participated in professional development of direct instruction and using ongoing assessment to guide instruction, but she did not feel that it had led to changes in her teaching of mathematics. She participated in some professional growth activities on the school's mathematics curriculum, mathematics teaching techniques, and student activities through SHS. Ms. Gibson had read the school district's curriculum guide, the state's mathematics academic standards, and the CCSSM (Teacher Professional Opportunities).

5.2.1 Perception of School Context

When asked about school policy, Ms. Gibson felt that teachers at SHS had very little influence on areas such as evaluating teachers, hiring new teachers, and deciding how the school budget would be spent. She did feel that there was some teacher influence on educational decisions, establishing curriculum, and determining the content of professional development (Teacher School Context and Attitude SB). Ms. Gibson felt that she had control over many aspects of her classroom such as selecting instructional materials, selecting teaching methods, determining the amount of work to be assigned, and evaluating students (Teacher School Context and Attitude SB).

Ms. Gibson agreed that she was supported by school administrators to try out new ideas and to select instructional strategies that addressed individual students' learning. She felt that the school administration encouraged teachers to cover the mathematics content in the current state mathematics standards, provided time for teachers to meet and share ideas, and encouraged her to attend professional meetings (Teacher School Context and Attitude SB). Her opinions about other teachers in her school were generally neutral. For example, she did not agree or disagree with statements about the other teachers in the school seeking new ideas or maintaining high performance standards (Teacher School Context and Attitude SB).

5.2.2 Attitude towards Standards-Based Mathematics Instruction

When surveyed about standards-based mathematics instruction, Ms. Gibson agreed with seven of the thirteen items. The items she agreed with primarily emphasized student-centered instruction and teaching mathematics in the context of everyday situations. She did not agree or disagree with four of the statements consistent with standards-based mathematics instruction. Her responses varied on the statements "it is more important to cover fewer topics in greater depth than it is to cover the text" and "students should learn mathematics through regularly discussing their ideas with other students." In both cases she initially disagreed with the statements, but agreed with both at the end of the school year in May (Teacher School Context and Attitude SB).

Ms. Gibson agreed with three of the five items inconsistent with standards-based mathematics instruction. All three of these statements had a common idea that students needed to master basic mathematical skills before they could be expected to apply mathematical knowledge. Her responses to the idea that students won't learn the mathematics they need to know if they use calculators varied. On the first two surveys she disagreed with this statement, but agreed with it on her final survey in May 2016 (Teacher School Context and Attitude SB).

Her attitude towards standards-based instruction in mathematics was mixed between agreement and disagreement, but changed to more agreement on the final survey. Ms. Gibson's responses were consistent with standards-based mathematics instruction on seven items, no opinion on five items, inconsistent with standards-based instruction on three items, and varied on three items. At the end of the year she was consistent with nine items, no opinion on five items, and inconsistent with four items.

5.2.3 Interpretations of Professional Development

After the professional development summer institute, Ms. Gibson was asked to describe the goals of the professional development in her own words.

> KG: Well, I don't know. I guess I would say the goals for me would have been to get more activities and more things that I could use in class that had a higher depth of knowledge questions and how I could improve in that area. I guess that was my main goal.

WW: What do you think the goals were for the presenters? What do you think [professional development facilitator] was trying to accomplish or [other professional development facilitator]? Do you think it was the same thing?

KG: I don't know. (KG PD Interview, 20150917, Segment 2)

Initially, Ms. Gibson answered with her personal goals for the professional development. She wanted to get more activities to use in her class with higher depth of knowledge questions. When she was asked what the goals were for the program, she replied that she did not know.

During the interviews, Ms. Gibson made twenty-eight positive comments about using the professional development in her class. Twelve of the comments were about new ways to use small group work and whole class discussion during mathematics instruction. For example, after teaching her first lesson she was asked:

WW: What aspects of the professional development did you incorporate into the lesson?

KG: Well, I was trying to get more of that group work, the cooperative learning going on. And I definitely, from the professional development, the presenting at the end. We talked a lot about that.

WW: Did those aspects of the professional development help the success of the lesson?

KG: I feel like yes because I feel like I had more of an idea of what to look for as they were presenting. I felt like the professional development gave me more ideas on how to have students present things and how to try and get, I guess just using

> the group work in general. (KG Post Lesson Interview, 20160301, Segments 8 and 9)

Ms. Gibson felt that the professional development provided ideas for group work in a mathematics class and planned to use small group and whole class discussions in her lesson. She described some of the positive outcomes from the group work.

> WW: Was there any part of the lesson that you felt like it went exceptionally well?
>
> KG: I thought they, when they were working together, I thought they did a great job of critiquing each other's ideas in their small groups. They were thinking about things. They weren't just taking one group members word for granted. They were actually thinking about it and challenging the ideas. I thought that went really well. (KG Post Lesson Interview, 20160301, Segment 17)

She valued students critiquing each other in small groups. Rather than passively accepting mathematical ideas, Ms. Gibson felt that the students were considering and appropriately challenging the mathematical ideas of other students.

Ms. Gibson made ten comments about improvements in student understanding of mathematical content by using ideas from the professional development. For example, Ms. Gibson was asked about an upcoming lesson on the relationship between a unit circle and the sine and cosine functions.

> WW: Do you have any other expectations for your students as far as what they will be doing or some of the outcomes they should have for this?
>
> KG: I'm hoping the outcome is they understand why the graph of a sine looks like it does. Because I know for me personally, I never really understood that. And

> I'm hoping they'll see the connection [to the unit circle]. I hope they make the connection. (KG Planning Interview, 20150917, Segment 44)

After the lesson, Kathy Gibson described outcomes from the lesson.

> WW: Did it play out the way that you planned?
>
> KG: It did. It actually played out better than what I had planned. I hadn't expected them to make the connections as quickly as they did. I felt like they did a really good job of discovering what they were doing. I was impressed by how well they made the connections. (KG Post Lesson Interview, 20150929, Segment 7)

Based on her assessment during small group work and whole class discussions, Ms. Gibson determined that the students made connections between the unit circle and the sine and cosine graphs. She felt that students developed a deeper understanding of the mathematics content by using ideas from the professional development.

Finally, Ms. Gibson made five positive comments about using practice standards in her class. She was asked:

> WW: What aspects of the professional development did you incorporate into the lesson?
>
> KG: Well, I tried to get more of the [practice] standards in; just the communicating math. I also, I didn't realize this until a little bit later, but I saw that they were using the repeated reasoning, finding structure. So they weren't [starting over] each time. They were using reasoning and thinking it through. They were making connections. (KG Post Lesson Interview, 20150929, Segment 9)

Ms. Gibson's intended curriculum included practice standards, especially standards focused on communication. She also noticed that the students were using more practice standards such as repeated reasoning and making use of structure.

There were seven comments from Ms. Gibson about challenges with using ideas from the professional development. Four of the comments were about students not being able to participate in class due to inexperience with ideas from the professional development. For example, during a follow-up interview, Ms. Gibson was asked if there was an idea that was difficult for her students.

> KG: I think, what it seemed like was, and I can't remember if it was this class or the other one or maybe a little bit of both. The idea that they struggled with the most was just the fact that they could do whatever they wanted with their circle. Like a lot of groups wanted to ask me, "What is the radius, what is the center?" And I told them it can be whatever you want. And that was something that, I guess that was another thing that I wasn't expecting them to struggle with. Because they are so used to us telling them, "Here's the circle's equation," instead of the other way around. (KG Post Lesson Interview, 20160301, Segment 16)

Ms. Gibson felt that the students struggled with the open-endedness of the mathematical task. The students were accustomed to being told what to do or being given all of the necessary information. In this case, her students struggled when they were told that they could work with the mathematics any way that they wanted. This is similar to Mr. Collins' challenge with using the professional development due to students who were not familiar with standards-based mathematics classes.

The other challenge area for Ms. Gibson was that the content of the professional development focused on a different grade level. She was asked to identify the least useful part of the professional development.

> KG: I felt like all the patterns stuff we did, all those activities with patterns. I felt like after we had done two of them I was done with it. I didn't feel like it was going to help me in my teaching. I didn't feel like it was going to help my kids pass the [state accountability test]. It just didn't apply to what I teach. (KG PD Interview, 20150917, Segment 5)

Similar to Mr. Collins, Ms. Gibson stated that the professional development was not useful when it did not apply to what she taught. During the same interview, she described more about wanting the professional development to directly relate to what she teaches.

> KG: Well, I've tried to get in more of the student-centered activities. I'm trying to look at how I can get higher-depth knowledge questions into my classroom. I wish there was more from the professional development that was ready to go in my classroom, like here it is all I have to do is make the copies and I can go with it. (KG PD Interview, 20150917, Segment 10)

Ms. Gibson wanted ready-to-go activities for her class. She perceived that using the professional development would be a challenge for her if she had to modify the ideas or activities to fit her classroom.

5.2.4 Classroom Lessons and Use of Professional Development

5.2.4.1 Lesson One: Intended Curriculum

Ms. Gibson planned to teach her first lesson aligned with the professional development on September, 2015 in a Pre-Calculus class. The lesson would be an introduction to graphing sine and cosine functions. Her desired outcomes were for students to understand the relationship between a unit circle and the graph of a sine wave and why the graph of a sine looks like it does. When asked about the planned activities for student learning Ms. Gibson replied:

> KG: They are going to create a circle. And then they are going to use spaghetti to measure different heights along the circle. And they are going to graph those heights. And hopefully they will do it correctly and they will see what a sine wave looks like. (KG Planning Interview, 20150917, Segment 43)

Ms. Gibson felt that the lesson would be aligned to the professional development because the activity focused on incorporating the practice standards (KG Planning Interview, 20150917, Segment 42). She planned to monitor the students as they did their work (KG Planning Interview, 20150917, Segment 43). This was the first time that she taught this lesson (KG Planning Interview, 20150917, Segment 47).

5.2.4.2 Lesson One: Enacted Curriculum

Ms. Gibson's first observed lesson was taught over two consecutive days. Day one was a full seventy-minute class period and day two was the first fifty minutes of a class period. The lesson started when students were given a packet and told that they would need to read the packet in order to know what to do (KG Observation One, 20150921, 0:00 to 1:00, Page 1). The students worked in small groups of three or four on the activity. The students collected the needed materials and began to work on the packet (KG Observation One, 20150921, 3:00 to 4:00, Page 1). The materials included a large sheet of paper (approximately three feet by seven feet), a protractor, a compass, a meter stick, a piece of yarn about seven feet long, and several pieces of uncooked spaghetti.

Students used the compass to draw a unit circle with a radius equal to the length of one of the spaghetti noodles (about fifteen inches) on one end of the large piece of paper. After creating the unit circle, the students used the protractor to mark fifteen-degree increments around the circle. Students created a Cartesian plane next to the unit circle on the large piece of paper. The x-axis was labeled with the degrees of the circle and the y-axis was labeled with the vertical distances from each of the given degrees to a horizontal diameter of the circle (see Figure 5.1). Students used additional spaghetti pieces to measure the perpendicular heights at the given degrees and transferred the ordered pairs of degree and vertical height to their graph. The resulting graph was a sine curve.

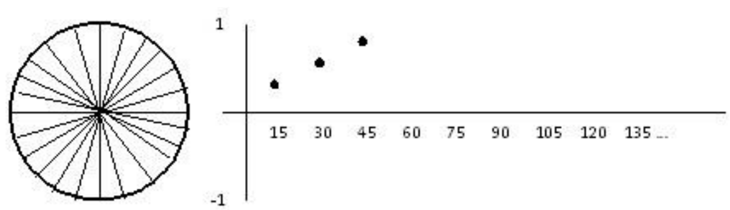

Figure 5.1 Example of Activity Comparing Unit Circle to Sine Curve

Ms. Gibson walked around the room checking on the groups. Students asked for clarification and she redirected them responding, “What does the packet say?” or “What do your partners think?" (KG Observation One, 20150921, 19:00 to 22:00, Page 1). Ms. Gibson offered some suggestions when a group needed help in order to continue. For example, one group was not using distances that were perpendicular to the horizontal line at the given angles to create the sine curve. Ms. Gibson redirected this group by explaining why they needed the perpendicular distances (KG Observation One, 20150921, 50:30 to 51:30, Page 1).

Students worked together to make sense of the instructions, agree on terminology, use tools to construct a sine or cosine curve, and respond to questions in the packet. Student comments included, "If the spaghetti is the radius, then the circle is two-spaghetti wide," and "The curve follows the same pattern" (KG Observation One, 20150921, 10:00, Page 1; KG Observation One, 20150921, 65:00, Page 2). Many groups noticed patterns with the different lengths. For example, students noticed that the perpendicular distance to the point on the circle at 45 degrees was the same as the distance at 135 degrees. At the end of the first day, Ms. Gibson announced that they would finish up the activity the next day (KG Observation One, 20150921, 66:00, Page 2).

On the second day students gathered up their work and needed materials from the first day. Ms. Gibson told the groups that she would check their work when they were done with the first part of the activity and then give them the second part of the activity (KG Video Lesson One, 20150921, 0:00 to 0:30, Tape 3). The second part was creating a cosine curve using a unit circle. Ms. Gibson walked around the room checking on the progress of the groups and asking questions to monitor student thinking. The students continued to work in small groups to make sense of the problem, to use tools to construct a sine or cosine curve, and to respond to questions in the packet. Mathematical terminology and reasoning were negotiated in the small groups as students completed the graphs and answered questions in the packet. Comments included, “This is the sine curve because sine is the y-values,” and “One hundred eighty degrees is zero because it is flat” (KG Observation One, 20150921, 5:00, Page 2; KG Observation One, 20150921, 24:00, Page 2). All of the student groups completed a sine curve. A few groups worked on a cosine curve.

After about thirty-five minutes of small group work, Ms. Gibson asked the students to put their materials away so the class could discuss the project. One group displayed a graph in the front of the class with a sine and cosine curve that was used as a reference during the discussion. The class discussed questions from the packet such as, “What is the period or the wavelength of the sine curve?” and “What are the zeros of the graph?” Students shared their thinking about the graphs such as, “It repeats after 360 because 0 and 360 are coterminal.” Ms. Gibson finished the whole class discussion by explaining to the students that these were the parent graphs for the sine and cosine functions and the class would learn more about the properties of these functions (KG Video Lesson One, 20150921, 45:30 to 46:00, Tape 3).

5.2.4.3 Lesson One: Summary and Alignment to Professional Development

The first observed lesson included many elements of standards-based instruction emphasized by the professional development. In comparison to the CCSSM SMPs, there was evidence of students *making sense of problems and persevering to solve them*. During the partner work, the students worked together to understand the instructions and work on the mathematical task, consider the relationship between the unit circle and the two trigonometric functions, and answer questions about the characteristics of the functions. The students also *looked for and expressed regularity in repeated reasoning* during the lesson. This occurred when the students noticed patterns in the vertical distances at different degree measures around the circle (e.g., the sine values at 60 degrees and 120 degrees are equal) and when the students answered questions in the packet about the characteristics of the functions such as maximum and minimum values. There was also evidence of the students *using appropriate tools strategically*. Throughout the lesson students used traditional and non-traditional tools to construct the unit circle and the trigonometric curves such as a compass, straight edge, protractor, string, and the spaghetti.

Students sometimes *constructed viable arguments and critiqued the reasoning of others* during the small group work. Students used reasoning to make sense of the problem, questioned each other when ideas were unclear, and worked together to negotiate the meaning of mathematical terms and ideas related to the problem. *Attending to precision* was also observed sometimes during the small group work. Students used traditional and non-traditional methods for measuring angles and distances to construct the curves from the unit circle. Students compared measurements and noticed patterns in the values of sine and cosine at the different angles around the unit circle.

In comparison to the NCTM MTPs, evidence was seen of Ms. Gibson *promoting reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse, posing purposeful questions,* and *supporting productive struggle in learning mathematics*. She *promoted reasoning and problem solving* and *facilitated meaningful mathematical discourse* by providing a challenging mathematical task that helped the students learn about the relationship between a unit circle and trigonometric functions. The task was used to introduce sine and cosine curves to the students. It provided them an opportunity to investigate patterns and clarify terminology. Students had opportunities to *connect mathematical representations* by making the sine and cosine curves in proximity to a unit circle and using non-standard methods for measurement to find values of sine and cosine at different angles. Ms. Gibson *posed purposeful questions* during small group work and during the whole class discussion such as, "Do you see any patterns in the graph of the sine curve?" or "How are the graphs of sine and cosine the same and how are they different?" (KG Observation One, 20150921, 23:00 to 31:00, Page 2). By using the mathematical task as an introduction to this new concept, allowing students to struggle with the task in small groups, and asking questions about the characteristics of the graphs, Ms. Gibson *provided opportunities for the students to struggle in a productive manner* while developing understandings about this mathematical topic.

Establishing mathematics goals to focus learning, building procedural fluency from conceptual knowledge, and *eliciting and using evidence of student thinking* were observed sometimes. Near the end of the activity, she told the students that the goal of this activity introduced them to the parent graphs of sine and cosine and they would use what they learned to understand transformations of these curves. Students had opportunities to *build fluency* with patterns for the values of the sine and cosine functions. Also, Ms. Gibson circulated from group to group during the small group work time checking for understanding, asking purposeful questions, and redirecting students when needed.

5.2.4.4 Lesson Two: Intended Curriculum

Ms. Gibson planned to teach her second lesson aligned with the professional development in February, 2016 with a different Pre-Calculus class. The topic and content standards for the lesson were solving non-linear systems of equations (KG Planning Interview, 20160210, Segments 1 and 2). The addressed practice standards for the lesson would include using appropriate tools strategically, making sense of problems, persevering in solving problems, and constructing viable arguments and critiquing the reasoning of others (KG Planning Interview, 20160210, Segment 2). This was the only time a teacher included practice standards as standards being addressed during a lesson.

Ms. Gibson explained that the lesson would be aligned to the professional development because the activity was a higher-level mathematical task "instead of a procedure without connections, which is probably what it was before" (KG Planning Interview, 20160210, Segment 3). She planned for the students to work in small groups and present solutions to the whole class so that they would communicate and critique different mathematical ideas (KG Planning Interview, 20160210, Segment 4).

The lesson would start with the students finding the number of possible intersection points for a line and a circle. They would move on to finding the number of possible intersection points for a line and a parabola. The students would look for patterns in the number of intersections and find different methods to check the points of intersection (KG Planning Interview, 20160210, Segment 4).

The students would be assessed for progress as Ms. Gibson circulated between the groups and asked questions about their work (KG Planning Interview, 20160210, Segment 5). It was important to her that the students have more than one method to verify any answers they found. When asked where this lesson was situated in the unit, Ms. Gibson stated that they just finished a different topic and this was a stand-alone lesson (KG Planning Interview, 20160210, Segment 6). She had taught solutions to non-linear systems in prior years, but this year she was teaching the topic in a new way by turning the lesson into a mathematical task (KG Planning Interview, 20160210, Segment 7).

5.2.4.5 Lesson Two: Enacted Curriculum

At the beginning of the second observed lesson Ms. Gibson told the students that they could work in small groups to answer two questions that were written on the white-board in the front of the class. The questions were: (1) How many different possible intersection points are there if a line and a circle are graphed in the same coordinate plane? and (2) Write a set of equations for each of the possibilities you have and find the intersection points for each part (KG Observation Two, 20160216, 0:00 to 2:00, Page 1). Students moved into small groups and began reading the questions several times. Groups had as many as four students and some students chose to work individually. Ms. Gibson clarified the questions saying, “Number one is not asking for the maximum number of intersections, but how many different things could happen” (KG Observation Two, 20160216, 4:00, Page 1). One group noted that there could be zero, one, or two intersections. Students asked Ms. Gibson clarifying questions such as, “Can the line go in any direction?” (KG Video Lesson Two, 20160216, 1:00 to 2:00, Tape 1).

The students discussed many important mathematical ideas in relationship to the questions. For example, they discussed that the circle and the line consisted of an infinite number of points, that the line extended on infinitely, and the meaning of intersection

(KG Observation Two, 20160216, 7:00 to 8:00, Page 1). Students also made drawings to demonstrate the different intersection possibilities. The possibility of a circle and line intersecting at one point was debated by many of the students (KG Video Lesson Two, 20160216, 7:00 to 9:30, Tape 1). The students also organized their thinking and work. For example, one group decided that there could be two, one, and zero intersections between a circle and a line. They struggled to find equations for each of the examples. A student suggested that they simplify the problem by first working only on the example with no intersections (KG Video Lesson Two, 20160216, 10:00, Tape 1).

The students made several drawings and used graphing calculators as they worked to answer the two questions. Some students discussed the equation of a circle (represented as $(x - h)^2 + (y - k)^2 = r^2$) and how h, k, and r influence the graph of the circle (KG Video Lesson Two, 20160216, 11:00 and 14:00, Tape 1). Other students held each other accountable for mathematical justifications. For example, a group member questioned another member asking, “Can you prove the radius of the circle would be one?” (KG Video Lesson Two, 20160216, 20:00, Tape 1). Another student drew a diagram of a line tangent to a circle and a different student challenged her saying, “You just drew a diagram and said, ‘It goes like that.’ How can you prove that?” (KG Video Lesson Two, 20160216, 18:30, Tape 1).

Ms. Gibson moved around the room to monitor the different student groups. She answered questions about the activity such as clarifying that the students needed to come up with an equation for a circle and an equation for a line that had two points of intersection (KG Video Lesson Two, 20160216, 6:00, Tape 1). She also discussed important ideas in the lesson with the students such as how to find the points of intersection, but typically suggested that they work with their group to figure it out. The students justified their answers asking questions such as, “If that is your answer, how can you check it?” (KG Video Lesson Two, 20160216, 21:30, Tape 1). She also challenged their current understandings by asking questions such as, “Can you do this in a different way?” (KG Observation Two, 20160216, 1:30 to 2:00, Page 2).

When a group finished the question about the number of possible intersections for a line and a circle, Ms. Gibson asked them to find the number of intersections between a parabola and a circle. Groups debated the possibility of a circle and a parabola intersecting at an infinite number of points if the circle aligned “just right” with the vertex of a parabola (see Figure 5.2). The students also discussed the possibility of zero, one, two, three, and four intersections between the parabola and circle (KG Video Lesson Two, 20160216, 11:30 to 12:30, Tape 2).

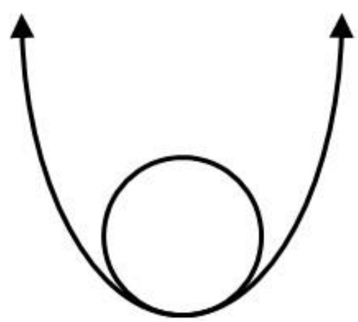

Figure 5.2 Image of Parabola and Circle Debated as having Infinite Points of Intersection

With about fifteen minutes remaining in the class period, Ms. Gibson announced that the groups were going to share their solutions with the class (KG Observation Two, 20160216, 0:00 to 1:00, Page 3). Different groups shared equations that were examples of a line and a circle intersecting or a parabola and a circle intersecting. The groups justified the points of intersection and in most cases explained how they selected the equations that they used. For example, one group explained:

> Student 1: We centered our circle around zero so it would be easier to work with. For one intersection we put our circle right underneath the parabola so it just hit at one point. From there we slowly started moving our circle up until it hit [the parabola] two, three, or four times. (KG Video Lesson Two, 20160216, 3:30 to 4:00, Tape 3)

Ms. Gibson asked questions to encourage the students to compare different answers such as, “Do you see how they did that? Show them how you moved the circle” (KG Observation Two, 20160216, 4:00 to 5:30, Page 3). At the end of the class Ms. Gibson collected the work from each group of students.

5.2.4.6 Lesson Two: Summary and Alignment to Professional Development

There was evidence of many of the CCSSM SMPs in Ms. Gibson’s second lesson. The lesson included opportunities for students to *make sense of the problem and persevere in solving* it. Ms. Gibson provided an opportunity for students to investigate the intersection of linear and non-linear relations and allowed the students to negotiate meaning and struggle to find solutions. The students *constructed arguments* and justified their reasoning during the small group work and during the whole class discussions. Students *used appropriate tools* such as graphing calculators and graph paper to investigate, solve, and check answers to the problem. Throughout the lesson the students *attended to precision* by determining the points of intersection and using multiple methods to justify the intersections. The students *made use of structure* when they used the forms of the equations for a line, parabola, and circle to manipulate their graphs. They *used repeated reasoning* when they developed patterns for moving or changing properties (e.g. slope, radius, intercepts) of the lines, parabolas, or circles.

There was some evidence of *reasoning abstractly* when the students contextualized the problem by checking ordered pairs as points of intersection and decontextualized the problem by manipulating the equations and the resulting graphs. The students sometimes *modeled the mathematical situations* using tables and graphs to explain different intersection possibilities.

All of the NCTM MTPs were evident during this lesson. The practices that were present throughout the lesson included *using mathematical tasks that promote reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse, posing purposeful questions,* and *supporting productive struggle in learning mathematics*. Two elements of this lesson were important with implementing many of the MTPs. First, the task included two challenging questions that required the students to conduct a mathematical investigation and apply many conceptual mathematical ideas. This allowed the students to *problem solve, make representations,* and *struggle in a productive manner*. Second, Ms. Gibson expected the students to come up with solutions to the question and justify the solutions without relying on her to guide their thinking. She also asked questions that encouraged the students to find different methods and consider solutions from other groups.

There was some evidence of *establishing mathematics goals to focus learning, building procedural fluency from conceptual knowledge,* and *eliciting and using evidence of student thinking*. At the beginning Ms. Gibson focused the students on the idea of different ways that mathematical relations could intersect. The students built *procedural fluency* with the different forms for the relations (e.g. $y - k = a(x - h)^2$). She circulated between the groups asking questions about their thinking and used what she learned to encourage the different student groups to understand different solutions.

5.2.5 Summary, Kathy Gibson

Ms. Gibson was an experienced teacher who participated in professional development activities prior to the TAPS program, including work on a master's degree in mathematics education. Through reading and professional development work she was familiar with standards-based instruction before participating in TAPS. Ms. Gibson's attitude towards mathematics instruction was generally consistent with standards-based practices, especially with providing student-centered instruction and teaching mathematics in the context of everyday situations. She felt that she had control over most aspects of her classroom including selecting instructional materials, selecting teaching methods, and evaluating students. Ms. Gibson also felt that she was supported by teachers and administrators to try out new ideas in teaching mathematics.

When asked about the goals of the professional development program Ms. Gibson replied that she wanted to get more activities to use in her class with higher depth of knowledge questions. She identified three ideas from the professional development as useful for her class: strategies to use small group work and whole class discussion; using standards-based instruction to improve student understanding of mathematical content; and using practice standards in her class. She also noted that she was challenged to use ideas from the professional development because her students were inexperienced with participating in a standards-based class and that the content of the professional development was focused on classes that she did not teach.

Many of the practice standards were observed in Ms. Gibson's lessons. Eight practice standards were observed throughout the first lesson and six of the practice standards were observed sometimes. The second lesson included eleven of the practice standards throughout and five of the practice standards observed sometimes. Eight of the practice standards observed throughout the two observed lessons: *making sense of problem and persevering in solving*, *using appropriate tools strategically, looking for and expressing regularity in repeated reasoning*, *implementing tasks that promote reasoning and problem solving*, *using and connecting mathematical representations, facilitating meaningful mathematical discourse*, *posing purposeful questions,* and *supporting productive struggle in learning mathematics*.

Ms. Gibson's use of higher-level mathematical tasks, students working in small groups, and students participating in whole class discussions were key instructional practices that supported standards-based instruction. Factors that likely influenced her use of ideas from the professional development included her goal to include higher depth of knowledge questions, the elements from the professional development that she felt were helpful, her prior professional development experience, and her perception of control over most aspects of her classroom. The goal to include higher depth of knowledge questions was observed when Ms. Gibson posed purposeful questions and facilitated meaningful mathematical discourse in both lessons. She included small group work and planned for the use of practice standards, both of which she identified as useful ideas from the professional development. Her prior professional development experience, including prior knowledge of the practice standards, likely influenced the intended and enacted lessons. Similar to Mr. Collins, Ms. Gibson perceived that she had control over most of the instructional decisions in her classroom. She did not report any classroom-based factors that would discourage the use of the practice standards.

Consistent with her perception that it would be a challenge to use ideas from the professional development because the sample activities did not align with the courses that she taught, Ms. Gibson had to create or modify existing lessons to align with the goals of the professional development. Despite this challenge, she was able to develop two mathematical tasks that incorporated the practice standards.

5.3 Laura Henderson

Laura Henderson was a Caucasian female high school mathematics teacher with four years of teaching experience. This was her second year teaching at SHS and she taught Algebra 1. She had also taught Geometry and Algebra 2. Her bachelor's degree was in mathematics education and included more than ten mathematics courses (Teacher Background Experience).

In the eighteen months prior to this research Laura Henderson attended meetings on the school's mathematics curriculum, mathematics teaching techniques, and assessing student learning. She also participated in a professional development workshop on core ideas of mathematics and basing instructional practices on student knowledge, but she did not feel that this workshop led to changes in her teaching of mathematics. Ms. Henderson had read the state mathematics academic standards and the *Principles and Standards for School Mathematics* (Teacher Professional Opportunities).

5.3.1 Perception of School Context

Ms. Henderson felt that teachers had very little influence in most school policy areas including setting discipline policy, determining the content of professional development, and evaluating teachers. She perceived that there was some teacher influence on important educational decisions and establishing curriculum (Teacher School Context and Attitude SB). Ms. Henderson felt that she had control over all aspects of her classroom, including evaluating students, selecting instructional materials, selecting content to be taught, and selecting teaching methods (Teacher School Context and Attitude SB).

When asked about the support environment at her school, Ms. Henderson agreed that she was supported by other teachers to try out new ideas in teaching mathematics. She felt that the school administration encouraged her to select mathematics content and instructional strategies that address individual students' learning and to cover the mathematics content in the current state standards for mathematics education. Ms. Henderson did not feel that the school administration enhanced the mathematics program by providing the needed materials and equipment. She also felt that it was somewhat common for teachers to be left on their own to seek out professional development opportunities (Teacher School Context and Attitude SB).

5.3.2 Attitude towards Standards-Based Mathematics Instruction

Ms. Henderson agreed with nine of the thirteen statements consistent with standards-based mathematics. She typically agreed with items about student centered instruction such as students should write and discuss how they solve mathematical problems and students learn best when they study mathematics in the context of everyday situations. She had no opinion on three statements consistent with standards-based statements. One of these statements was that students learn mathematics best in classes where they are able to work in small groups. Her responses varied on encouraging students to find their own strategies to solve problems even if the strategies are inefficient, but she strongly agreed with the statement on the final survey (Teacher School Context and Attitude SB).

On the statements inconsistent with standards-based mathematics instruction, Ms. Henderson agreed that when teaching mathematics her primary goal was to help students master basic concepts and procedures. She had no opinion on three of the statements and disagreed that if students use calculators, they won't learn the mathematics they need to know (Teacher School Context and Attitude SB).

Ms. Henderson had more agreement than disagreement with standards-based instruction in mathematics. Her responses were consistent with standards-based mathematics instruction on ten items, no opinion on six items, inconsistent on one item, and varied on one item. Her attitude did not change much at the end of the year, such that she was consistent with eleven items, no opinion on six items, and inconsistent with one item.

5.3.3 Interpretations of Professional Development

Ms. Henderson described the goals of the professional development in the following way, "I think the goals are to align the [practice] standards and the content standards to make an algebra class more enriching to take it to that next level for the kids" (LH PD Interview, 20150902, Segment 3). She felt that the goals for the professional development were to align the practice standards to the content standards and to use the standards to improve her algebra class.

There were twenty positive comments by Ms. Henderson about using ideas from the professional development throughout her interviews. Seven of the comments related to having activities to use in her class. For example, she was asked which part of the professional development was most useful and why.

> LH: I think when we actually gave the activities and performed the activities, when all the groups did that, I think that was probably most beneficial because we got to see kind of how it would look in a real classroom. And it was more; I think we all tried to pick something that we could actually use in algebra. It was a little bit harder to get to that high school level. I feel like most of them were still stuck in the middle school, but that was probably the most useful part. (LH PD Interview, 20150902, Segment 5)

Similar to Mr. Collins and Ms. Gibson, Ms. Henderson's comments reflect wanting activities for her class. She stated that having different teacher groups present activities gave her ideas about how the activities would play out in a classroom. Also similar to Mr. Collins and Ms. Gibson, she noted that was a challenge when the activities were not appropriate for the content in her high school algebra class.

Ms. Henderson used one of the activities from the professional development for her second lesson observation. She felt that having a good mathematical task helped her incorporate the practice standards into her teaching.

> WW: Is there any reason why or any factors that made it easy to use the [professional development] in those situations?

> LH: Well I think on a task like that the kids will always want to struggle and lean on you. So that made it really easy for me to be able to use that.
>
> WW: So having a good mathematical task as described by the stuff that you read during the summer workshop; that was helpful in using some of the ideas from the [professional development] like productive struggle. Is that what you are saying?
>
> LH: Yes. (LH Post Lesson Interview, 20160509, Segment 24)

Ms. Henderson identified and used a mathematical task that helped her use ideas from the professional development. Although the students struggled and tried to rely on Ms. Henderson, she was still able to incorporate the practice standards into her lesson.

Five of Ms. Henderson's comments identified the use of productive struggle as a positive outcome from the professional development. For example, she was asked why she wanted to continue to use ideas from the professional development in her class.

> LH: I feel like the kids struggle, and then when they struggle they get frustrated. But I think the outcome makes them feel better. I guess I just think that they retain it more because they want to get there more. (LH Post Lesson Interview, 20160509, Segment 5)

Ms. Henderson felt that students accomplished and retained more if they had opportunities to struggle through a challenging mathematical task. Accomplishing and retaining more relates to her goals for improving her class. The students' success provided motivation for her to continue to use ideas from the professional development, in this case to continue to use productive struggle.

There were four positive comments by Ms. Henderson about the use of small groups and whole class discussions. She used the whole class discussions to help her students learn about different ideas for solving mathematical problems.

> WW: What was your purpose behind that part [the whole class discussion] of the class?
>
> LH: I think I kind of wanted some of the groups to see that it could have been different than what they had done. So a lot of the groups had done basic operations. I wanted them to see that other groups came up with things that were outside the box. So I wanted them to be kind of inspired the next time we do an activity like that that they could think of different ways of getting the same numbers. (LH Post Lesson Interview, 20151001, Segment 23)

Recall that Laura Henderson did not agree or disagree with the idea that students learn mathematics best in classes where they are able to work in small groups. Although she was neutral about using groups in her survey responses, she included small group and whole class discussions in both of the observed lessons.

Ms. Henderson also made four positive comments about students learning mathematics content better. In the fall, she was asked what parts of the professional development she would use during her upcoming lesson. “I think having them be able to thoroughly explain themselves and understand the content” (LH Planning Interview, 20150902, Segment 47). She identified explanations and understanding the content as ideas from the professional development that she planned to include in her lessons.

Ms. Henderson made five comments related to challenges with using the ideas from the professional development. She mentioned three times that the professional development was challenging to use because the content was focused on a different grade level or course.

> WW: Which part of the professional development was least useful and why?
>
> LH: I think a lot of it was geared towards younger kids. So as the high school teacher I felt like a good bit of what we talked about was something that I wouldn't necessarily use. And then there was a day when we spent just working on [computer software]… and we have no technology at school so that was pretty un-useful for us. Because there is no way that I would ever be able to use it in class. (LH PD Interview, 20150902, Segment 6)

Similar to Mr. Collins and Ms. Gibson, when the activities were not appropriate for an Algebra 1 course, Ms. Henderson felt that she worked on something that she could not use. She also noted that when an activity required a resource that was not available through her school, such as software or technology, then the professional development was not useful.

In addition, Ms. Henderson made two comments about struggling to use ideas from the professional development due to the inexperience of her students.

> WW: Was it difficult to incorporate any parts of the professional development into your lesson?
>
> LH: I think maybe establishing that sense of independence is always a little difficult. It's not relying on me as the teacher, relying on each other as well to kind of give them the push that they want. I think that kind of coddling is always hard to break. So that was probably the worst. (LH Post Lesson Interview, 20160509, Segment 25)

Again similar to Mr. Collins and Ms. Gibson, Ms. Henderson noted that it was difficult to use the professional development in her lesson because of the students' inexperience or lack of ability to work independently in a mathematics class. Higher-level mathematical tasks provided opportunities for students to work independently and in small groups on challenging mathematical ideas. Students' prior experiences of being mathematically "coddled" made it a challenge for Ms. Henderson to use the higher-level tasks in her classroom.

5.3.4 Classroom Lessons and Use of Professional Development

5.3.4.1 Lesson One: Intended Curriculum

Ms. Henderson planned to teach her first lesson aligned with the professional development in September, 2015 in an Algebra 1 class. The topic for the lesson was order of operations (LH Planning Interview, 20150902, Segment 45). Although order of operations was not an Algebra 1 standard, Ms. Henderson stated that her students were reviewing important concepts for the upcoming year (LH Planning Interview, 20150902, Segment 46). She felt that the lesson was aligned to the professional development because the activity provided opportunities for her students to explain the mathematical content and because the students would be working in small groups (LH Planning Interview, 20150902, Segment 47).

Ms. Henderson described the planned activities for student learning in this lesson.

> LH: It is called order of operations bowling. So they are going to be given the numbers one through ten and they have to roll four dice and add up the four numbers that they rolled. They have to use the order of operations to get to the

numbers one through ten. And they can do this in any way. But it will have to involve parentheses and exponents, and things that maybe they, [pause] because most kids want to do just adding or just subtracting. So it will be kind of just taking their knowledge of the order of operations and really just putting it to the test. (LH Planning Interview, 20150902, Segment 45)

The planned assessment for the activity was grading the worksheets that the students would complete (LH Planning Interview, 20150902, Segment 50). This lesson was a review of order of operations before an upcoming test, and it was the first time that Ms. Henderson had used this activity (LH Planning Interview, 20150902, Segment 51).

5.3.4.2 Lesson One: Enacted Curriculum

The class started with “bell work”, which was four review problems that the students worked on individually for fifteen minutes. Ms. Henderson walked around the room checking on students as they worked. She asked four students to come to the front of the class and write out a solution to each problem. Ms. Henderson fixed one of the solutions that was incorrect and confirmed that the other solutions were correct. The students compared their answers to the correct answers and passed in their bell work (LH Observation One, 20150904, 13:00, Page 1).

After the bell work Ms. Henderson gave a worksheet to each student that included a diagram with the numbers one through ten organized in a triangle-shape; the way bowling pins are organized on a bowling lane. She explained that they were going to play order of operations bowling (LH Observation One, 20150904, 15:00 to 20:00, Page 1). The students would roll four dice and record the outcomes. They would use the four numbers with the order of operations to equal different values one through ten. For example, if *1, 2, 4,* and *5* were rolled the students could do $5 \times 4 \div 2 - 1$ to get *9* and could do $5 + 4 - 2 - 1$ to get *6*. If students could not find a way to get all of the values one through ten, then they could roll the dice a second time and use the new outcomes to get the remaining values. Ms. Henderson demonstrated an example and emphasized using exponents and grouping symbols (e.g. $(5^2 - 1) \div 4 = 6$). Students were told to work with a partner and show all of their work on the worksheet (LH Observation One, 20150904, 22:00, Page 1).

Students worked in pairs for about thirty minutes. Some students worked independently in the pairs, some passed the worksheet back and forth taking turns, and some worked together discussing ways to get the ten different answers (LH Observation One, 20150904, 26:00, Page 1). Students asked clarifying questions such as, "Can we use exponents?" or "Do we have to use all of the numbers?" (LH Observation One, 20150904, 32:00, Page 2). Most of the student discussions centered on checking answers and explaining how they used the four numbers to find values between one and ten.

Ms. Henderson walked around the room checking the work done by the students. She reminded them to use grouping symbols and exponents (LH Observation One, 20150904, 39:00, Page 1). Some groups were not able to find a combination to get one of the values between one and ten. Ms. Henderson provided hints to groups that were stuck and would help groups find a solution when they only had a few numbers remaining. For example, she visited one group and said, "You need an eight? What about six times five, divided by three, minus two?" (LH Video Lesson One, 20150904, 43:00, Tape 1).

Ms. Henderson gave the class a ten-minute warning to let them know that they would talk about the activity. During the whole class review, Ms. Henderson asked the students to share the craziest equations they found (LH Observation One, 20150904, 55:00 to 57:00). One student shared, “I had five to the power of one, minus two, minus two” (LH Video Lesson One, 20150904, 57:30, Tape 1). She asked if anyone used a square root, but none of the students shared an example. The students handed in their worksheets at the end of the class.

5.3.4.3 Lesson One: Summary and Alignment to Professional Development

The first observed lesson included some of the practice standards emphasized by the professional development. There was evidence of the CCSSM SMP *attend to precision*. The main focus of the activity was applying the rules for order of operations to find different integer answers. Students manipulated numbers, performed calculations, and checked their work to calculate the different integer answers.

Reasoning quantitatively was observed sometimes as they manipulated the four given numbers and used different mathematical operations. There was some evidence of *using appropriate tools strategically* when a few of the students used calculators to test different number combinations and to check their answers. Finally, students sometimes *looked for and made use of structure* when they developed and redeveloped different mathematical expressions using the properties of the numbers and operations.

A few of the MTPs were observed sometimes during the lesson. Ms. Henderson implemented a task that *promoted problem solving* and *built procedural fluency* during the lesson. Rather than performing calculations using order of operations to find an answer, the students had an opportunity to manipulate given numbers using their understandings of order of operations. There was also some evidence of *supporting productive struggle* when the students were challenged to find an expression that would equal each of the integers between one and ten. In most cases the student pairs found five or six of the outcomes quickly, but struggled using different operations to find the remaining outcomes.

5.3.4.4 Lesson Two: Intended Curriculum

Ms. Henderson planned to teach her second lesson aligned with the professional development in May, 2016 again with an Algebra 1 class. The topic for the lesson was analyzing data and creating approximate best fit lines (LH Planning Interview, 20160429, Segment 1). She felt that the lesson was aligned to the professional development because she was using a mathematical task that was shared by the facilitators during one of the follow-up sessions. She described the learning activities for the students.

> LH: So they are going to be given the graphs with the data points on it. And they are going to have to answer the guided questions, I guess, to kind of see how lines and slopes fit together with data and statistics. (LH Planning Interview, 20160429, Segment 4)

Ms. Henderson planned to assess the students by walking around and listening to the students' ideas. In addition, she planned to grade the students' solutions to the guided questions at the end (LH Planning Interview, 20160429, Segment 7). This lesson was at the end of a unit and had not been taught prior (LH Planning Interview, 20160429, Segment 8).

5.3.4.5 Lesson Two: Enacted Curriculum

The class started with the students working independently on bell work for about fifteen minutes. When most students were finished, the teacher led the class on how to solve the problems with input from the students. She asked questions such as, "How do we start solving this?" or "What is the next step?" (LH Observation Two, 20160504, 8:30, Page 1). The students shared solution ideas and watched Ms. Henderson write out a solution to each of the questions. At the end she asked the students to hand in the bell work pages.

Ms. Henderson introduced the activity for the day to the students.

> LH: You are going to work on a task involving bird eggs. It involves bivariate data, which we have talked about. You will need to read the questions and answer them the best that you can. If you get confused I will clarify the question for you. After a while you can work with a partner and compare what you have with what they have. There isn't just one right answer for these. Just because someone has a different answer doesn't mean that you are completely wrong. (LH Video Lesson Two, 20160504, 18:00 to 19:00)

Ms. Henderson handed out a packet with a scatter plot graph of data comparing the length and the width of different bird eggs (modified from Mathematics Assessment Resource Service, 2011). Students were instructed to use the data to answer a series of questions about the relationship (LH Observation Two, 20160504, 18:00, Page 1).

The students worked independently on the task at the beginning. Ms. Henderson walked around the classroom checking student work (LH Observation Two, 20160504, 20:00 to 24:00, Page 1). Some students asked her questions to clarify the work. She typically responded with a question and encouraged them to use their own thinking to work on the problem (LH Video Lesson Two, 20160504, 25:00 to 26:00). After about twelve minutes of independent work, Ms. Henderson asked the students to work with a partner and explained that the whole class would talk about the questions in about fifteen minutes (LH Observation Two, 20160504, 5:45, Page 2). The students started comparing answers and explaining their solution methods to each other (LH Observation Two, 20160504, 7:00 to 10:00, Page 2). Ms. Henderson walked around the class checking work done by the students and listening to the small group discussions. She asked some groups clarifying questions such as, "What can you do to check the equation?" (LH Video Lesson Two, 20160504, 18:30, Tape 2). The students returned to their seats for the whole class discussion.

Similar to the beginning of the class, Ms. Henderson led the whole class discussion on how to solve the problems with input from the students. She asked questions such as, "How did you start this?" and "What do we do next?" (LH Video Lesson Two, 20160504, 23:00 to 25:00). The students responded and explained steps in their solutions. For example, Ms. Henderson asked one student how he added a point to the graph given an egg with a length of 57 millimeters and width of 41 millimeters. The student explained how he graphed the point with length on the x-axis and width on the y-axis (LH Video Lesson Two, 20160504, 23:30, Tape 2). In other cases, Ms. Henderson re-read the questions from the packet and explained how to do the problems. For example, one question asked which egg had the greatest ratio of length to width. She explained that the students needed to create ratios for five different eggs and see which ratio was the largest (LH Observation Two, 20160504, 1:00 to 2:00, Page 3). In general, Ms. Henderson wrote students' answers on the board and explained if they were correct or incorrect. After the whole class demonstration and answer checking, the students passed in their work from this task.

5.3.4.6 Lesson Two: Summary and Alignment to Professional Development

Ms. Henderson's second lesson included some of the practice standards aligned to the goals of the professional development. In comparison to the CCSSM SMPs, evidence was seen of students *making sense of problems and persevering to solve them*. Ms. Henderson facilitated instruction by requiring the students to read and understand the mathematical task, limiting the amount of direction and answer-giving to students, and having the students work independently and in small groups. There was evidence of *constructing viable arguments and critiquing the reasoning of others* and evidence of *attending to precision* when the students compared and checked solutions. The students also *attended to precision* when they constructed an estimated best fit line and estimated the length or width of eggs that were not on the provided scatter plot. There was some evidence of the students *reasoning abstractly and quantitatively* and *modeling with mathematics*. Both of these occurred when the students represented the given scatter plot data with a best fit line.

For the NCTM MTPs, Ms. Henderson implemented a task that *promoted reasoning and problem solving, supported the students to use and connect mathematical representations, facilitated meaningful mathematical discourse,* and *supported productive struggle*. These were evident when the students made sense of the problem during individual work, compared answers during the small group work, and represented the data graphically and algebraically. *Establishing goals to focus learning* was sometimes evident when she noted that this lesson involved bivariate data. Also, there was some evidence of Ms. Henderson *posing purposeful questions* when working with the different groups during the small group work time.

5.3.5 Summary, Laura Henderson

This was Ms. Henderson’s second year at SHS. Before participating in TAPS she attended professional development on core ideas of mathematics and basing instructional practices on student knowledge. Ms. Henderson felt that she had control over all aspects of her classroom including selecting instructional materials, selecting content to be taught, and selecting teaching methods. She had varying perceptions of instructional support at her school. Overall, her attitude towards mathematics instruction was consistent with standards-based practices, especially agreement on statements about providing student-centered instruction.

Ms. Henderson described the goals of the professional development as aligning the practice standards to mathematics content standards to improve her algebra class. Providing activities for her class, using productive struggle, strategies to use small group work, and improving student understandings of mathematical content were four ideas from the professional development that were useful in her class. She felt challenged to use ideas from the professional development because the content was focused on a different grade level and her students were inexperienced with participating in a standards-based mathematics class.

The use of the practice standards increased from Ms. Henderson’s first lesson to her second lesson. One practice standard was observed throughout the first lesson and seven of the practice standards were observed sometimes. The second lesson included seven of the practice standards throughout and four practice standards sometimes. *Attending to precision* was observed throughout both lessons.

In the second lesson, Ms. Henderson incorporated the practice standards into her instruction by requiring the students to read and understand a higher-level mathematical task, limiting the amount of answer-giving she provided to students, having the students work independently and in small groups, and encouraging the students to compare solutions. Factors that most likely influenced her use of ideas from the professional development included the elements she thought were helpful from the professional development, her goal to improve her class by using practice standards with content standards, her perception of control over her classroom, and her lack of experience with practice standards.

All of the areas from the professional development that Ms. Henderson identified as helpful were observed. Her interpretation of the professional development goals was an influence on the lessons because practice standards such as productive struggle and attend to precision were observed. Similar to Mr. Collins and Ms. Gibson, Ms. Henderson noted that she had control over aspects of her classroom, such as selecting instructional materials and selecting instructional strategies. Her perception of control allowed her to use instructional materials or practices from the professional development without concern. Finally, Ms. Henderson had an attitude that was consistent with standards-based mathematics instruction, but was not observed using many practice standards between the two lessons. Her lack of experience may explain this. As a newer teacher, it is likely that her familiarity with the practice standards was emerging, which is consistent with the lack of practice standards observed in the first lesson and the larger number observed in the second lesson.

5.4 Ruth Lawrence

Ruth Lawrence was a Caucasian female with nine years of teaching experience, eight of them at SHS. At the time of this research she was teaching Algebra 1 and Geometry. She had also taught Algebra 2 and Honors Geometry. Her bachelor's degree was in mathematics, which included more than ten mathematics courses (Teacher Background Experience).

She had participated in some professional development during the last eighteen months, but she felt that it was rare for the school to support professional development opportunities and that teachers were left on their own to seek out professional development. She had attended three meetings on the SHS mathematics curriculum and one meeting on mathematics teaching techniques. Ms. Lawrence had read the state mathematics academic standards and the CCSSM (Teacher Professional Opportunities).

5.4.1 Perception of School Context

Ms. Lawrence's perception of the SHS environment varied more than the other three teachers. Her perceptions about school policy and administrative support tended to decline, her perceptions about teachers moved toward neutral or no opinion, and her perceptions about the school context improved.

Ms. Lawrence felt that there was some influence on making important educational decisions, but very little on setting discipline policy or evaluating teachers. Her opinion varied related to influence on establishing curriculum and determining the content of professional development. On the original survey she felt that teachers had a great deal of influence in these areas, but responded that there was very little influence on the final survey (Teacher School Context and Attitude SB). When asked about the school administration, on the first two surveys Ms. Lawrence felt that the school administration let staff members know what is expected of them, were supportive and encouraging to the staff, and had a clear vision for the school at the beginning. On the final survey, she disagreed or strongly disagreed with all three of these statements (Teacher School Context and Attitude SB).

Ms. Lawrence felt that she had classroom control over selecting instructional materials, determining the amount of homework to be assigned, and evaluating students. Her responses varied with respect to selecting content and topics to be taught and selecting teaching methods. Early in the school year she felt that she had some control in these two areas, but changed to little control at the end of the year (Teacher School Context and Attitude SB).

Ms. Lawrence felt that teachers in the school exhibited a commitment to student learning in mathematics, but her opinions varied about cooperative effort among the teaching staff, teachers continually learning and seeking new ideas, and having a shared vision for student learning in mathematics. Her opinions were mixed on these items during the school year. At the end she had no opinion about any of these three areas (Teacher School Context and Attitude SB).

When asked about the environment at her school, Ms. Lawrence felt that she was supported by other teachers to try out new ideas in teaching mathematics, and the school administration encouraged teachers to cover the mathematics content in the current state standards for mathematics. On other items such as the school administration encouraging the implementation of process standards in the current state standards in mathematics education and the school administration providing time for teachers to meet and share ideas with one another, she initially disagreed with these statements, but changed to agree on the final survey (Teacher School Context and Attitude SB).

5.4.2 Attitude towards Standards-Based Mathematics Instruction

Ms. Lawrence agreed with nine of the thirteen statements that were consistent with standards-based mathematics instruction. Generally, she was in agreement with providing student-centered mathematics instruction, teaching fewer mathematical topics, making connections with other disciplines, and including problem solving as a central feature. She did not agree or disagree with the statement that students learn mathematics best in classes where they are able to work in small groups. The three items where her responses varied were: students learn best when they study mathematics in the context of everyday situations, it is important to use thematic units focused on one or two mathematical ideas rather than daily lessons focused on individual topics, and instruction should include many open-ended tasks. On the final survey, she agreed with the first two statements and was neutral on the statement about open-ended tasks (Teacher School Context and Attitude SB).

On the items inconsistent with standards-based mathematics instruction, Ms. Lawrence agreed with two statements about students needing to master basic mathematics skills before they can be expected to analyze, compare, and generalize. She disagreed that students won't learn the mathematics they need to know if they use calculators and that instruction should include step-by-step directions. Her responses varied on the statement that, her primary goal is to help students master basic concepts and procedures. Originally she strongly agreed, then did not agree or disagree at the beginning of the school year, and then disagreed on the final survey (Teacher School Context and Attitude SB).

Ms. Lawrence's attitude towards standards-based instruction in mathematics was more in agreement than disagreement with standards-based practices. She started with more responses consistent with standards-based practices than the other three teachers. She was consistent on eleven items, had no opinion on one item, was inconsistent on two items, and varied on four items. At the end of the year she was consistent with fourteen standards-based items, had no opinion on two items, and was inconsistent with two items.

5.4.3 Interpretations of Professional Development

Ms. Lawrence was asked to describe the goals for the professional development program.

> RL: I think the goals were to expose us to mathematically rich tasks. And I think also we were supposed to learn about the SMPs and the MTPs and maybe how to keep those in our focus while we are teaching throughout the school year. (RL PD Interview, 20150914, Segment 2)

She remembered two important aspects of the professional development. First, she noted that one of the goals was to expose the teachers to mathematical tasks. Second, she stated that the teachers learned about the practice standards and how to incorporate these standards in instruction throughout the school year.

Ms. Lawrence made twenty-six positive comments about using ideas from the professional development during mathematics instruction. Eleven of her comments were that the professional development provided activities for her class. For example, following the professional development summer institute she was asked:

> WW: What was most useful [during the professional development] and why?
>
> RL: Well, like that one thing I told you. Truly honestly I loved every task that you guys shared with us that was high school level. I didn't think any of them, typically the tasks that I am shown, are 'hocus pocus.' [That] is what I like to call them. I'm sure there is a better word. They [other tasks] are just like sloppy and they are not rich. The tasks that you guys showed us were, like I don't know, they were just the best tasks that I have ever been exposed to. I want more like that, like I love that. (RL PD Interview, 20150914, Segment 6)

She was excited about the rich mathematical tasks that were shared during the professional development. Similar to the other teachers, she states that the tasks that she found to be useful were the ones that were related to the courses she taught.

There were five comments by Ms. Lawrence indicating that she valued the professional development because the students would learn mathematical content better. For example, she was asked what advantages she expected from using the professional development.

> RL: I think deeper understanding. If I get good at teaching these kids to be good thinkers, they'll learn to be persistent, like you were saying earlier. They will be able to think harder through a problem and hopefully some strategies, hopefully they will gain some strategies. (RL PD Interview, 20150914, Segment 14)

She expected the mathematical tasks to challenge her students and encourage them to use different strategies. According to Ms. Lawrence, working on mathematical problems in this way would help the students have a deeper understanding.

There were four comments by Ms. Lawrence about benefits of having the students work in small groups when learning mathematics. When asked about the intended curriculum, she mentioned the use of small groups.

> WW: Are you going to be doing anything different in the way that you plan?
>
> RL: I feel like at the beginning of the school year I was reinvigorated and motivated by our professional conference. And I was motivated to be, to not be so worksheet, so lame as a teacher. I was trying to do more posters and more group work and I felt inspired. (RL Planning Interview, 20150914, Segment 11)

Ms. Lawrence was excited about using ideas from the professional development. In particular, she planned on including more small group work during her lessons.

Ms. Lawrence made six comments about challenges with using ideas from the professional development. She referred to two different challenges twice: the content of the professional development focusing on a different grade level or course and leading class discussions. Similar to the other three teachers, she did not value the parts of the professional development that she did not think applied to her grade level or courses. For example, she said during an interview, “Any time we addressed the elementary or the middle school level tasks, those were typically, I kind of tuned out because they didn’t really apply to me” (RL PD Interview, 20150914, Segment 7).

Ms. Lawrence was the only teacher who identified the class discussions as a challenge.

WW: Do you anticipate there being any disadvantages or challenges with using the professional development goals?

RL: Yeah. I think it is going to be challenging to get these kids thinking for themselves and to be persistent. I think they are going to struggle with that. And me [the teacher] leading the right discussions and me asking the right questions, to just give them that right little push. Help them discover things on their own. I think that will be challenging. (RL PD Interview, 20150914, Segment 15)

Her concern was about asking the right questions and leading the students. She seemed to be concerned about the students ending up with the correct mathematics when the activity is done, but she also stated that she wanted the students to discover things on their own. It could be a dilemma if Ms. Lawrence wants the students to end up with correct mathematics while at the same time building personal understandings of mathematics.

5.4.4 Classroom Lessons and Use of Professional Development

5.4.4.1 Lesson One: Intended Curriculum

Ms. Lawrence planned to teach her first lesson aligned with the professional development in January, 2016 in an Algebra 1 class. The topic for the lesson was modeling a pattern using quadratic equations (RL Planning Interview, 20160107, Segment 1). The academic standard that would be addressed by the lesson was representing real-life situations using quadratic expressions (RL Planning Interview, 20160107, Segment 2). She felt that the lesson was aligned to the professional development because the activity was a mathematical task from the professional development and because she was including the practice standards (RL Planning Interview, 20160107, Segment 3).

Ms. Lawrence described what the students would be doing during the lesson.

> RL: They are going to be counting the boxes in the shape. … They are going to be drawing representations of the pattern as it continues. That is something that they are going to be doing. They are going to try and answer questions relative to the pattern once they kind of identify the pattern's quadratic expression. Then they are going to try and push that knowledge, so what would it be if there were this many squares? (RL Planning Interview, 20160107, Segment 4)

She planned to assess the students by checking them as they worked and helping them if they were stuck (RL Planning Interview, 20160107, Segment 5). The lesson occurred midway through a unit on quadratic expressions and equations (RL Planning Interview, 20160107, Segment 6). As mentioned earlier, she learned about this activity during the professional development, but she had not used this activity with students before (RL Planning Interview, 20160107, Segment 7).

5.4.4.2 Lesson One: Enacted Curriculum

The first lesson took place over two days. The first day was a full seventy-minute class period, and it took about twenty minutes on the second day to conclude the lesson. The lesson was referred to as the S-Pattern (Institute for Learning: Learning Research and Development Center, 2015) and involved writing algebraic expressions to represent the number of squares in each figure of a sequence using the figure number (see Figure 5.3). The lesson began on a Friday with Ms. Lawrence passing out worksheets and asking the students to get into pairs (RL Observation One, 20160108, 2:00, Page 1). She explained that the worksheet included a pattern, and the students needed to work in pairs to find answers to the questions about the pattern (RL Video Lesson One, 20160108, 0:00, Tape 2). Ms. Lawrence also said that she would help the students if they had questions (RL Video Lesson One, 20160108, 0:30, Tape 2).

The students read the questions on the worksheet and started describing different patterns that they saw in the picture. Students worked together to answer questions such as, “Describe a figure in the sequence that is larger than the 20th figure without drawing it.” and “Determine an equation for the total number of tiles in any figure in the sequence. Explain your equation and show how it relates to the visual diagram of the figures.” Students were observed asking their partners questions such as, “How do you explain that?” and justifying work such as, “It is *F – 1* because it is the fifth figure, but there are only four squares in the row” (RL Observation One, 20160108, 10:00 and 15:00, Page 1). When the students shared their patterns and solutions, they frequently asked each other if they understood. When students did not understand, they would ask for an explanation (RL Video Lesson One, 20160108, 26:00 to 27:00, Tape 2).

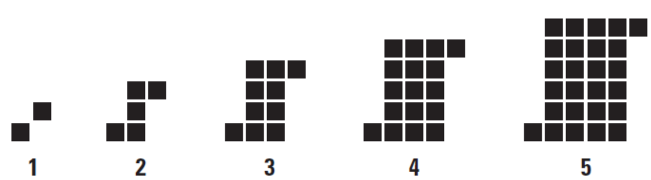

Figure 5.3 Sequence of Figures with an Increasing Number of Squares in a Pattern

The teacher walked around the room checking on the student work and asking questions such as, “Are there other ways to think about it?” (RL Observation One, 20160108, 10:00, Page 1). She encouraged the students to consider other students' patterns by asking questions such as, "You are doing different patterns. Are you noticing anything else?" (RL Observation One, 20160108, 34:00, Tape 2). Ms. Lawrence also probed for student understanding with questions such as, "Does the height change too? Can you relate it to that?" (RL Observation One, 20160108, 14:00, Page 1). In addition, it appeared that Ms. Lawrence avoided giving excessive guidance to the students. Instead she asked a few questions and then exited the groups leaving them with a question such as, "That is something to notice. Can you tell me more?" (RL Video Lesson One, 20160108, 2:30, Tape 2).

The groups worked on answering questions about the pattern for the total number of squares and representing the patterns algebraically until the end of the class. As the students left, Ms. Lawrence asked the students to complete the worksheet for homework.

The students returned on a Monday. Ms. Lawrence asked the students to get out the worksheet with the pattern task so they could go over it (RL Observation One, 20160108, 0:00, Page 2). As students were getting out their sheets, she looked over some of their work and asked the individual students questions such as, "I like this algebraic expression. Do you remember how you got it?" (RL Video Lesson One, 20160108, 0:30, Tape 4). Ms. Lawrence announced:

> RL: I have seen three or four or five solutions to this pattern from Friday. So I want a couple of the different groups to share the equation that they wrote for their pattern, and then I want to talk about where we saw these. Then, I want to compare these different representations that we have. (RL Video Lesson One, 20160108, 1:45 to 2:15, Tape 4)

Different students came up to the front of the class and shared the equations they created. They explained how they developed the parts of the equations based on the figures. For example, one student shared:

> Student 1: F is figure number and T is total squares. [Writes *T = (F – 1) (F + 1) + 2* on the board] (see Figure 5.4). If we talk about figure five, five would go where the F's are. [Draws a circle around the *4 × 6* rectangle in the middle of the picture, excluding the two individual squares on the top right and bottom left]. This is *F + 1* [points to the side with length 6] and this is four [points to the top with length 4] and five minus one is four. And you add these two [points to the two excluded individual squares] at the end. So it is 26 squares. Six times four is twenty-four and add two. (RL Video Lesson One, 20160108, 2:30 to 3:30, Tape 4)

Ms. Lawrence came to the front of the class and re-explained Student 1's equation to the class. She finished by asking the class, "Do you understand where [Student 1's] equation came from? You can know yours then try to understand somebody else's" (RL Video Lesson One, 20160108, 4:30, Tape 4).

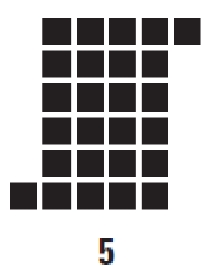

Figure 5.4 Growing Pattern Figure Five

A second student came to the front of the class to share the equation she created (RL Observation One, 20160108, 5:00 to 6:30, Page 2). Her equation was $T = (F \times 2) + (F - 1)(F - 1)$. She explained that the $F \times 2$ represented the number of squares in the top row and bottom row. The $(F - 1)(F - 1)$ represented the number of squares in the middle rows that formed the larger square. Ms. Lawrence came up and re-explained the second student's equation to the class (RL Observation One, 20160108, 6:30 to 7:00, Page 2).

Ms. Lawrence shared a third equation with the class (RL Observation One, 20160108, 7:00, Page 2). The equation was $T = (F + 1)(F + 1) - 2F$. She explained that students in the different class turned the figure into a large $(F + 1)$ by $(F + 1)$ square by adding F smaller squares to each side. The total number of squares was calculated by multiplying $(F + 1)(F + 1)$. The $2F$ added squares were subtracted to find the total number of squares in the figure.

After the different equations were shared, Ms. Lawrence demonstrated how to algebraically simplify each equation to $F^2 + 1$ (RL Observation One, 20160108, 11:00, Page 2). She told the students that she wanted them to see how the equations matched the figures and compare them to show that they were algebraically all the same.

For the final ten minutes on this activity, Ms. Lawrence led a discussion about whether or not the relationship between the figure number and the total number of tiles was linear. She explained that linear meant it increased by the same amount each time. She asked the students for the equation of a line and they replied $y = mx + b$ (RL Video Lesson One, 20160108, 17:00 to 18:00, Tape 4). Ms. Lawrence explained that the slope of the line (m) is the amount by which the line changes each time. She showed the class that the number of tiles did not change by the same amount, so it is not a linear relationship. Ms. Lawrence told the class that $F^2 + 1$ was a quadratic relationship because the F was squared (RL Observation One, 20160108, 18:00 to 19:00, Page 3).

5.4.4.3 Lesson One: Summary and Alignment to Professional Development

All of the SMPs were observed sometimes or throughout Ms. Lawrence's first lesson. The alignment with the mathematical practices was largely due to her use of a high-level mathematical task, providing opportunities for students to make sense of the problem, working in small groups, encouraging students to explain their thinking, and encouraging students to compare their solutions to other solutions. During the small group work students *made sense of the mathematical task and persevered in solving* it. Students *reasoned abstractly and quantitatively* when they developed an equation to represent the relationship between the figure number and the number of squares in each figure. Students *constructed viable arguments* and *attended to precision* during the small group and whole class discussions. They described patterns and developed algebraic relationships to answer the questions for the mathematical tasks. They also regularly explained their thinking to each other and clarified if ideas were unclear. Opportunities for students to *look for and make use of structure* were observed as the students manipulated the figures into sub-figures, represented the sub-figures with algebraic expressions, and compared the different algebraic equations.

There was some evidence of the students *modeling with mathematics* as they created equations to model situations and interpreted their results in context of the visual pattern. Students sometimes *used appropriate tools strategically* when they used calculators to check their computation and to justify answers to their partners. Ms.

Lawrence and the students *looked for and expressed regularity in repeated reasoning* when they examined patterns in the figures and discussed linear and quadratic relationships at the end in the whole class discussion.

Most of the MTPs were observed during this first lesson. Ms. Lawrence selected a mathematical task from the professional development and used pedagogical strategies that *promoted reasoning*, *problem solving,* and *productive struggle*. The students *connected mathematical representations* by creating algebraic equations to represent the relationship between figure number and number of squares. In some cases, students created data tables for the figures. Ms. Lawrence *facilitated meaningful mathematical discourse* by having the students work in pairs and asking them to explain patterns or solutions to their partners. She *posed purposeful questions* during the small group time when she asked questions such as, "Does this always work?" or "How do you know the equation matches the pattern?" (RL Observation One, 20160108, 36:00, Page 2)

Building procedural fluency from conceptual knowledge was sometimes evident when the students developed and redeveloped algebraic expressions to represent the pattern. There was also some evidence of Ms. Lawrence *eliciting and using evidence of student thinking*. She asked questions to learn about each student's current thinking during the small group work and she organized the whole class discussion around the different solutions.

5.4.4.4 Lesson Two: Intended Curriculum

Ms. Lawrence planned to teach her second lesson shortly after the first lesson later in January, 2016 with the same Algebra 1 class. The topic and academic standards for the lesson were writing linear, quadratic, and cubic algebraic expressions (RL Planning Interview, 20160112, Segment 1 and 2). She felt that the lesson was aligned to the professional development because the activity included algebraic habits of mind and productive struggle (RL Planning Interview, 20160112, Segment 3). Ms. Lawrence explained that the learning activities for the students would start with a discussion about faces, vertices, and edges of a cube. They would look at cubes of different sizes such as three by three by three and four by four by four and examine what the cubes would look like if they were painted on the surface. The students would record the number of unit cubes that had paint on one, two, three, or no sides for the different sized cubes. They would look for patterns in the numbers and write algebraic expressions to represent the patterns (RL Planning Interview, 20160112, Segment 4).

Ms. Lawrence expected her students to do well in this activity because she had recently done a similar activity (RL Planning Interview, 20160112, Segment 5). She did not have an assessment planned (RL Planning Interview, 20160112, Segment 6). The painted cube lesson was at the end of a unit on quadric expressions and equations (RL Planning Interview, 20150914, Segment 7). This was the first time she had taught this lesson (RL Planning Interview, 20150914, Segment 8).

5.4.4.5 Lesson Two: Enacted Curriculum

The second lesson took place over two class periods. The first class period was seventy minutes long. The second class period was about half of a seventy-minute class period. The mathematical task for this class was the painted cube problem (Lappan, Fitzgerald, & Fey, 2006), which was shared during the professional development. To start the lesson, Ms. Lawrence asked the students to get into small groups of two or three and passed out a worksheet and a data collection table (RL Observation Two, 20160115, 0:00 to 2:00, Page 1). The data collection table contained rows for different cubes with edge length of two, three, four, five, six, and *n* units. The columns of the table were for number of unit cubes painted on three, two, one, and zero faces. Ms. Lawrence read the instructions for the task and led a discussion about faces, edges, and vertices of a cube. She asked the students questions such as, “What is a face of a cube?” and “How many edges does a cube have?” (RL Observation Two, 20160115, 5:00 to 7:00, Page 1). During the discussion she used multi-link cubes to demonstrate the parts of a cube and what it would look like if a unit cube was painted on one, two, or three sides.

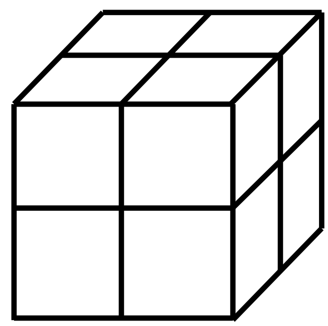

Figure 5.5 Cube with Edge Length Two Consisting of Eight Unit Cubes

The class discussed painting the outside of a large cube with edge-length two consisting of eight total unit cubes (see Figure 5.5). The students agreed that all eight of the unit cubes would be painted on three sides (RL Observation Two, 20160115, 8:00, Page 1). Ms. Lawrence showed the class how to fill in their data table for the cube with edge length two such that eight unit cubes would have paint on three faces, zero unit cubes would have paint on two faces, zero unit cubes would have paint on one face, and zero unit cubes would have paint on no faces (RL Observation Two, 20160115, 9:00, Page 1). She then led the class through completing the data table for a cube with edge length three.

Following the introduction, the students were told that they should complete the table for cubes with edge length four, five, six, and any length *n* (RL Observation Two, 20160115, 14:00, Page 1). The students used multi-link cubes to build models of the large cubes (RL Observation Two, 20160115, 17:00, Page 1). They worked in groups of two or three to complete the data collection table. Students asked questions such as, “Are there twenty-four cubes with one face painted?” and “Is it always times six?” (RL Observation Two, 20160115, 18:30, Page 1). They explained answers to their partners while pointing to models and counting cubes located in the correct positions for three, two, one, or zero faces painted.

Ms. Lawrence walked around the room checking on groups and answering students’ questions. She asked questions to encourage students to think about different ways to work on the problem such as, “Is there a faster way to find the number of cubes in the middle instead of adding nine and nine and nine?” or “Can you think about the cubes in groups?” (RL Observation Two, 20160115, 20:00, Page 1; RL Observation Two, 20160115, 5:00, Page 2). She also encouraged the students to share and understand different methods. For example, she said, “That is a nice way to count the cubes. Can you [different student in the group] count like that? I am going to have her share that with you” (RL Video Lesson Two, 20160115, 24:00, Tape 1). Ms. Lawrence also shared ideas to help the students find patterns for a cube with any unit length. For example, she told a student, “I want you to go back and see how you found these [the number of cubes with paint on one side]. That will help you see the pattern" (RL Video Lesson Two, 20160115, 26:00 to 26:30, Tape 1). She encouraged the students to find patterns and think about how the numbers related to the edge length of the cube. At the end of the first class period Ms. Lawrence announced that they would continue to work on the problem in the next class.

On the second day, there were five students who were absent on the first day and had not worked on the problem. Ms. Lawrence put the five absent students into groups with the returning students and told them that they needed to help catch the absent students up on the work that they had done to this point. Worksheets and multi-link cubes were passed out. Ms. Lawrence told the class that they needed to write algebraic equations for a cube with an edge length of n, make a graph for each of the equations, and be prepared to discuss their work with the whole class (RL Video Lesson One, 20160115, 2:00 to 3:00, Tape 3).

The students worked in small groups to find algebraic equations for the number of unit cubes that have paint on three, two, one, or zero sides in relationship to the edge-length of the cube. Returning students explained the task to the students who were absent the prior day (RL Observation Two, 20160115, 0:30 to 4:00, Page 3). Groups rebuilt cubes with edge length four or five to help the absent students understand how to complete the table. The returning students asked the absent students to explain their thinking as they learned how to work on the mathematical task asking questions such as, "How did you get twenty-four?" (RL Video Lesson Two, 20160115, 15:00 to 15:30, Tape 5). Students debated some of the patterns and algebraic equations they had found. Students made comments such as, "That number does not fit the pattern" (RL Video

Lesson Two, 20160115, 18:00, Tape 5). Some of the absent students appeared to be frustrated because they did not understand the mathematical task, and some of the returning students appeared to be frustrated because they had to explain rather than continuing to work on the algebraic equations. After about fifteen minutes, most of the absent students were able to work on the mathematical task based on the help provided by the returning students.

Ms. Lawrence walked around the room checking the work being done in the small groups (RL Observation Two, 20160115, 6:00, Page 3). Early in the class period, she focused her effort on helping the absent students understand the mathematical task. She continued to talk with students to help them think about patterns. Her comments included, “Go back and look at the numbers and see how you got the one face painted cubes.” and “Share the patterns you found so your partners understand” (RL Video Lesson One, 20160115, 18:30, Tape 5). Near the end of the small group work time, Ms. Lawrence invited different groups to write values from the table on the white-board in the front of the class for unit cubes with three, two, one, or zero painted faces.

The whole class discussion started with a student describing patterns she found with the numbers in the table for unit cubes painted on one face (see Figure 5.6). The student first explained that each of the numbers is a multiple of six. Zero is 6×0, six is 6×1, twenty-four is 6×4, fifty-four is 6×9, and ninety-six is 6×16 (RL Observation Two, 20160115, 12:30 to 13:30, Page 4). The student explained a pattern with the numbers being multiplied by six. She noted that from one to four increased by three, from four to nine increased by five, and from nine to sixteen increased by seven. Ms. Lawrence explained that the student noticed that each of those differences (three, five, and seven) increased by two (RL Video Lesson One, 20160115, 13:30 to 14:00, Tape 6). She told the students that if you keep taking the differences until you get the same difference, then you will know the degree of the polynomial. For example, the first set of differences was not the same, but the second set of differences was the same, so this was a second degree polynomial and should include a square in the algebraic equation. Ms. Lawrence told the class that the relationship between the edge length and unit cubes painted on two faces was linear and the relationship between the edge length and unit cubes painted on zero faces was cubic (RL Video Lesson One, 20160115, 16:00 to 19:00, Tape 6).

X	Y
Edge length of large cube	Unit cubes painted on 1 face
2	0
3	6
4	24
5	54
6	96
n	$(n-2)^2 \times 6$

Figure 5.6 Table Completed by Student Comparing Edge Length of Large Cube and Number of Unit Cubes Painted on One Face

With about five minutes left in class, Ms. Lawrence asked each group to make a graph of each relationship: three; two; one; and zero faces (RL Observation Two, 20160115, 23:00, Page 4). A few students were confused about whether to put the edge length or the number of unit cubes with paint on the horizontal or the vertical axis. Ms. Lawrence walked around the room and answered questions to help each group start making the graphs. She encouraged students to think about the scale they would need to use so their data would fit on the graphs (RL Observation Two, 20160115, 24:00, Page 4). At the end, she announced that they would finish making the graphs the next day.

5.4.4.6 Lesson Two: Summary and Alignment to Professional Development

All of the CCSSM practice standards were observed during Ms. Lawrence's second lesson. Five were observed throughout the lesson and three were observed sometimes during the lesson. The students were given a task and allowed to work in small groups to *make sense of the problem and persevere to solve it*. The students *reasoned abstractly and quantitatively* when they developed algebraic equations for the relationships between edge length of the large cube and the number of unit cubes with three, two, one, or zero faces painted. They also *reasoned abstractly and quantitatively* when they considered relationships between the number patterns and the degrees of the polynomials. Students *modeled with mathematics* by creating data tables, algebraic equations, and graphs from the cube models. Students *used appropriate tools* such as multi-link cubes and calculators to investigate the relationships and check work. They also had opportunities to *look for and make use of structure* by using the algebraic equations to represent mathematical relationships they found with the cubes.

There was some evidence of the students *constructing viable arguments and critiquing the reasoning of others* during the small group work. They clarified terminology, justified the number of unit cubes in the data tables, and explained how the algebraic equations were created in relationship to the physical properties of the large cubes. Some opportunities to argue and critique were minimized by the teacher when she told the students about the patterns at the end of the class. The students also had some opportunities to *look for and express regularity in repeated reasoning* when analyzing number patterns in the data tables.

The second lesson included most of the MTPs. There was evidence of Ms. Lawrence *promoting reasoning and problem solving* by using a higher-level mathematical task and allowing the students to work in small groups to make sense of the problem. She also provided opportunities for the students to *connect mathematical representations* as they created models, completed data tables, wrote algebraic equations, and graphed the relationships. The students negotiated an understanding of these relationships during the small group and whole class discussions. Ms. Lawrence was observed *posing purposeful questions* throughout the lesson asking questions such as, “Tell me your thinking about that,” and “How did you get twenty-four here?” (RL Observation Two, 20150918, 0:00, Page 2). She *supported productive struggle* by having the students work in small groups, expecting students to explain their thinking to others, and encouraging students to understand solutions shared by other students.

During the observation, there was some evidence that Ms. Lawrence *facilitated meaningful mathematical discourse* between the students when they were working in small groups. This occurred when she asked the students to explain their thinking to each other and when the returning students explained the task to the absent students. There was some evidence of *building procedural fluency from conceptual knowledge* when the students used algebraic equations to represent the number of unit cubes with paint on three, two, one, or zero sides. *Eliciting and using evidence of student thinking* was observed sometimes when Ms. Lawrence circulated between the groups and asked questions about their progress. If several groups had a similar question she would make an announcement to the class with a question to help the class. She also managed the whole class discussion by inviting students who had different solutions to share.

5.4.5 Summary, Ruth Lawrence

Ruth Lawrence was an experienced teacher who had not participated in large amounts of professional development activities prior to TAPS, possibly due to a lack of support from the school. Her attitude towards mathematics instruction was consistent with standards-based practices, especially with providing student-centered mathematics instruction, teaching fewer mathematical topics, and including problem solving as a central feature. When asked about her classroom, Ms. Lawrence felt that she had control over some aspects of mathematics teaching including selecting instructional materials and determining the amount of homework to be assigned. Her perception trended towards less control on items such as selecting content and topics to be taught and selecting teaching methods at the end of the school year. Her perceptions about administrative support tended to decline and her perceptions about teachers moved toward neutral by the end of the school year.

Ms. Lawrence interpreted the goals for the professional development as providing the teachers with mathematically rich tasks and teaching them about including practice standards during teaching. There were three ideas from the professional development that were useful in her class: providing activities; using standards-based instruction to improve student understanding of mathematical content; and having the students work in small groups. She said that she was challenged to use ideas from the professional development because the some of the content from the professional development was focused on classes that she did not teach, and she was worried about leading discussions and asking appropriate questions to help her students.

Many of the practice standards were observed in the lessons taught by Ms. Lawrence. Nine practice standards were observed throughout the first lesson and six of the practice standards were observed sometimes. The second lesson included ten of the practice standards throughout and five of the practice standards sometimes. There were seven practice standards observed throughout both lessons including: *making sense of problem and persevering in solving; reasoning abstractly and quantitatively; looking for and making use of structure; implementing tasks that promote reasoning and problem solving; using and connecting mathematical representations; posing purposeful questions;* and *supporting productive struggle in learning mathematics*.

The alignment with the mathematical practices was largely due to Ms. Lawrence's use of high-level mathematical tasks, providing opportunities for students to make sense of the problem, working in small groups, encouraging students to explain their thinking, and encouraging students to compare their solutions to other solutions. Factors that likely influenced her use of ideas from the professional development included her goal to use mathematically rich tasks and process standards in her class. Her goal to include mathematical tasks and practice standards from the professional development appeared to be a strong influence on the lessons, since both lessons were taught using mathematical tasks from the professional development summer institute, and since she was observed utilizing many of the practice standards.

CHAPTER 6. THEMES, CONCLUSIONS, AND DISCUSSION

6.1 Common Themes

All four teachers had different backgrounds, different interpretations of the goals of the professional development, and used the practice standards with different frequencies in the observed lessons. At the same time, some common themes provided insight to how interpretations of professional development goals and context factors influence mathematics instruction.

One common theme was that all sixteen practice standards were observed through the eight observed lessons, but some practice standards were more evident than others (see Table 6.1). The practice standards that were observed most frequently were m*aking sense of problems and persevering in solving them, attending to precision, implementing tasks that promote reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse*, and *supporting productive struggle in learning mathematics*. Many frequently observed practice standards were emphasized during the professional development summer institute. The least frequently observed practice standards were *modeling with mathematics, looking for and expressing regularity in repeated reasoning, establishing mathematics goals to focus learning,* and *eliciting and using evidence of student thinking*. All of the practice standards were discussed during the professional development summer institute and follow-up sessions, but less time was spent on some standards such as establishing mathematics goals and expressing regularity and repeated reasoning.

Table 6.1 Observation Frequency of Practice Standards

	Observation Frequency		
CCSSM Standards for Mathematical Practice	Yes	Some	No
1. Make sense of problems and persevere in solving	7+	0	1
2. Reason abstractly and quantitatively	2	5	1
3. Construct viable arguments and critique the reasoning of others	4	3	1
4. Model with mathematics	2~	3	3
5. Use appropriate tools strategically	3	3	2
6. Attend to precision	5+	3	0
7. Look for and make use of structure	3	1	4
8. Look for and express regularity in repeated reasoning	2~	3	3
NCTM Mathematics Teaching Practices			
1. Establish mathematics goals to focus learning	0~	3	5
2. Implement tasks that promote reasoning and problem solving	7+	1	0
3. Use and connect mathematical representations	5+	1	2
4. Facilitate meaningful mathematical discourse	5+	2	1
5. Pose purposeful questions	4	2	2
6. Build procedural fluency from conceptual understanding	1	6	1
7. Support productive struggle in learning mathematics	7+	1	0
8. Elicit and use evidence of student thinking	0~	5	3
+ Observed frequently ~ Observed infrequently			

A second common theme was that each of the teachers maintained or increased the number of observed practice standards from the first observation to the second observation. In Doug Collins's first lesson, five practice standards were observed throughout and three practice standards were observed sometimes. In his second lesson, six practice standards were observed throughout, and seven were observed sometimes. Kathy Gibson exhibited three additional practice standards throughout her second lesson, but there was one fewer practice standard observed sometimes. Laura Henderson showed an increase in the use of practice standards, going from one practice standard throughout and six sometimes in the first lesson to seven practice standards throughout and four sometimes. Ruth Lawrence used the practice standards consistently since nine practice standards were observed throughout and six sometimes in her first lesson and ten throughout and five sometimes in her second lesson (see Table 6.2).

Table 6.2 Practice Standards Observed for Each Lesson

	Observation Frequency			Change in Use of Practice Standards
Teacher and Lesson #	Yes	Sometimes	No	
D. Collins lesson 1	5	3	8	
D. Collins lesson 2	6	7	3	Increase
K. Gibson lesson 1	8	6	2	
K. Gibson lesson 2	11	5	0	Increase
L. Henderson lesson 1	1	6	9	
L. Henderson lesson 2	7	4	5	Increase
R. Lawrence lesson 1	9	6	1	
R. Lawrence lesson 2	10	5	1	Consistent

A third common theme was the four elements of the professional development that the teachers identified as positive outcomes. These four elements were learning about mathematical tasks that could be used in the classroom, strategies for small group work, including the practice standards during instruction, and perceiving that students would learn content better through standards-based instruction. These four elements addressed curricular, pedagogical, and outcome needs of the teachers as described by Ball (1996) and Loucks-Horsley et al. (2010) because teachers were provided tools and support to plan for and enact the use of practice standards during instruction.

A fourth common theme was the intended and enacted curriculum features selected by the teachers that supported the use of practice standards. The common features among the four teachers that supported addressing practice standards during instruction were the use of mathematical tasks, providing opportunities for students to make sense of the problem, having students work in small groups, and encouraging students to compare and explain different solutions to each other. For example, when the teachers used higher-level mathematical tasks in their lessons, practice standards were commonly observed such as *make sense of problems and persevere, implement tasks that promote reasoning and problem solving,* and *build procedural fluency from conceptual understanding*. Teachers' planning for the students to work in small groups helped support *constructing viable arguments, critiquing the reasoning of others,* and *facilitating meaningful mathematical discourse*. This does not imply that using a mathematical task or putting students into small groups automatically addresses the mentioned practice standards, but these intended and enacted curriculum features were used by the four teachers to address practice standards during instruction.

A fifth common theme was that the teachers participating in the professional development felt that they had control over most aspects of their classroom such as selecting instructional materials, selecting teaching methods, and evaluating students. A sense of control could be due to educational policies, teacher evaluation programs, administrative requirements, perceptions of students, or general community support. More investigation is needed to understand the meaning of classroom control and how it influences the intended and enacted curriculum. Additionally, it would be interesting to conduct a similar study with a group of teachers who did not feel that they had control over aspects of their class to see if fewer professional development outcomes were evident.

A sixth common theme was the limited number of context factors that the teachers identified during the interviews. I expected to hear several comments from the teachers describing challenges with using the professional development such as limited time, lack of support from a variety of sources, or misalignment of the professional development goals and the teacher evaluation program. Factors such as these were rarely mentioned. One explanation for the limited number of context factors identified by the teachers could be that all four teachers perceived control over their classrooms, and they did not feel that outside factors influenced their pedagogical decisions. A second explanation could be that the interview questions were not adequate for encouraging the teachers to share this information.

A seventh common theme was limited change with each teacher's attitude towards standards-based instruction after one year of professional development. Table 6.3 provides a summary of the number of standards-based mathematics instruction items that each teacher was consistent with, had no opinion on, or was inconsistent with. For example, Laura Henderson was consistent with ten items that described standards-based mathematics instruction, had no opinion on six items, disagreed with one item, and her responses varied on one item during the school year. At the end of the year, she was consistent with eleven items, no opinion on six items, and disagreed with one item. Based on a comparison of the responses during the year, with the final responses at the end of the year, changes in attitude towards standards-based mathematics instruction were limited.

Table 6.3 Attitude towards Standards-Based Mathematics Instruction

Teacher and Time of Year	Number of Items and Relationship to Standards-Based Instruction			
	Consistent	No Opinion	Disagree	Varied
D. Collins during school year	7	5	4	2
D. Collins end of school year	7	6	5	NA
K. Gibson during school year	7	5	3	3
K. Gibson end of school year	9	5	4	NA
L. Henderson during school year	10	6	1	1
L. Henderson end of school year	11	6	1	NA
R. Lawrence during school year	11	1	2	4
R. Lawrence end of school year	14	2	2	NA

6.2 Conclusions

In this research, I examined teachers’ interpretations of the goals of a professional development program for mathematics and how those interpretations and other context factors influenced the intended and enacted curriculum. The research questions investigated in this study were:

1. What are the teachers’ interpretations of the goals of a K-12 professional development program for mathematics?
2. How do context factors and interpretations of professional development goals influence the intended curriculum and enacted curriculum of mathematics lessons when the intent is to incorporate goals from the professional development program?

There were two goals for the professional development program in this research. The first goal was to enrich teachers' knowledge and skills for teaching algebra. This would be accomplished by engaging the teachers in solving algebra tasks to enhance algebraic understanding and habits of mind, developing activities for each teacher’s classroom that would address practice standards for mathematics, enacting research-based pedagogical strategies within a system of structured reflection and feedback, and participating in a collaborative action research project. The second goal was to improve students' algebraic knowledge, algebraic skills, and disposition toward algebra. This goal included building upon students' prior knowledge, engaging students in solving rich algebra tasks to enhance algebraic understanding, providing opportunities for students to make meaning of algebra, and improving students' performance on standardized and class-level assessments and motivation to engage with algebraic concepts.

6.2.1 Teachers' Interpretations of the Professional Development Goals

When the teachers were asked to describe the goals of the professional development in their own words, each teacher provided a concise goal that was consistent with the professional development goals, but often focused on one of the objectives aligned to the goals. Doug Collins identified the goal of the professional development as improving student scores on the state accountability and graduation exam. This description aligned with the program's second goal and improving students' performance on standardized and class-level assessments. Kathy Gibson described her personal goal as getting more activities to use in her class with higher depth of knowledge questions. She described a goal different from Doug Collins, but consistent with the first goal of the professional development and the objective to develop algebra activities that would address practice standards. Laura Henderson's interpretation of the goals was to align the practice standards and the content standards in order to improve her algebra class. Her goal included objectives from the first and the second professional development goals: developing algebra activities that would address practice standards and engaging students in solving rich algebra tasks to enhance understanding. Finally, Ruth Lawrence interpreted the goals of the professional development as exposing the teachers to mathematical tasks and using the practice standards with the content standards throughout the school year. Her interpretation was aligned with the first goal and the objective to develop activities that would address practice standards for mathematics.

A key to the consistency between the teachers' interpretations of the goals and the actual professional development goals was the use of the two sets of practice standards for mathematics as an organizing theme. The professional development facilitators included active learning opportunities for the teachers to build an understanding of the process standards and how they could be enacted in a classroom. At the same time, each teacher had a particular interpretation of the goals. They interpreted the goals to address a need that he or she had for his or her class.

6.2.2 Influence of Teachers' Interpretations on Intended and Enacted Instruction

The teachers' interpretations of the goals influenced their intended and enacted curriculum when trying to teach a lesson that incorporated ideas from the professional development. Ruth Lawrence and Kathy Gibson were examples of this. Ruth Lawrence's goal to include mathematical tasks and practice standards from the professional development was a strong influence on the decisions she made when planning and teaching her lessons. They started with her choice to use mathematical tasks from the professional development for each of her lessons. In addition, her intended and enacted use of instructional strategies such as providing opportunities for students to make sense of the problem, working in small groups, encouraging students to explain their thinking, and encouraging students to compare their solutions reflects her goal to include practice standards in her lessons. Kathy Gibson's goal to include higher depth of knowledge questions influenced her planning and teaching as well. The influence of including practice standards in the intended curriculum was evident when she was asked about the standards that would be addressed in her lesson and she replied, "Standard one, make sense of problems and persevere in solving them and standard three, construct viable arguments and critique the reasoning of others" (KG PD Interview, 20160210, Segment 2). There was also evidence of Ms. Gibson's goal to use higher depth of knowledge questions during instruction. During the observations she *posed purposeful questions* and *facilitated meaningful mathematical discourse*. The students *constructed viable arguments* and *critiqued the reasoning of others*. Each of these practice standards is consistent with using higher depth of knowledge questions.

Similarly, there was evidence that Doug Collins's interpretation of the professional development goals influenced his intended and enacted curriculum. He described the goal of the professional development as helping him improve student scores on the state accountability exams. Both observed lessons were reinforcement or extension activities where students applied learned content before an upcoming unit test. Laura Henderson's interpretation of the goal of the professional development was to align practice standards with content standards and improve her algebra class. Her interpretation influenced her lessons in two ways. First, her perception of aligning the practice standards with the mathematics content standards to enrich her class was observed when she incorporated practice standards such as productive struggle and attending to precision with activities about order of operations and bivariate data. Second, each lesson was an enrichment activity after she taught the content and basic skills the students would need to work on the mathematical tasks.

6.2.3 Other Context Factors Influencing the Use of Professional Development

The perception of classroom control (Supovitz & Turner, 2000) was likely a context factor that supported the use of practice standards by the teacher during instruction. If a teacher perceives that he or she has control over aspects of his or her classroom, then the teacher is likely to feel capable of attempting new ideas during instruction. It appeared that teachers in this research felt free to select and apply ideas from the professional development in their classrooms as desired. This was consistent with the fact that all four teachers responded “no” when they were asked if they anticipated anything that would limit their ability to use the professional development or if there was anything from the professional development that they wanted to include, but could not (DC PD Interview, 20150915, Segment 15; KG Post Lesson Interview, 20150929, Segment 12; KG Post Lesson Interview, 20160301, Segment 11; LH Post Lesson Interview, 20151001, Segment 12; LH Post Lesson Interview, 20160509, Segment 11; RL Post Lesson Interview, 20160112, Segment 13; and RL Post Lesson Interview, 20160122, Segment 11).

Attitude towards standards-based instruction may have been a context factor, but may not have been a determining factor. Laura Henderson and Ruth Lawrence had attitudes consistent with standards-based mathematics instruction, with more responses agreeing than no opinion or disagreement (see Table 6.3). Doug Collins and Kathy Gibson had somewhat mixed attitudes about standards-based mathematics instruction with similar numbers of agreement, no opinion, and disagreement on the responses. In comparison, Kathy Gibson and Ruth Lawrence exhibited a larger number of practice standards and Doug Collins and Laura Henderson exhibited fewer practice standards (see Table 6.2). This conclusion is different from Supovitz and Turner (2000), who found that the strongest influences on teaching practices were teachers' content preparation and attitudes towards reform. This difference could be because the Supovitz and Turner (2000) study was a statistical analysis of self-reported data from three hundred teachers, whereas this is a multiple-case study of four teachers.

Two additional context factors were identified when the teachers were asked about challenges with using ideas from the professional development. One factor was that the lessons from the professional development were not useful when they focused on a different grade level or course. The second factor was that the teachers did not feel that their students would be successful in a class using ideas from the professional development because the students were inexperienced with standards-based instruction. These are professional development features that relate to addressing the learning needs of students and teachers (Ball, 1996; Loucks-Horsley et al., 2010). Although the teachers identified these as challenges for using the professional development, there was evidence that they overcame the challenges by implementing practice standards in their classroom using activities from the program or teacher modified activities.

6.2.4 Updated Model of the Relationship between Professional Development, Curriculum, and Student Learning

Five context factors that influenced curriculum use have been presented: teachers' interpretations of the goals of professional development; perceptions of classroom control; attitude towards standards-based instructional practices; teacher perceptions that students will be unable to participate in a standards-based mathematics class; and professional development activities being grade level or course appropriate. All five of the context factors can influence the intended and enacted curriculum, so they were added to the model as explanations for transformations (see Figure 6.1).

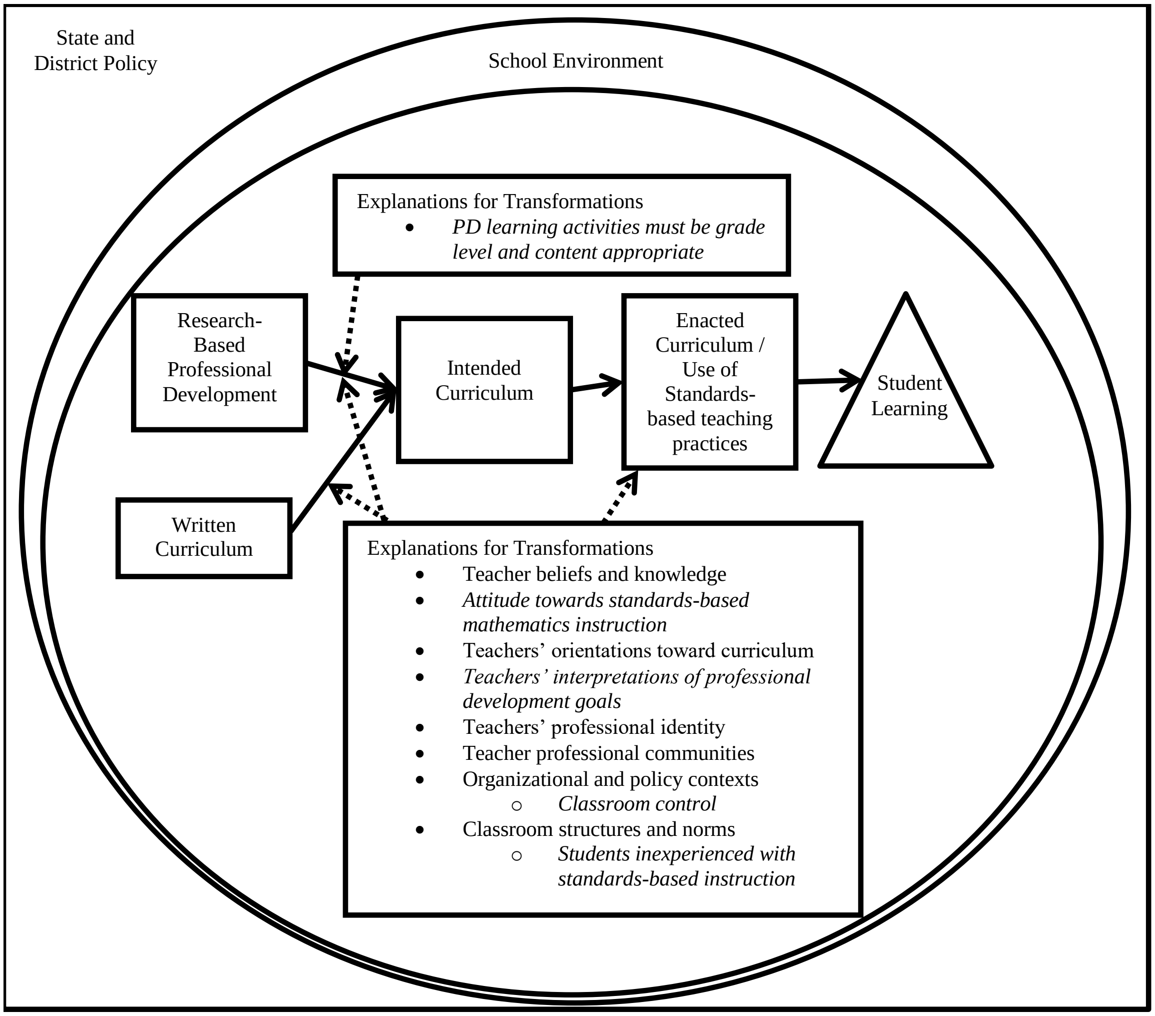

Figure 6.1 Updated Model Depicting a Theoretical Relationship between Professional Development and Student Learning Incorporating the *Temporal Phases of Curriculum Use*

Teachers' interpretations of the goals of professional development influenced the intended and enacted curriculum for all four teachers in this research. The teachers tended to interpret the goals in a narrow way, focusing on one or two of the objectives that would address a need their classes. In each case, their interpretations influenced their planning and observed features of the enacted curriculum.

Perception of classroom control was added as a component of organizational and policy contexts. Sense of control is related to the organizational culture of the school as a workplace and is influenced by educational policies and support from the educational community (Loucks-Horsley et al., 2010; Shafer, Davis, et al., 1997c). A perception of control can support and a perception of no control can discourage teachers with trying new standards-based strategies during the intended and enacted curriculum.

Attitude towards standards-based mathematics instruction was added as an explanation for transformation similar to teacher beliefs and knowledge and teachers' orientations toward curriculum, but distinct from the two. Teachers' beliefs and knowledge focus on teachers' ideas about mathematics and how it is learned (Remillard, 1999) along with their knowledge of content, pedagogy, and pedagogical content (Shulman, 1986). Teachers' orientations toward curriculum includes "views of the particular curriculum, the extent to which it matched their own ideas about mathematics, and their stance toward curriculum materials in general" (Remillard & Bryans, 2004, p. 364). Attitude towards standards-based instructional practices is similar to productive and unproductive beliefs about teaching and learning mathematics (NCTM, 2014). For example, a teacher may agree that mathematics is an interconnected logical system that is dynamic and changes, but may also agree that mathematics learning should focus on practicing procedures and memorizing basic number combinations.

The teachers' perception that students would be inexperienced with participation in a standards-based mathematics class was added as a component of classroom structures and norms. Since classroom norms influence participation in a class (Stein et al., 2007; Yackel & Cobb, 1996), students inexperienced with norms for standards-based instruction could influence their participation in a standards-based mathematics class. Three of the four participating teachers identified lack of experience in a standards-based class as a challenge for using ideas from the professional development during the interviews. As noted earlier, the teachers overcame this challenge by implementing practice standards in their classroom. Professional development work needs to provide strategies for teachers to create a classroom environment that will support students learning about and participating in standards-based instruction.

Finally, professional development activities being grade level or course appropriate was added as a transformation between research-based professional development and the intended curriculum. When the teachers felt that an activity used in the professional development was not aligned with the grade level or courses they taught, they were quick to identify it as not useful and dismiss it. Once the activity was dismissed, it would have little or no influence on any transformations beyond the intended curriculum.

6.3 Implications for Professional Development for K-12 Teachers of Mathematics

The findings of this research have implications for providers of professional development for K-12 teachers of mathematics. A first implication is that professional development providers need to spend time learning about teachers' interpretations of the goals of the professional development. This research found that each of the teachers interpreted the goals of the professional development in a different and narrower way than what was intended and presented by the professional development providers. Each teacher focused on objectives that addressed a perceived need for his or her class. The interpretations influenced the intended and enacted curriculum for each teacher. Spending time understanding and working on individual goals with teachers should influence the use of professional development ideas by teachers in the classroom.

A second implication is that professional development providers should use a framework of content to be learned that is aligned with the goals of a professional development program. In this research the professional development facilitators used the CCSSM SMPs and the NCTM MTPs as a content framework that was aligned to the goals of the professional development. The teachers learned about the practice standards and how they could be enacted in a mathematics classroom. Results were that all of the practice standards were observed to varying degrees in the first year.

A third implication is that learning activities and sample lessons need to be grade level or course appropriate. There are two reasons for this. First, when teachers identify an activity as not applicable for the grade-level or course they teach, they are likely to label it as not useful and dismiss it. Second, teachers can use grade level or course appropriate sample lessons in their classrooms following the professional development workshops. This is likely to help teachers use strategies from the professional development in their classrooms, especially in the first year.

6.4 Implications for Future Research

During this research, additional questions came up about the impact of professional development for mathematics teachers. The questions revolved around the circumstances of this research. I found that all four of the teachers felt that they had control over most aspects of their classroom and all four of the teachers had attitudes that were consistent with or mixed towards standards-based mathematics instruction. In addition, all four teachers taught in the same high school and volunteered to participate in the professional development. Further research on teachers who do not feel that they have control over aspects of their class, have inconsistent attitudes towards standards-based instruction, are participating in a mandatory professional development program, or teach in schools with different contexts would add additional information to these findings.

Second, this research would have benefitted from a survey to measure attitude towards standards-based mathematics instruction that was better aligned to the current practice standards identified by the CCSSM and the NCTM. The survey used was modified from surveys used by Shafer, Davis, et al. (1997c) and Supovitz and Turner (2000). These surveys were aligned with earlier visions of standards-based instruction (NCTM, 1989, 2000). The *Principles and Standards for School Mathematics* (NCTM, 2000) presented recommendations to help all students learn important mathematical concepts with understanding. *Principles and Standards* included problem solving, reasoning and proof, communication, connections, and representation as principles of high-quality mathematics education (c.f. NCTM, 2000, p. 11).The CCSSM (NGACBP & CCSSO, 2010) were designed to be more focused than previous academic standards for mathematics. Based on a concept of college and career readiness, they describe student proficiencies and teacher practices that support mathematical literacy for all students (NGACBP & CCSSO, 2010). The CCSSM include mathematical practices such as *looking for and making use of structure* or *attending to precision* which are different from the prior principles and were not well-aligned with the surveys used in this research. New surveys based on the CCSSM would provide better measures of attitude towards current definitions of standards-based mathematics instruction.

Third, the methodology of this research provided data about teachers' interpretations of the professional development and instructional practice. This is different from the methodology suggested by Sztajn (2006) to use a participation perspective to account for teacher learning and professional development impact. This does not suggest that the participation perspective is not an appropriate methodology. Rather, different research questions require different methodologies. In this research, the questions focused on the interpretations of the teachers, which necessitated an acquisition perspective (Sztajn, 2006). A participation perspective would be more appropriate when the research questions are about community changes that are evident.

Finally, it was found that each teacher's interpretation of the professional development goals was consistent with the actual professional development goals, but focused on one of the objectives. It is not clear if this was because of how the goals were shared during the professional development, if it was because the goals were already aligned to the needs of the school and the teachers, or if they aligned for other reasons. Since the teacher's interpretations of the goals were an influence on their instructional practice, additional research on why the interpretations were aligned to the program goals would add to the understanding about impact on classroom practices.

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APPENDICES

Appendix A Professional Development Data Collection Guide

Time (duration, span, organization)
Program goals
Strategies for a systemic approach (includes collective participation (Garet et al., 2001; Sztajn, 2011))
Participants' voice in decision making about the mathematics professional development
Theory of learning basis
Accounting for the contexts of teaching
Educational leadership (administrator support, administrator learning, developing teachers as educational leaders)
Continuous and ongoing support
Use of formative and summative assessment
Content focus on mathematics, student thinking, and/or curriculum materials
Specific mathematics content topic(s) addressed
Strategies used to address the learning of K-12 mathematics teachers
Description of artifacts and activities used in the professional development
Ethical decisions
Costs

Appendix B District Profile

District Profile

School District: ____________________

Academic Year: ____________________

Thank you for completing this survey. Your responses will help the researcher gain a clearer understanding of the districts that are participating in this study. We are particularly interested in characteristics of the school district that may influence the use of mathematics instruction as supported by the current professional development program. Please return the completed survey as soon as possible.

Name of the person completing this survey:

____

Last name First name MI

Position: ____

District Name: ____

<u>District</u>

Number of years current superintendent has held this position: ________________________

District Mission and/or Vision statement: ____

____

____

District improvement goals: ____

____

____

____

Any special district initiatives or programs? ____

____

Schools

Indicate the number of district schools in the following categories (specify the grades in the space provided):

	Number of Schools	Grade Range
Elementary		
Middle / Junior High		
High		

Special school initiatives, programs, or circumstances (STEM school, teaming, recent awards, Title I, etc.)? ____

____

____

____

Students

What is the total district student enrollment? ______________________________

Please indicate the percentage of the student population in the school district according to racial/ethnic categories and gender.

	Female	Male
American Indian		
Asian		
Black		
Hispanic		
Multiracial		
Native American or Pacific Islander		
White		
Other (please specify)		
Totals		

What percentage of the district's students in the most recent school year are **English Language Learners**? ____

What percentage of the district's students in the most recent school year participate in a **Free/Reduced Price Meal** program?______________________________________

What percentage of the district's students in the most recent school year participate in **Special Education**? ____

What was the **attendance rate** for students in the most recent school year?_____________

What was the **graduation rate** for students in the most recent school year?_____________

How many **attendance days** are there for students in the current school year? _______

What was the **passing rate** for state accountability testing in Mathematics, English/Language Arts (ELA), and both in the most recent school year?

Grade	Mathematics	ELA	Both
3			
4			
5			
6			
7			
8			
ECA			

What is the mathematics program for the school district? How was it chosen? How is it implemented? ____

____

____

____

Teachers

What is the total number of teachers in the school district? ___________________________

Please indicate the percentage of the teacher population in the school district according to racial/ ethnic categories and gender.

	Female	Male
American Indian		
Asian		
Black		
Hispanic		
Multiracial		
Native American or Pacific Islander		
White		
Other (please specify)		
Totals		

For each of the categories below, indicate the number of paid in-service training days for general professional development and mathematics teaching professional development in particular.

	Number of days for general professional development	Number of days for professional development related to mathematics teaching
Elementary		
Middle / Junior High		
High		

How many working days are there for teachers in the current school year? ____________

Describe briefly any specific state-mandated math requirements for preliminary teacher certification and how many math-related courses are required of practicing teachers as part of continuing education. ____

____

____

____

Describe briefly any specific district-mandated math requirement for preliminary teacher certification and how many math-related courses are required of practicing teachers as part of continuing education. ____

____

____

____

Adapted from:

Shafer, M.C., Davis, J., & Wagner, L. (1997). *District profile* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 13). Madison, WI: University of Wisconsin–Madison.

Appendix C School Profile

School Profile

School District: ___________________

Academic Year: ___________________

Thank you for completing this survey. Your responses will help the researcher gain a clearer understanding of the schools for the teachers that are participating in this study. We are particularly interested in characteristics of the school that may influence the use of mathematics instruction as supported by the current professional development program. Please return the completed survey as soon as possible.

Name of the person completing this survey:

____

Last name First name MI

Position: ____

District Name: ____

School Name: ____

School: General Information

Number of years current school principal has held this position: _____________________

Grades served by the school: ____

School Mission and/or Vision statement: ______________________________________

____

School improvement goals: ____

____

____

Any special district initiatives or programs? ___________________________________

____

Students

Please indicate the percentage of the student population in the school district according to racial/ ethnic categories and gender.

	Female	Male
American Indian		
Asian		
Black		
Hispanic		
Multiracial		
Native American or Pacific Islander		
White		
Other (please specify)		
Totals		

Indicate the student enrollment in the current year by grade level.

Grade level	Enrollment

What percentage of the school's students in the most recent school year are **English Language Learners**? ____

What percentage of the school's students in the most recent school year participate in a **Free/Reduced Price Meal** program?__________________________________

What percentage of the school's students in the most recent school year participate in **Special Education**? ____

What was the **attendance rate** for students in the most recent school year?__________

If high school, what was the **graduation rate** for students in the most recent school year?

How many **attendance days** are there for students in the current school year? _____

What was the **passing rate** for state accountability testing in Mathematics, English/Language Arts (ELA), and both in the most recent school year?

Grade	Mathematics	ELA	Both
3			
4			
5			
6			
7			
8			
ECA			

<u>Teachers</u>

What is the **total number of teachers** in the school district? ____________________

How many **working days** are there for teachers in the current school year?_____________

For the current school year, how many teachers in your school who are teaching mathematics are certified mathematics teachers? _________________________________

For the current school year, how many teachers in your school who are teaching mathematics are certified in an area other than math or have general teacher certification?

____

Please indicate the percentage of the teacher population in the school district according to racial/ ethnic categories and gender.

	Female	Male
American Indian		
Asian		
Black		
Hispanic		
Multiracial		
Native American or Pacific Islander		
White		
Other (please specify)		
Totals		

<u>School Mathematics Program</u>

How often does a math class meet per week?____

What is the typical length of a math class per meeting? ___________________________

What is the mathematics program for the school or school district? How was it chosen? How is it implemented? ____

____

____

____

____

____

Are there any particular activities related to the school mathematics program in which the parents participate (e.g., Family Math, in-class aides, tutoring, mentoring, guest speaking)? If so, please describe these activities.

____

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Adapted from:
Shafer, M. C., Davis, J., & Wagner, L. (1997). *School profile* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No 14). Madison, WI: University of Wisconsin–Madison.

Appendix D Teacher Background and Experience

Teacher Background and Experience

Teacher Code:

1. Gender (Circle one) Female Male

2. Which of the following describes you best? (Circle one)

American Indian	Asian	Black	Hispanic
Multiracial	Native Hawaiian or Pacific Islander		White

3. How many years of **full-time** teaching experience do you have? ____________

4. How many years of **part-time** teaching experience do you have? ____________

5. How many years of teaching experience do you have **at this school**? ____________

6. Which of the following describe your role at your school? (Circle all that apply)

Classroom teacher	Lead teacher	Mathematics specialist for the school
Mentor teacher	Department chair	Other (please specify): ________________

7. Please check the box(es) next to the degree(s) you hold. Write in your major and minor fields of study for each degree.

Degree	Major	Second Major or Minor	Number of Math Courses Taken
Bachelor's ☐			
Master's ☐			
Doctorate ☐			
Other credentials ☐	Please specify:		

8. What grade level(s) and/or courses are you currently teaching? ________________

9. What grade level(s) and/or courses have you taught? ________________________

Adapted from:
Shafer, M. C., Wagner, L. R., & Davis, J. (1997). *Teacher questionnaire: Background and experience* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 9). Madison, WI: University of Wisconsin.

Appendix E Teacher Professional Opportunities

Teacher Professional Opportunities

Teacher Code:

1. Which of the following have you read? (Circle all that apply)
    a. Your school district mathematics framework or curriculum guide
    b. Your state mathematics academic standards, framework, or curriculum guide
    c. *Curriculum and Evaluation Standards for School Mathematics* published by the National Council of Teachers of Mathematics (1989)
    d. *Principles and standards for school mathematics* published by the National Council of Teachers of Mathematics (2000)
    e. *Common Core State Standards for Mathematics* published by the National Governors Association Center for Best Practices and the Council of Chief State School Officers (2010)
    f. Journals specifically related to mathematics teaching and learning such as *Teaching Children Mathematics* (formerly *Arithmetic Teacher*), *Mathematics Teaching in the Middle School*, and *Mathematics Teacher*
    g. Journals related to teaching and learning in the elementary and middle school that are not specifically targeted for mathematics
2. During the past 12 months, how many college or university courses did you take? (Circle one)

    0 1 2 3 4 more than 4

3. During the last school year, how often did you do the following? (Circle one response for each statement)	
Activity statement	Number of times
a. Visit another teacher's classroom to observe and discuss his/her mathematics teaching	0 1 2 3-4 5-9 10+
b. Have another teacher observe your mathematics teaching	0 1 2 3-4 5-9 10+
c. Receive meaningful feedback on your mathematics teaching from peers or supervisors	0 1 2 3-4 5-9 10+
d. Participate in a group or network with other mathematics teachers outside of your school	0 1 2 3-4 5-9 10+

4. During the last school year, how often did you participate in formal meetings (e.g., department meetings) with other mathematics teachers in your school related to the following discussions? (Circle one for each statement)	
Activity statement	Number of times
a. The mathematics curriculum	0 1 2 3-4 5-9 10+
b. Mathematics teaching techniques and student activities	0 1 2 3-4 5-9 10+
c. Ideas for assessing student learning of mathematics	0 1 2 3-4 5-9 10+
d. Evaluation of your mathematics program	0 1 2 3-4 5-9 10+

5. What type of support did you receive for attending professional development meetings, workshops, and conferences? (Circle all that apply)
   a. None
   b. Release time from teaching
   c. Continuing Education Units
   d. Paid travel expenses
   e. Honorarium
   f. Other (Please specify): ___________________________________

6. During the contracted school week, how much planning time do you typically have?

   a. ____________ minutes/day
   b. ____________ minutes/week

7. How often do you spend at least 15 minutes (in formal or informal sessions) planning mathematics lessons, activities, assessments, etc., with other mathematics teachers per month? (Circle one)

   Number of days per month: 0 <1 1-3 4-6 > 6

8. When you plan mathematics lessons, activities, assessments, etc., with other mathematics teachers, when does this collaboration take place? (Circle one)
   a. Does not apply
   b. During formal meetings
   c. During contracted planning time
   d. After school on your own time

9. Answer the following questions for each topic in the left column: a. Have you participated in professional development activities during the past 18 months that have addressed that topic? If yes, please answer part b. b. Did that professional development activity lead to changes in your teaching of mathematics? If you agree or strongly agree, please answer part c. c. Did the changes in your teaching enhance your students' learning?									
	a. My professional development activities addressed this topic		b. My professional development on this topic led to changes in my teaching of mathematics				c. The changes inspired by this professional development activity were effective in facilitating/enhancing student learning.		
	Yes	No	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Effective	Moderately Effective	Not Effective
Core ideas of mathematics	Yes	No	SA	A	D	SD	VE	ME	NE
Techniques of classroom discourse	Yes	No	SA	A	D	SD	VE	ME	NE
Direct instruction	Yes	No	SA	A	D	SD	VE	ME	NE
Student reasoning	Yes	No	SA	A	D	SD	VE	ME	NE
Using on-going assessment to guide instruction	Yes	No	SA	A	D	SD	VE	ME	NE
Basing instructional practices on student knowledge	Yes	No	SA	A	D	SD	VE	ME	NE

10. In general, how would you characterize the support of your efforts to improve the mathematics program at your school? (Circle one)

    Strong opposition   Slight opposition   Slight support   Strong support

11. About what percent of the mathematics teachers at your school are involved in efforts to improve the mathematics program? ________________%

12. In a typical formal and informal meeting or planning session with other mathematics teachers, indicate the number of times you participated in each of the following types of discussion. (Circle one response for each statement)				
a. Decisions about concepts to be emphasized in instruction, guiding instruction, obtaining materials, or including related activities	Always	Frequently	Sometimes	Never
b. Teaching materials and activities	Always	Frequently	Sometimes	Never
c. Specific teaching techniques	Always	Frequently	Sometimes	Never
d. Assessment procedures that reveal how students understand mathematics	Always	Frequently	Sometimes	Never
e. Problems with specific students and arrangement of appropriate help for them	Always	Frequently	Sometimes	Never
f. Individual preparation of lessons, tests, or grades	Always	Frequently	Sometimes	Never
g. Develop course goals or objectives for mathematics	Always	Frequently	Sometimes	Never
h. Scheduling, student grouping, or planning group events or projects	Always	Frequently	Sometimes	Never
i. Sharing ideas about mathematics that are interesting to you as an adult	Always	Frequently	Sometimes	Never
j. Sharing stories about teaching experiences in mathematics	Always	Frequently	Sometimes	Never
k. Discussing something you have read from professional literature about mathematics	Always	Frequently	Sometimes	Never
l. Parent issues	Always	Frequently	Sometimes	Never
m. Other typical activity. Please describe.	Always	Frequently	Sometimes	Never

Adapted from:
Shafer, M. C., Davis, J., & Wagner, L. R. (1997). *Teacher questionnaire: Professional opportunities* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 11). Madison, WI: University of Wisconsin–Madison.

Appendix F Teacher School Context and Attitude towards Standards-Based Instruction

Teacher School Context and Attitude towards Standards-Based Instruction

Teacher Code:

1. At this school, how much actual influence do you think teachers have over school policy in each of the following areas? (Circle one response for each statement.)

	A great deal of influence				No influence
Making important educational decisions	5	4	3	2	1
Setting discipline policy	5	4	3	2	1
Establishing curriculum	5	4	3	2	1
Determining the content of professional development programs	5	4	3	2	1
Evaluating teachers	5	4	3	2	1
Hiring new full-time teachers	5	4	3	2	1
Deciding how the school budget will be spent	5	4	3	2	1

2. At this school, how much control do you feel you have in your classroom over each of the following areas of your planning and teaching? (Circle one response for each statement.)

	Complete control				No control
Selecting textbooks and other instructional materials	5	4	3	2	1
Selecting content, topics, and skills to be taught	5	4	3	2	1
Selecting teaching methods	5	4	3	2	1
Determining the amount of homework to be assigned	5	4	3	2	1
Evaluating and grading students	5	4	3	2	1
Disciplining students	5	4	3	2	1

3. Please indicate how strongly you agree or disagree with each of the following statements about your school. (Circle one response for each statement.)

	Strongly Agree	Agree	No opinion	Disagree	Strongly Disagree
The school administration lets staff members know what is expected of them.	5	4	3	2	1
The school administration is supportive and encouraging to the staff.	5	4	3	2	1
The school administration does a good job of obtaining resources for this school.	5	4	3	2	1
The school administration has a clear vision for the school and has communicated this to the staff.	5	4	3	2	1
There is a great deal of cooperative effort among the staff members at my school.	5	4	3	2	1
Teachers in this school are continually learning and seeking new ideas.	5	4	3	2	1
Staff members maintain high standards of performance for themselves.	5	4	3	2	1
Teachers in this school exhibit a focused commitment to student learning in mathematics.	5	4	3	2	1
A vision for student learning in mathematics is shared by most staff in this school.	5	4	3	2	1

4. To what extent has each of the following people helped you improve your teaching or solve an instructional or class management problem? (Circle one for each statement.)

	Extremely helpful				No help	Not applicable
Principal of this school	5	4	3	2	1	NA
Assistant/vice-principal	5	4	3	2	1	NA
School curriculum specialist	5	4	3	2	1	NA
District curriculum specialist	5	4	3	2	1	NA
Other teachers at this school	5	4	3	2	1	NA
Other teachers in the district	5	4	3	2	1	NA
University professors or researchers	5	4	3	2	1	NA
Other (Please specify)	5	4	3	2	1	NA

Support Environment

5. Please indicate how strongly you agree or disagree with each of the following statements about your school. (Circle one response for each statement.)

	Strongly Agree	Agree	No opinion	Disagree	Strongly Disagree
I feel supported by other teachers to try out new ideas in teaching mathematics.	5	4	3	2	1
The school administration talks with me frequently about my instructional practices.	5	4	3	2	1
I am encouraged by school administrators to try out new ideas in teaching mathematics.	5	4	3	2	1
The school administration encourages me to observe exemplary mathematics teachers.	5	4	3	2	1
The school administration enhances the mathematics program by providing me with the materials and equipment that I need.	5	4	3	2	1
The school administration encourages me to select mathematics content and instructional strategies that address individual students' learning.	5	4	3	2	1
The school administration accepts the noise that comes with an active classroom.	5	4	3	2	1
The school administration encourages the implementation of current national standards in mathematics education.	5	4	3	2	1
The school administration encourages teachers to focus on covering the mathematics content in the current state standards for mathematics education.	5	4	3	2	1
The school administration encourages the implementation of process standards in the current state standards for mathematics education.	5	4	3	2	1
The school administration encourages innovative instructional practices.	5	4	3	2	1

(Continued)
5. Please indicate how strongly you agree or disagree with each of the following statements about your school. (Circle one response for each statement.)

	Strongly Agree	Agree	No opinion	Disagree	Strongly Disagree
The school administration provides time for teachers to meet and share ideas with one another.	5	4	3	2	1
The school administration encourages teachers to make connections across disciplines.	5	4	3	2	1
The school administration acts as a buffer between teachers and external pressures.	5	4	3	2	1
The school administration encourages me to attend professional meetings to learn about innovative instructional practices in mathematics.	5	4	3	2	1

6. Consider the professional development climate in your school. How common is each of the following? (Circle one response for each statement.)

	Always	Very common	Somewhat common	Rarely	Never
When my school decides upon a change (e.g., in policy or in curriculum), the change is supported with professional development opportunities.	5	4	3	2	1
Most professional development at this school enables us to build on our teaching experience.	5	4	3	2	1
This school draws upon teachers' knowledge and practical experience as resources for professional development.	5	4	3	2	1
Teachers in this school help one another put new ideas from professional development activities to use.	5	4	3	2	1
Teachers are left completely on their own to seek out professional development opportunities.	5	4	3	2	1

Attitude Towards Standards-Based Instruction

7. Please indicate how strongly you agree or disagree with each of the following statements about mathematics teaching and learning. (Circle one response for each statement.)

	Strongly Agree	Agree	No opinion	Disagree	Strongly Disagree
Students learn best when they study mathematics in the context of everyday situations.	5	4	3	2	1
Students need to master basic computation facts and skills before they can engage effectively in studying more mathematics.	5	4	3	2	1
Students should write about how they solve mathematical problems.	5	4	3	2	1
Students learn mathematics best in classes where they are able to work in small groups.	5	4	3	2	1
If students use calculators, they won't learn the mathematics they need to know.	5	4	3	2	1
It is more important to cover fewer topics in greater depth than it is to cover the text.	5	4	3	2	1
In teaching mathematics, my primary goal is to help students master basic concepts and procedures.	5	4	3	2	1
Instruction should include step-by-step directions.	5	4	3	2	1
Teachers should plan instruction based upon their knowledge of their students' understanding.	5	4	3	2	1
Teachers should encourage children to find their own strategies to solve problems even if the strategies are inefficient.	5	4	3	2	1
Students must learn basic skills before they can be expected to analyze, compare, and generalize.	5	4	3	2	1
Instruction should include many open-ended tasks.	5	4	3	2	1

(Continued)

7. Please indicate how strongly you agree or disagree with each of the following statements about mathematics teaching and learning. (Circle one response for each statement.)

	Strongly Agree	Agree	No opinion	Disagree	Strongly Disagree
Students should learn mathematics through regularly discussing their ideas with other students.	5	4	3	2	1
More emphasis should be given to simple mental computation, estimation, and less emphasis to practicing lengthy pencil-and-paper calculation.	5	4	3	2	1
Mathematical problem solving should be a central feature of the elementary and middle school curriculum.	5	4	3	2	1
In my teaching I try to make connections among mathematical topics and between mathematics and other disciplines.	5	4	3	2	1
In my teaching I try to use thematic units focused on one or two mathematical ideas rather than daily lessons focused on individual topics	5	4	3	2	1
In my teaching I try to engage students in applications of mathematics in a variety of contexts	5	4	3	2	1

8. How well **prepared** do you feel to teach the mathematics content that you currently teach? (Circle one)

   Very well   Well   Moderately   Not well   Not at all

Adapted from:

Shafer, M. C., Davis, J., & Wagner, L. R. (1997). *Teacher questionnaire: School context* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 10). Madison, WI: University of Wisconsin–Madison.

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980.

Appendix G Teacher Interpretation of Professional Development Goals and Intended Curriculum

Teacher Interpretation of Professional Development Goals and Intended Curriculum

I will be asking you questions about the summer professional development workshop you just completed and how you will plan for your teaching. Please answer the following questions as truthfully as possible. There are no right or wrong answers to these questions. I am only interested in your opinions and ideas. Your responses will be audiotaped. Your responses will be kept confidential. Your responses will not be used to evaluate you in any way, and your name will not be mentioned in reports of this research. You may skip any questions you do not wish to answer.

1. In your own words, what are the goals for the mathematics PD that you are participating in?

2. What did you learn while participating in the mathematics PD?

3. Which part of the PD has been most useful and why?

4. Which part of the PD has been least useful and why?

5. Is the mathematics PD standards-based? If so, what does that mean to you?

6. Using Mathematical Tasks was an important idea in the PD. In your own words, what is a Mathematical Task? What are some identifying characteristics of a Mathematical Task (in other words, what helps you identify something as a Mathematical Task)?

7. How do you expect to use the mathematics PD when you plan mathematics units/chapters that you will teach this year?
    A. What will you take into consideration in your planning and how will it affect the planning?
    B. How do you anticipate upcoming planning to be different from your planning before you participated in the PD?
    C. Will you regularly work with anyone else when you plan?

8. Do you anticipate that teaching using the PD will be different than the way you taught in the past?
    A. For you as the teacher?
    B. For the students?
    C. For the classroom atmosphere?
    D. What advantages do you anticipate with teaching using the PD goals?
    E. Do you anticipate any disadvantages or challenges with teaching using the PD goals?

9. Do you anticipate anything that will limit your ability to use what you learned during the mathematics PD during the mathematics units/chapters that you will teach this year? If so, what are they and how will they limit the use?

Adapted from:
Shafer, M. C., Davis, J., & Wagner, L. R. (1998). *Teacher interview: Instructional planning and classroom interaction (Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 3). Madison, WI: University of Wisconsin–Madison.

Appendix H Teacher Planning and Intended Curriculum

Teacher Planning and Intended Curriculum

I will be asking you questions about how you plan for your teaching. I am also interested in how you plan to monitor student learning and how you expect students to contribute to classroom discussions. Please answer the following questions as truthfully as possible. There are no right or wrong answers to these questions. I am only interested in your opinions and ideas. Your responses will be audiotaped. Your responses will be kept confidential. Your responses will not be used to evaluate you in any way, and your name will not be mentioned in reports of this research. You may skip any questions you do not wish to answer.

1. In general, how do you plan for each mathematics unit/chapter that you teach?
   A. Which of these do you take into consideration in your planning? Explain how.
      i. Students' prior knowledge
      ii. Textbook scope and sequence
      iii. District curriculum scope and sequence
      iv. State standards
      v. District tests or other large-scale testing
      vi. Teacher evaluation program
      vii. Other resources
   B. How does the statewide testing program influence your instruction?
      i. Probe: Content selection
      ii. Probe: Time spent in preparation
      iii. Probe: Changes in instruction
   C. Do you plan with anyone?
   D. How do you set the pace for instruction?
   E. How is your planning for mathematics instruction different from your planning before you participated in the PD?

2. How do you plan for *individual* lessons?
   A. What considerations do you give in your planning to how students performed in previous lessons?
   B. Do you use examples or mathematical tasks in your lessons? If so, how do you select them and how are they used in the lessons?
   C. Do you work through the problems in the unit/chapter before teaching? How does this affect how you teach the lessons?

3. What has happened earlier in this school year that you are taking into consideration as you plan the upcoming mathematics lesson?

4. In what ways do students contribute to whole class discussions?
    A. In comparison to past mathematics instruction, how does student participation in discussions differ when using goals from PD?
        i. Type of answers and explanations
        ii. Type of conversation (e.g., conjectures, support for their reasoning)

5. Do you think it is valuable for students to work in small groups? Why?
    A. When is working in small groups useful?
    B. How do you plan for small group instruction?
    C. What type of grouping have you found to be the best for you and your students in terms of instruction (e.g., individual, occasional small groups, small groups that change over time, large group, etc.)?

6. Do you anticipate that teaching this lesson using the PD will be different than the way you taught in the past?
    A. For you as the teacher?
    B. For the students?
    C. For the classroom atmosphere?
    D. What advantages do you anticipate with teaching using the PD goals?
    E. Do you anticipate any disadvantages with teaching using the PD goals?

7. Do you anticipate anything that will limit your ability to execute this mathematics lesson? If so, what are they, how will they limit your ability to teach, and how will you address these limitations?

Adapted from:

Shafer, M. C., Davis, J., & Wagner, L. R. (1998). *Teacher interview: Instructional planning and classroom interaction (Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 3). Madison, WI: University of Wisconsin–Madison.

Shafer, M. C., Davis, J., & Wagner, L. R. (1997). *Teacher interview: Instructional planning and classroom interaction* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 4). Madison, WI: University of Wisconsin–Madison.

Appendix I Standards-Based Mathematics Instruction Observation Tool

Standards-Based Mathematics Instruction Observation Tool

Observer: ________________________ Time Lesson Begins/Ends: ________/_________

Teacher: _________________________ Duration of lesson: ________________________

School: __________________________ Textbook: _______________________________

Grade: ___________________________ Chapter/Unit: ____________________________

Date of Observation: _______________ Lesson (pages): ___________________________

BEFORE THE LESSON - Pre-Observation Conversation with Teacher

If possible, have a brief, informal conversation with the teacher prior to the lesson inquiring about:

1. What is the main topic and purpose of the lesson?

2. What academic standards will be addressed in this lesson?

3. What parts of the professional development are being used during this lesson?

4. What are the planned activities for student learning?

5. What are your expectations for the students?

6. What assessments do you have planned during the lesson (i.e. how will you know if the students understand the main concept)?

7. Where is the lesson situated within the unit?

8. Has the teacher taught this lesson before?

DURING THE LESSON
Use the lined sheets that follow for making detailed “lesson tape” notes. You will use these notes to summarize the observation and complete the remainder of this form.
Take notes describing the activities of the teacher and students occurring during the class period. Provide a time stamp in the “Time” column to correspond to the events. (Record a time stamp at least every 4 minutes.) Indicate use of any instructional materials (by teacher or student).

Line	Time	Event
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AFTER THE LESSON

After the lesson, please review your notes and respond to each of the following sections.

1. Describe the main activities that occurred during the class period and the amount of time devoted to each activity.

Example: Opening problem – 5 minutes
Review homework – 10 minutes
Instruction by teacher – 15 minutes
Group work – 10 minutes
Summary by teacher – 5 minutes
Students work individually on homework – 10 minutes

Activity	Time

2. What was the **primary mathematical focus** of the lesson (check the strand that best applies)?

   Strand: __ Number __ Geometry __ Algebra __ Statistics
   __ Probability __ Other

Topic or objective: ____

3. Which of the following **best describes the primary emphasis** of the lesson?

   __ procedures __ conceptual development __ problem solving/investigation
   __ Other (write below)

4. How was the class organized for the lesson?

   __ Whole class lecture ___ Whole class discussion ___ Small group
   __ Combination of whole class and small group ___ Individual work

5. In your opinion, to what extent did the district-adopted textbook influence the content and presentation of the lesson?

   Content: ___ A great deal ___ Somewhat ___ Very little ___ Not at all
   ___ Can't tell

   Presentation: ___ A great deal ___ Somewhat ___ Very little ___ Not at all
   ___ Can't tell

6. Classroom Events (CCSSM) (No Evidence, Sometimes, Yes)

A. The lesson provided opportunities for students to **make sense of problems and persevere in solving them**. **Supporting examples:**	NE S Y
B. The lesson provided opportunities for students to **reason abstractly and quantitatively**. **Supporting examples:**	NE S Y
C. The lesson provided opportunities for students to **construct viable arguments and critique the reasoning of others**. **Supporting examples:**	NE S Y
D. The lesson provided opportunities for students to **model with mathematics**. **Supporting examples:**	NE S Y
E. The lesson provided opportunities for students to **use appropriate tools strategically**. **Supporting examples:**	NE S Y
F.The lesson provided opportunities for students to **attend to precision**. **Supporting examples:**	NE S Y
G. The lesson provided opportunities for students to **look for and make use of structure**. **Supporting examples:**	NE S Y
H. The lesson provided opportunities for students to **look for and express regularity in repeated reasoning**. **Supporting examples:**	NE S Y

Overall rating

Provide a summary of the extent to which the teacher utilized NCTM "standards-based" instructional practices in teaching students in this lesson. Consider the following starters to create the description:

- The teacher did not utilize instructional practices consistent with standards-based instruction as described in the NCTM Standards documents.
- The teacher utilized a mixture of instructional practices including some elements of standards- based practices.
- The teacher consistently utilized instructional practices consistent with standards-based instruction as described in the NCTM Standards documents.

7. Classroom Events (Mathematics Teaching Practices, NCTM)

A. Establish mathematics goals to focus learning. **Supporting examples:**	NE S Y
B. Implement tasks that promote reasoning and problem solving. **Supporting examples:**	NE S Y
C. Use and connect mathematical representations. **Supporting examples:**	NE S Y
D. Facilitate meaningful mathematical discourse. **Supporting examples:**	NE S Y
E. Pose purposeful questions. **Supporting examples:**	NE S Y
F. Build procedural fluency from conceptual knowledge. **Supporting examples:**	NE S Y
G. Support productive struggle in learning mathematics. **Supporting examples:**	NE S Y
H. Elicit and use evidence of student thinking. **Supporting examples:**	NE S Y

Overall rating
Provide a summary of the extent to which the teacher utilized NCTM "standards-based" instructional practices in teaching students in this lesson. Consider the following starters to create the description:

- The teacher did not utilize instructional practices consistent with standards-based instruction as described in the NCTM Standards documents.
- The teacher utilized a mixture of instructional practices including some elements of standards- based practices.
- The teacher consistently utilized instructional practices consistent with standards-based instruction as described in the NCTM Standards documents.

Additional Information
Please feel free to add any comments or information that you think would be of relevant in describing the classroom that you observed (in particular, the use of textbook or other curriculum materials).

Adapted from:
Shafer, M. C., Wagner, L. R., & Davis, J. (1997). *Classroom observation scale* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 6). Madison, WI: University of Wisconsin.

Romberg, T. A. & Shafer, M. C. (2003). Mathematics in Context (MiC)-Preliminary evidence about student outcomes. In S. Senk & D. Thompson (Eds.) *Standards-based school mathematics curricula: What are they? What do students learn?* (p. 225-284). Mahwah, NJ: Lawrence Erlbaum Associates.

Appendix J Teacher Post-Observation and Enacted Curriculum

Teacher Post-Observation and Enacted Curriculum

I will be asking you questions about the lesson you recently taught. I am interested in how your instruction took place with respect to goals for the professional development program you are currently participating in. Please answer the following questions as truthfully as possible. There are no right or wrong answers to these questions. I am only interested in your opinions and ideas. Your responses will be audiotaped. Your responses will be kept confidential. Your responses will not be used to evaluate you in any way, and your name will not be mentioned in reports of this research. You may skip any questions you do not wish to answer.

1. Describe the lesson
   A. Please describe the content to be learned that you emphasized and any modifications you made in the lesson as compared to its presentation in the unit or chapter of the text.
   B. What was the role of the teacher during the lesson?
   C. What was the role of the students during the lesson?
   D. Were there any particular examples, problems, or aspects of the lesson that were emphasized and explain why they were emphasized?
   E. Were there any particular examples, problems, or aspects of the lesson that were deleted and explain why they were deleted?
   F. Were there any additional examples, activities, problems, or procedures that were included in the lesson and explain why they were added?
   G. What was the order of presentation of lesson activities and/or content as compared to its presentation in the unit or chapter?
      a. If you changed the order of presentation, please describe how it was changed and explain why.
   H. Did anything happen in the lesson that informed how you will plan or teach upcoming lessons?
   I. Were there any other changes, please describe?

2. How did the lesson compare to planning and professional development?
   A. What parts of the lesson were successful in relationship to how you planned?
   B. What did not work the way you planned?
   C. What aspects of PD did you incorporate into the lesson?
      a. Did the aspects of the PD help the success of the lesson?
      b. Did the aspects of the PD restrict the effectiveness of the lesson?
      c. Were there any aspects of the PD that you wanted to include, but could not? If so, what and why not?
   D. What parts of the lesson would you like to go in the same way next year?
   E. How would you teach this lesson differently next year?

3. Please describe any notable classroom event(s) related to the lesson.
   A. Did the lesson or part of the lesson go exceptionally well?
   B. Did something surprising occur?
   C. Was there an idea was particularly difficult for the students?
   D. Did the students seem to comprehend an idea that had previously been troublesome?
   E. Did any student misconceptions emerge?
   F. Did a student offer an unusual or unexpectedly sophisticated strategy?
   G. Did a student's question cause a modification in the lesson?
   H. Were there any other notable events, if so please describe?

4. Additional questions or discussion identified by the researcher specific to the observed lesson
   A. ____
   B. ____
   C. ____

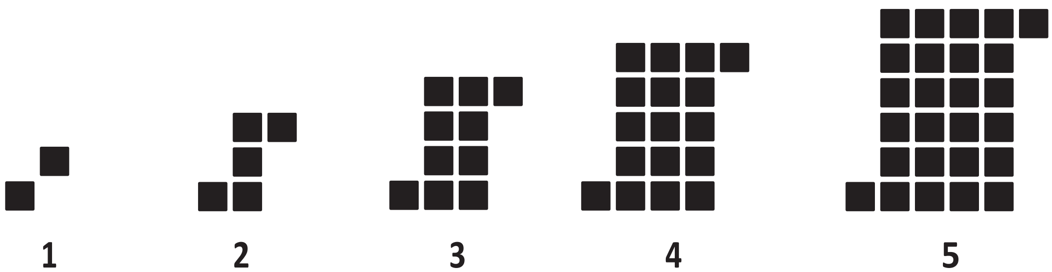
Adapted from:
Shafer, M. C., Wagner, L. R., & Davis, J. (1997). *Teaching log* (*Mathematics in Context* Longitudinal/Cross-Sectional Study Working Paper No. 5). Madison, WI: University of Wisconsin–Madison.

Appendix K Sample Mathematical Task from Professional Development

Name____Date__________________

TASK

S-Pattern Task[1]



1. What patterns do you notice in the set of figures?

2. Sketch the next two figures in the sequence.

[1] Adapted from Foreman, L.C. & Bennett, A.B., Jr. (1995). *Visual Mathematics: Course II, lessons 1-10*. Salem, OR: Math Learning Center.

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TASK

3. Describe a figure in the sequence that is larger than the 20th figure without drawing it.

4. Determine an equation for the total number of tiles in *any* figure in the sequence. Explain your equation and show how it relates to the visual diagram of the figures.

5. If you knew that a figure had 9802 tiles in it, how could you determine the figure number? Explain.

6. Is there a linear relationship between the figure number and the total number of tiles? Why or why not?

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VITA

VITA

WILLIAM S. WALKER, III

EDUCATION

Doctor of Philosophy in Mathematics Education. (2016, December). Purdue University, West Lafayette, Indiana.

Dissertation: Factors Influencing Teacher Instructional Practice in Mathematics when Participating in Professional Development

Master of Science in Mathematics Education. (1998, August). Purdue University, West Lafayette, Indiana.

Thesis: Creating a Problem-Solving Classroom at the Secondary Level.

Bachelor of Science in Mathematics. (1993, May). Purdue University, West Lafayette, Indiana.

WORK EXPERIENCE

Director, College of Science K-12 Outreach. (2004 – 2016). Purdue University.

Supervise Science Outreach program with 6 Outreach Coordinators utilizing approximately $1,000,000 per year to improve science and mathematics education. Collaborate with Purdue University faculty and staff on grant proposals and projects. Create measurement system and evaluation reports aligned to University strategic plan.

Senior Advisor, Indiana – Science, Engineering, Technology, and Mathematics Resource Network. (2013 – 2016). Purdue University. Advise a statewide resource network for K-12 STEM education in the areas of educational policy and K-12 teacher professional development. Host and participate in committees that advocate for and/or provide programming to improve K-12 STEM education in Indiana.

Executive Director, Indiana – Science, Engineering, Technology, and Mathematics Resource Network. (2007 – 2012). Purdue University. Initiated a statewide network with 11 regional lead institutions of higher education to facilitate regional and statewide improvement in K-12 STEM education. Developed a strategic plan aligned with national standards, research on effective STEM education reforms, and state visions for STEM education provided by the Office of the Governor of Indiana and the Indiana Department of Education. Co-convened a committee that created a series of credit courses to address needs in middle level mathematics. Provided leadership during the development of the Indiana Science Initiative that involved 130 schools representing 2,000 teachers and 53,000 students in systemic reform of K-8 science education. Helped to develop a webpage that will be a leading information source to students, parents, teachers, administrators, and higher education personnel in K-12 STEM education. Convened a policy committee representing key stakeholders in K-12 STEM education from higher education, K-12 education, business, government, and philanthropic organizations.

Mathematics Outreach Coordinator. (2003 – 2007). Purdue University**.** Created and provided professional development for K-12 teachers on content, standards, instructional strategies, technology integration, and preparing students for college.

Math Department Coordinator. (2002 – 2003). Benton Central Junior/Senior High School. Directed monthly math department meetings and revised course offerings and content to align with Indiana Mathematics Standards.

Secondary Mathematics Teacher. (1995 – 2003). Benton Central Junior/Senior High School. Taught Algebra I, Calculus, Geometry, Investigative Geometry, Pre-Algebra, Pre-Calculus, Problem Solving, Seventh Grade Math Enrichment, and Trigonometry.

Research Assistant. (1994 – 1995). Purdue University. Observed a third grade problem-centered mathematics classroom. Assisted in data analysis of classroom learning environment using a problem-centered curriculum. PI: Wood, T. *Recreating Teaching of Mathematics in the Elementary School*. (with Cennamo, K., & Lehman, J., 1994-1996) (with Lehman, J., & Warfield, J., 1997-1998), National Science Foundation, $859,370.

PUBLICATIONS

Walker, W. S., III, & Drnevich, V. P. (2016). Middle school students show math prowess in MATHCOUNTS competition. *Indiana Professional Engineer*, *79*(3), 8-9.

Chapman, C., Cook, N. D., **Walker, W. S., III.**, Sorge, B. H., & Weaver, G. C. (2015). Addressing science learning through science notebooks and discussion. *School Science and Mathematics*, Research to Practice Article.

Cook, N. D., **Walker, W. S., III.**, Weaver, G. C., & Sorge, B. H. (2015). The Indiana Science Initiative: Lessons from a classroom observation study. *School Science and Mathematics, 115*(7), 318-329.

Walker, W. S., III. (2015, Spring). Long-term partnerships with K-12 schools. *Insights,* 15.

Walker, W. S., III. (2009). Science's key role in launching tomorrow's leaders. *Insights, 5*(2), 37.

REPORTS AND SUMMARIES

Walker, W. S., III. (2015, December). *Purdue University College of Science academic year engagement report*. Unpublished manuscript, Purdue University.

Walker, W. S., III. (2014, December). *Purdue University College of Science academic year engagement report*. Unpublished manuscript, Purdue University.

Walker, W. S., III., & Sorge, B. H. (2012, December). *Indiana Science Initiative update: Student performance on state accountability testing from ten schools participating school-wide for two years*. Unpublished manuscript, Purdue University.

Walker, W. S., III., Hicks, J. L., & Sorge, B. H. (2012, July). *The Indiana Science Initiative: Goals, history, and moving forward*. Unpublished manuscript, Purdue University.

Evaluation Team of the Discovery Learning Research Center, **Walker, W. S., III.**, Sorge, B. H., Hicks, J. L., & Cook, N. D. (2012, January). *Evaluation of the Indiana –*

Science, Technology, Engineering, & Mathematics Network's science education project. Unpublished manuscript, Purdue University.

Walker, W. S., III. (2010). *College of Science K-12 Outreach annual report*. Unpublished manuscript, Purdue University.

Tyminski, A. M., **Walker, W. S., III.**, & Sorge, B. H. (2008, March). *Indiana – Science, Technology, Engineering, and Mathematics (I-STEM) Resource Network Middle Level Mathematics Initiative: Evaluation – Fall 2007*. Unpublished manuscript, Purdue University.

Walker, W. S., III. (2008). *College of Science K-12 Outreach annual report*. Unpublished manuscript, Purdue University.

Walker, W. S., III. (2007). *College of Science K-12 Outreach annual report*. Unpublished manuscript, Purdue University.

Walker, W. S., III. (2006). *College of Science K-12 Outreach annual report*. Unpublished manuscript, Purdue University.

Walker, W. S., III. (2005). *College of Science K-12 Outreach annual report*. Unpublished manuscript, Purdue University.

Walker, W. S., III. (2004). *College of Science K-12 Outreach annual report*. Unpublished manuscript, Purdue University.

Wood, T. L., Turner-Vorbeck, T., **Walker, W. S., III.**, Larsen, S., Fox, M., & de Souza, L. (1999). *Coding scheme for videotape analysis of classroom episodes.* (Tech. Rep.). West Lafayette, IN: School Mathematics and Science Center, Purdue University.

UNPUBLISHED WORK

Walker, W. S., III. (2016). *Factors influencing teacher instructional practice in mathematics when participating in professional development.* Unpublished doctoral dissertation, Purdue University, West Lafayette, IN.

Walker, W. S., III. (1998). *Creating a problem-solving classroom at the secondary level.* Unpublished master's thesis, Purdue University, West Lafayette, IN.

PROCEEDINGS OF NATIONAL MEETINGS AND SYMPOSIA

Cook, N. D., **Walker, W. S., III.,** & Weaver, G. C. (2011, June). *Teachers' beliefs about student learning in science*. Poster session presented at the Second Chemistry Education Research Graduate Student Conference, Oxford, OH.

Walker, W. S., III., Tyminski, A. M., & Woodward, J. A. (2008, April). *Standards-based instruction through professional development partnerships*. Poster session presented at the Research Presession during the Annual Meeting of the National Council of Teachers of Mathematics, Salt Lake City, UT.

VanFossen, P. J., & **Walker, W. S., III.** (2006, September). *Assessing the impact of 'Mathematics and Economics: Connections for Life': A pilot study*. Paper presented at the Annual Meeting of the National Council on Economic Education/National Association of Economic Educators, New York, NY.

Wood, T. L., **Walker, W. S., III.**, Turner-Vorbeck, T., & Cennamo, K. (1996, April). *Recreating mathematics teaching: An initial analysis of the practice of everyday teachers*. Paper presented at the Annual Meeting of the American Educational Research Association, New York.

PROCEEDINGS OF REGIONAL AND STATE MEETINGS AND SYMPOSIA

Walker, W. S., III., Bayley, W. G., Julien, I., Sands, P., Sederberg, D. C., & Smith, S. C. (2015, April). *Purdue University Science K-12 Outreach: Impact for K-12 schools in Indiana*. Poster session presented at the Purdue University P-12 Networking Summit, West Lafayette, IN.

Sorge, B. H., **Walker, W. S., III.**, & Feldhaus, C. R. (2013, April). *Evaluating K-12 STEM education programs in Indiana: The SERI/I-STEM partnership*. Poster session presented at the IUPUI Research Day, Indianapolis, IN.

INVITED AND PLENARY PRESENTATIONS

Ainslie, P., & **Walker, W. S., III.** (2016, May). *STEM in Indiana*. Panel presentation for the Indiana Library Federation District 2 Conference, West Lafayette, IN.

Walker, W. S., III., & Bayley, W. G. (2016, April). *Partnering with K-12 schools*. Session presented at the Purdue University P-12 Networking Summit, West Lafayette, IN.

Moreman, A., Tyrie, N., **Walker, W. S., III.** (2015, April). *Creating mutually beneficial partnerships between Purdue University and K-12 schools: Matching expectations of K-12 schools with Purdue projects*. Session presented at the Purdue University P-12 Networking Summit, West Lafayette, IN.

Walker, W. S., III. (2014, January). *Broader impacts through Science K-12 Outreach*. Panel presentation for the College of Science Diversity in Grants Improves Them Meeting, West Lafayette, IN.

Bossung, S., **Walker, W. S., III.**, Shane, A., & Bailey, M. (2012, November). *STEM education and the next generation workforce: Are we prepared*? Panel presentation for the New Economy New Rules Series presented by Barnes & Thornburg LLP, TechPoint, and Western Governor's University Indiana, Indianapolis, IN.

Walker, W. S., III., Cook, N. D., & Trujillo, C. (2012, September). *The Indiana Science Initiative: Research opportunities and preliminary teacher results*. Session presented at the Chemistry Education Seminar Series, Purdue University, West Lafayette, IN.

Walker, W. S., III. (2012, July). *Promoting K-12 STEM education in Indiana*. Presentation for the Indiana Automotive Council, Indianapolis, IN.

Bossung, S., & **Walker, W. S., III.** (2012, June). *The state of STEM in Indiana*. Panel presentation at the Frameworx Meeting, Indianapolis, IN.

Radcliffe, D., **Walker, W. S., III.,** Metzing, R. Richmond, L. Liebhouser, S. Kitterman, J., Caldwell, B. S., & Fleisher, G. (2012, April). *Industry, Government, and Academia: State and Local Organizational Perspectives on STEM*. Panel presentation at the AIA/NDIA/BISEC STEM Workforce Meeting, Indianapolis, IN.

Walker, W. S., III., & Grigsby, Z. P. (2011, October). *Purdue Science K-12 Outreach*. Presentation for the College of Science Dean's Leadership Council Meeting, West Lafayette, IN.

Walker, W. S., III., & Smith, S. C. (2010, October). *Purdue Science K-12 Outreach*. Presentation for the College of Science Alumni Board Meeting, West Lafayette, IN.

Walker, W. S., III. (2010, April). *Indiana Science Initiative*. Plenary session at the Discovery Learning Research Center's Second Annual PI Summit, West Lafayette, IN.

Hicks, J. L., & **Walker, W. S., III.** (2010, April). *Science Summit follow up: Academic standards for science and the Indiana Science Initiative*. Presentation for the Indiana State Board of Education, Indianapolis, IN.

Walker, W. S., III. (2010, February). *Pressing needs in STEM teacher professional development.* Panel presentation at the STEM Teacher Professional Development: Engineering in Context Meeting, West Lafayette, IN.

Hicks, J. L., & **Walker, W. S., III.** (2010, February). *The state of science education in Indiana.* Plenary session at the Indiana Science Summit, Indianapolis, IN. (Also see STATE MEETINGS AND CONFERENCES PLANNED OR HOSTED).

Sorge, B. H., & **Walker, W. S., III.** (2010, February). *Making the change in Indiana*. Plenary session at the Indiana Science Summit, Indianapolis, IN. (Also see STATE MEETINGS AND CONFERENCES PLANNED OR HOSTED).

Walker, W. S., III., Sorge, B. H., & Hicks, J. L. (2009, November). *Science education reform in Indiana*. Presentation for the National Science Resources Center's National Advisory Board Meeting, Washington D.C.

Walker, W. S., III. (2009, October). *I-STEM Resource Network: K-12 STEM education and business needs in Indiana*. Plenary session at the Business and Education Summit Meeting, Fort Wayne, IN.

Walker, W. S., III. (2009, October). *Systemic reform of K-8 science instruction in Indiana: Why aren't we doing this?* Closing remarks at the Indiana Building Awareness for Science Education Symposium, South Bend, IN. (Also see STATE MEETINGS AND CONFERENCES PLANNED OR HOSTED).

Walker, W. S., III. (2009, October). *I-STEM Resource Network: Promoting K-12 STEM education in Indiana*. Presentation for the Project Lead the Way BioMedical Science Teachers, Indianapolis, IN.

Walker, W. S., III. (2009, April). *I-STEM Resource Network: Promoting K-12 STEM education in Indiana*. Presentation for Rolls-Royce Corporation Spring Meeting, Indianapolis, IN.

Schuler, S. G, Armbrecht, R., Estes, J., Sorge, B. H., & **Walker, W. S. III.** (2009, February). *Public-private partnerships working to improve STEM education*. Panel presentation at the Annual Conference on STEM Education Policy of the Triangle Coalition for Science and Technology Education, Washington, D.C.

Drake, J., Morris, K., **Walker, W. S., III.**, & Schulz, T. (2009, February). *Teacher preparation and professional development*. Panel presentation at the Field Trip for State Policy Leaders for the American Youth Policy Forum and the State Higher Education Executive Officers, Indianapolis, IN.

Walker, W. S., III. (2009, January). *College of Science K-12 Outreach: Impact on K-12 science and mathematics education.* Presentation for the Lafayette Daybreak Rotary Club, Lafayette, IN.

Walker, W. S., III., Sorge, B. H., & Lechtenberg, V. L. (2008, December). *I-STEM Resource Network: Promoting K-12 STEM education in Indiana.* Presentation for Indiana's Education Roundtable, Indianapolis, IN.

Walker, W. S., III., & Feldhaus, C. R. (2008, November). *Engineering our students' future*. Session presented at the Annual Conference of the Engineering/Technology Educators of Indiana, Indianapolis, IN.

Walker, W. S., III. (2008, September). *Taking action in professional development*. Panel presentation at the Indiana Department of Education School Summit, Indianapolis, IN.

Walker, W. S., III. (2008, April). *Research-based Science Instruction for All Students in Indiana: Vision and Next Steps*. Closing remarks at the Indiana Building Awareness for Science Education Symposium, Indianapolis, IN. (Also see STATE MEETINGS AND CONFERENCES PLANNED OR HOSTED).

Walker, W. S., III. (2007, October). *The I-STEM Resource Network*. Presentation at the Indiana Life Science Luncheon sponsored by Barnes and Thornburg, LLP & the Indiana Health Industry Forum, Indianapolis, IN.

Shane, A., **Walker, W. S., III.**, Weisenbach, E. L., & Penca, A. (2007, September). *Linking STEM to economic needs: Indiana*. Panel presentation at the National Governor's Association Center for Best Practices K-12 STEM Learning Lab Meeting, Huntsville, AL.

REFEREED/JURIED PRESENTATIONS – NATIONAL CONFERENCES

Cook, N. D., **Walker, W. S., III.,** & Weaver, G. C. (2012, October). *The Indiana Science Initiative: Lessons from a classroom observation study*. Session presented at the National Outreach Scholarship Conference, Tuscaloosa, AL.

Walker, W. S., III., & Sorge, B. H. (2012, October). *The Indiana Science Initiative: Results from a partnership pilot*. Session presented at the National Outreach Scholarship Conference, Tuscaloosa, AL.

Trujillo, C., & **Walker, W. S., III.** (2012, October). *Nature of science and professional development of elementary educators*. Session presented at the National Outreach Scholarship Conference, Tuscaloosa, AL.

Trujillo, C. & **Walker, W. S., III.** (2012, January). *The nature of science from the viewpoint of a professional development team*. Poster session presented at the U. S. Department of Education Mathematics and Science Partnership Regional Conference, New Orleans, LA.

Cook, N. D., **Walker, W. S., III.**, & Weaver, G. C. (2011, October). *Impact of participation in the Indiana Science Initiative on teachers' beliefs about student learning*. Poster session presented at the American Chemical Society Midwest/Great Lakes Regional Meeting hosted by the St. Louis & Wabash Valley Local Sections, St. Louis, MO.

Tyminski, A. M., Woodward, J. A., & **Walker, W. S., III.** (2011, April). *Fraction division algorithms through generalizations*. Session presented at the Annual Meeting of the National Council of Teachers of Mathematics, Indianapolis, IN.

Hart, M. L., Grigsby, Z. P., **Walker, W. S., III.,** & McClure, P. (2010, February). *The ups, downs, and all-arounds of our MSP project*. Session presented at the United States Department of Education Math and Science Partnerships Regional Conferences, San Diego, CA.

Walker, W. S., III., & Sorge, B. H. (2009, September). *The I-STEM Resource Network: Promoting K-12 STEM education in Indiana*. Session presented at the Annual Meeting of the Outreach Scholarship Conference, Athens, GA.

Sorge, B. H., **Walker, W. S., III.**, & Hicks, J. L. (2009, September). *Partnerships with educational impact: Reforming science education in Indiana*. Session presented at the Annual Meeting of the Outreach Scholarship Conference, Athens, GA.

Walker, W. S., III., Bayley, W. G., Conlon, J. A., Hart, M. L., & Smith, S. C. (2006, October). *K-12 science and mathematics educational reform through university and school corporation collaborations*. Session presented at the Annual Meeting of the Outreach Scholarship Conference, Columbus, OH.

Walker, W. S., III., & VanFossen, P. J. (2006, October). *Mathematics and economics connections for life: Cross disciplinary collaboration and K-12 engagement*. Session presented at the Annual Meeting of the Outreach Scholarship Conference, Columbus, OH.

Walker, W. S., III., Bayley, W. G., Hart, M. L., & Smith, S. C. (2005, October). *Purdue University College of Science K-12 Outreach: Supporting teachers, inspiring students*. Session presented at the Annual Meeting of the Outreach Scholarship Conference, Athens, GA.

REFEREED/JURIED PRESENTATIONS – REGIONAL/STATE CONFERENCES

Walker, W. S., III., (2016, November). *Something to talk about: Using whole class discussions to enhance learning*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III. (2016, March). *Factors influencing teacher instructional practice in mathematics when participating in professional development*. Session presented at the Annual Conference of the Indiana Mathematics Education Research Symposium, Indiana University–Purdue University Indianapolis, Indianapolis, IN.

Walker, W. S., III., Payton, B., & Gran, S. (2016, February). *A framework for integrated STEM lessons*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III. (2016, January). *Integrated STEM curriculum development: Focusing on content*. Session presented at the Indiana STEM Education Conference, Purdue University, West Lafayette, IN.

Walker, W. S., III., (2015, October). *Integrated STEM from a mathematics viewpoint*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Vandrevala, A., Thomas, V., & **Walker, W. S., III.** (2015, February). *Developing integrated STEM lessons: Examples and challenges*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., & Sands, P. (2013, October). *Investigating the Common Core Standards for Mathematical Practices*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Bangel, E., Bricker, S., Werner, S., & **Walker, W. S., III.** (2013, February). *Notebooking for our youngest scientists*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Hicks, J. L., Sorge, B. H., Hansen, G., **Walker, W. S., III.** (2012, February). *Indiana Science Initiative*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., Cook, N. D., Sorge, B. H., Hicks, J. L., & Weaver, G. C. (2012, February). *The Indiana Science Initiative [ISI]: Results from a pilot study*. Poster session presented at the Discovery Learning Research Center Showcase and Symposium, West Lafayette, IN.

Woodward, J. A., & **Walker, W. S., III.** (2011, November). *Building mathematical concepts through patterns and generalizations*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III., Bayley, W. G., Hart, M. L., Julien, I., Smith, S. C., & Woodward, J. A. (2011, March). *College of Science K-12 Outreach: Over 20 years of engagement with Indiana's schools*. Poster session presented at the Purdue University P-12 Engagement Summit, West Lafayette, IN.

Bayley, W. G., **Walker, W. S., III.,** Smith, S. C., Hart, M. L., & Mikus, N. (2010, February). *Partners in inquiry-based science for student success.* Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Smith, S. C., Bayley, W. G., **Walker, W. S., III.,** Hart, M. L., Julien, I., & Dohnert, M. (2010, February). *Partnering together for an inquiry-based science classroom.* Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., & Sorge, B. H. (2009, October). *The Indiana STEM Resource Network*. Session presented at the Annual Conference of the Engineering/Technology Educators of Indiana, Indianapolis, IN.

Walker, W. S., III., Tyminski, A. M., & Woodward, J. A. (2009, October). *Implementing inquiry-based mathematics instruction*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Smith, S. C., Bayley, W. G., **Walker, W. S., III.**, Hart, M. L., Julien, I., & Woodward, J. A. (2009, February). *Implementing inquiry in the classroom: Modifying lessons to include more student centered science instruction*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Hart, M. L., McClure, P., **Walker, W. S., III.**, Bayley, W. G., Julien, I., Smith, S. C., Tyminski, A. M., Woodward, J. A., & Larrabee, B. (2009, February). *Partnerships supporting inquiry-based instruction*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Hart, M. L., McClure, P., Staver, J. R., **Walker, W. S., III.**, Bayley, W. G., Julien, I., Smith, S. C., Woodward, J. A., & Rieke, K. (2009, February). *Partners in inquiry-based science for student success*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., Sorge, B. H., & Hicks, J. L. (2009, January). *The Indiana Science, Technology, Engineering, Mathematics (I-STEM) Resource Network: Promoting STEM education in Indiana*. Session presented at the Winter Conference of the Indiana Principals Leadership Academy, Indianapolis, IN.

Walker, W. S., III., Bayley, W. G., Hart, M. L., Julien, I., Smith, S. C., & Woodward, J. A. (2008, October). *College of Science K-12 Outreach: Supporting teachers, inspiring students*. Poster session presented at the Back to Class Engagement Session, West Lafayette, IN.

Walker, W. S., III., & Sorge, B. H. (2008, October). *The I-STEM Resource Network*. Poster session presented at the Back to Class Engagement Session, West Lafayette, IN.

Walker, W. S., III., & Sorge, B. H. (2008, October). *The I-STEM Resource Network: Resources and information for K-12 teachers of mathematics*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III., Tyminski, A. M., & Woodward, J. A. (2008, October). *Using inquiry to impact mathematics instruction*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Sorge, B. H., & **Walker, W. S., III.** (2008, September). *The I-STEM Resource Network*. Session presented at the State Conference of the Indiana Association for Career and Technical Education, Indianapolis, IN.

Walker, W. S., III., Hands, N., Bayley, W. G., Conlon, J. A., Hart, M. L., Julien, I., Smith, S. C., Rose, T., & Larrabee, B. (2008, February). *Supporting standards-based interdisciplinary science and mathematics instruction through a science and mathematics partnership*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., Hands, N., Bayley, W. G., Conlon, J. A., Hart, M. L., Julien, I., Smith, S. C., Rieke, K. (2008, February). *Science partners: Moving towards inquiry together*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., & Sorge, B. H. (2007, November). *The I-STEM Resource Network: Promoting STEM education in Indiana*. Panel presentation at the Indiana's Future Conference: Equity, Engagement & Education for Economic Success, Indianapolis, IN.

Walker, W. S., III., Tyminski, A. M., Kastberg, S. E., & McMasters, J. (2007, November). *Preparing all students for success in high school math: The middle level mathematics initiative*. Panel presentation at the Indiana's Future Conference: Equity, Engagement & Education for Economic Success, Indianapolis, IN.

Walker, W. S., III., & Sorge, B. H. (2007, October). *The I-STEM resource network: Promoting STEM education in Indiana*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III., Tyminski, A. M., Woodward, J. A., & Hands, N. (2007, October). *Improving mathematics instruction through partnerships*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III., Smith, S. C., Bayley, W. G., Conlon, J. A., Hart, M. L., Julien, I., & Rose, T. (2007, February). *Promoting standards-based and inquiry-based science instruction through science partnerships*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., Bayley, W. G., Hart, M. L., Julien, I., & Smith, S. C. (2006, February). *Supporting teachers and inspiring students through inquiry*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., Bayley, W. G., Hart, M. L., Julien, I., Smith, S. C., Rose, T., Freeman, K. (2006, February). *Improving elementary science instruction through science partnerships*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

VanFossen, P. J., & **Walker, W. S., III.** (2005, October). *Mathematics and economics connections*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III., & Hart, M. L. (2005, October). *Linking mathematics and computer science*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

VanFossen, P. J., & **Walker, W. S., III.** (2004, October). *Mathematics and economics connections*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III. (2004, October). *Purdue University Mathematics Outreach: Opportunities in K-12 mathematics instruction*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Walker, W. S., III. (2004, October). *Tips for grant writing*. Presentation at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Sorge, D. H., **Walker, W. S., III.**, & Conlon, J. A. (2004, February). *Purdue University College of Science K-12 Outreach: Supporting teachers, inspiring students*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Sorge, D. H., Sorge, B. H., & **Walker, W. S., III.** (2000, November). *"Standard"izing technology integration: Strategies that work*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

GRANTS RECEIVED

Mathematics Field Day. (2016). PI: Campbell, R. Advisor: **Walker, W. S., III.**, & Kenney, R. H. Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,500.

Mathematics Field Day. (2015). PI: Campbell, R. Advisor: **Walker, W. S., III.**, & Kenney, R. H. Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,500.

The Indiana Science, Technology, Engineering, and Mathematics (I-STEM) Resource Network. (2015 – 2016). PI: Abel, S. R. Co-PI: Ainslie, P. J., Hicks, J. L., & **Walker, W. S., III.** Central Indiana Corporate Partnership, $600,000.

Content Thematic Units for Integrated STEM Education (CTU 4 ISE). (2014 – 2016). PI: **Walker, W. S., III.** Co-PI: Shepardson, D. P., Payton, B. K., Preston, M. E., Bayley, W. G., Smith, S. C., Julien, I. A., Sederberg, D., Grigsby, Z. P., Sands, P. A., & Hart, M. L. Indiana Department of Education Mathematics and Science Partnership Program, $246,632 (total project).

Mathematics Field Day. (2014). PI: Beckley, J. Advisor: **Walker, W. S., III.**, & Kenney, R. H. Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,360.

Mathematics Field Day. (2013). PI: Wicke, S. Advisor: **Walker, W. S., III.**, & Kenney, R. H. Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,350.

The Indiana Science, Technology, Engineering, and Mathematics (I-STEM) Resource Network. (2012 – 2013). PI: Lechtenberg, V. L. Co-PI: **Walker, W. S., III.**, & Sorge, B. H. Central Indiana Corporate Partnership, $1,530,000.

Mathematics Field Day. (2012). PI: Hanes, C. Advisor: Kenney, R. H., & **Walker, W. S., III.** Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,350.

Science through inquiry: The next steps. (2011 – 2013). PI: **Walker, W. S., III.** Co-PI: Eichinger, D. C., & Smith, S. C. Indiana Department of Education Mathematics and Science Partnership Program, $880,702 (total project).

Using science as the bonding agent to inquiry and global awareness. (2011 – 2013). PI: Eichinger, D. C. Co-PI: **Walker, W. S., III.**, Hart, M. L., & Bayley, W. G. Indiana Department of Education Mathematics and Science Partnership Program, $335,670 (total project).

Literacy enriched science through guided inquiry: Elevating thinking and knowledge. (2011 – 2013). PI: Sorge, B. H. Co-PI: **Walker, W. S., III.**, & Staver, J. R. Indiana Department of Education, $1,898,984.

Indiana Science Initiative multi-user database. (2011 – 2012) PI: **Walker, W. S., III.** Co-PI: Sorge, B. H. Eli Lilly & Company Foundation, $120,000.

Mathematics Field Day. (2011). PI: O'Neill, J. Advisor: Woodward, J. A., & **Walker, W. S., III.** Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,250.

Indiana Department of Education, Title II. (2011). PI: Sorge, B. H. Co-PI: **Walker, W. S., III.** Indiana Department of Education, $375,000.

I-STEM Resource Network/Indiana Science Initiative. (2010 – 2014). PI: Sorge, B. H., Co-PI: **Walker, W. S., III.** Eli Lilly & Company Foundation, $1,500,000.

Mathematics Field Day. (2010). PI: Giordano, M. Advisor: Woodward, J. A., & **Walker, W. S., III.** Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,200.

Indiana Department of Education, Title II. (2010). PI: Sorge, B. H. Co-PI: **Walker, W. S., III.** Indiana Department of Education, $375,000.

I-STEM K-5 science program. (2010). PI: Sorge, B. H. Co-PI: **Walker, W. S., III.**, Indiana Department of Education, $148,310.

Indiana modeling workshops. (2010). PI: Sorge, B. H., Co-PI: **Walker, W. S., III.**, Indiana Department of Education, $173,660.

The I-STEM Resource Network. (2009 – 2011). PI: Lechtenberg, V. L., Co-PI: **Walker, W. S., III.,** & Sorge, B. H. Central Indiana Corporate Partnership Foundation (Lilly Endowment), $2,000,000.

I-STEM Resource Network operations. (2009 – 2010). PI: **Walker, W. S., III.**, Co-PI: Lechtenberg, V. L., & Sorge, B. H. Indiana Department of Education, $500,000.

Indiana Science Summit. (2009). PI: Sorge, B. H., Co-PI: **Walker, W. S., III.** Eli Lilly & Company Foundation, $35,000.

Mathematics Field Day. (2009). PI: Rozin, K. Advisor: Woodward, J. A., & **Walker, W. S., III.** Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,500.

I-STEM professional development grants. (2009). PI: **Walker, W. S., III.**, Co-PI: Lechtenberg, V. L., & Sorge, B. H. Indiana Department of Education, $299,573.

Indiana Algebra Readiness Initiative. (2009). PI: **Walker, W. S., III.**, Co-PI: Sorge, B. H. Indiana Department of Education, $49,952.

Indiana science and mathematics initiatives. (2009). PI: Sorge, B. H. Co-PI: **Walker, W. S., III.** Indiana Department of Education, $64,000.

Grade Report. (2008 – 2009). PI: Sorge, B. H. Co-PI: Lechtenberg, V. L., & **Walker, W. S., III.** BioCrossroads/Lumina, $200,000.

Indiana science strategic plan. (2008). PI: **Walker, W. S., III.** Co-PI: Lechtenberg, V. L., & Sorge, B. H. Central Indiana Corporate Partnership, $25,000.

Indiana mathematics. (2008). PI: **Walker, W. S., III.**, Co-PI: Brown, C. A., & Sorge, B. H. Indiana Department of Education, $299,573.

Indiana Algebra Readiness Initiative. (2008). PI: **Walker, W. S., III.**, Co-PI: Brown, C. A., & Sorge, B. H. Indiana Department of Education, $249,791.

Mathematics Field Day. (2008). PI: Strand, A. Advisor: Woodward, J. A., & **Walker, W. S., III.** Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,500.

The I-STEM Resource Network. (2007 – 2009). PI: Lechtenberg, V. L., Co-PI: **Walker, W. S., III.** Central Indiana Corporate Partnership Foundation (Lilly Endowment), $3,015,800.

Mathematics and Science Readiness, Achievement, and Participation (MS-RAPs). (2007 – 2009). PI: **Walker, W. S., III.** Co-PI:, Smith, S. C., Tyminski, A. M., & Hart, M. L. Indiana Department of Education Mathematics and Science Partnership Program, $499,008 (total project).

Partners in Inquiry-based Science for Student Success (PIBS3). (2007 – 2009). PI: Staver, J. R. Co-PI: **Walker, W. S., III.**, Bayley, W. G., & Conlon, J. A. Indiana Department of Education Mathematics and Science Partnership Program, $389,659 (total project).

I-STEM Initiative. (2007 – 2008). PI: Lechtenberg, V. L. Co-PI: **Walker, W. S., III.** Central Indiana Corporate Partnership Foundation, $125,000.

INSCITED (INdiana SCIence Teacher EDucation) 2007-2008. (2007 – 2008). PI: **Walker, W. S., III.** Co-PI: Smith, S. C. Indiana Department of Education Office of Program Development, $29,466.

Middle Level Mathematics Initiative. (2007). PI: **Walker, W. S., III.** Co-PI: Lechtenberg, V. L., & Sorge, B. H. National Governor's Association, $220,000.

I-STEM communications and promotions. (2007). PI: **Walker, W. S., III.** Co-PI: Lechtenberg, V. L., & Sorge, B. H. National Governor's Association, $100,000.

Indiana High School Grade Report. (2007). PI: **Walker, W. S., III.** Co-PI: Lechtenberg, V. L., & Sorge, B. H. National Governor's Association, $80,000.

Mathematics Field Day. (2007). PI: Warner, S. Advisor: **Walker, W. S., III.,** & Woodward, J. A. Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,500.

Indiana STEM Resource Network. (2006 – 2007). PI: Lechtenberg, V. L. Co-PI: **Walker, W. S., III.** National Governor's Association (Indiana Office of the Governor), $315,000.

Discovery through science. (2006 – 2007). PI: Chou, H. Advisor: **Walker, W. S., III.** Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,500.

Mathematics Field Day. (2006). PI: Warner, S. Advisor: **Walker, W. S., III.** Purdue University Student Grant Program for Community Service/Service Learning Projects, $1,500.

INSCITED (INdiana SCIence Teacher EDucation) 2006-2007. (2006 – 2007). PI: **Walker, W. S., III.** Co-PI: Bayley, W. G., & Smith, S. C. Indiana Department of Education Office of Program Development, $46,628.

Improving inquiry and standards-based science instruction. (2005 – 2008). PI: McCabe, G. P. Co-PI: **Walker, W. S.,III.**, Krockover, G. H., & Julien, I. A. Indiana Department of Education Mathematics and Science Partnership Program, $306,007 (total project).

Mathematics and economics connections. (2005 – 2006). PI: VanFossen, P. J. Co-PI: **Walker, W. S., III**. National Council on Economic Education, $12,480.00 (outright); $24,690.95 (total project).

AWARDS

Purdue Momentum Maker. (2013). Recognition of outstanding achievement by Purdue University staff. (http://www.purdue.edu/momentummakers/).

Seeds for Success Award. (2012). Award recognizing principal investigators and co-investigators garnering $1 million or more in grants.

College of Science Leadership Award. (2010). award recognizing initiative, innovation, and leadership in College of Science at Purdue University.

Seeds for Success Award. (2010). Award recognizing principal investigators and co-investigators garnering $1 million or more in grants.

Seeds for Success Award. (2007). Award recognizing principal investigators and co-investigators garnering $1 million or more in grants.

Mike Keedy Graduate Scholarship Award in Mathematics Education. (2007). Scholarship given to a graduate student demonstrating potential for excellence in research related to mathematics teacher education.

Mike Keedy Graduate Scholarship Award in Mathematics Education. (2006). Scholarship given to a graduate student demonstrating potential for excellence in research related to mathematics teacher education.

Distinguished Master's Thesis Award of the Midwestern Association of Graduate Schools. (1998). Nominated by Terry L. Wood (Advisor) for distinguished scholarship and research at the master's level.

STATE MEETINGS AND CONFERENCES PLANNED OR HOSTED

Purdue P-12 Networking Summit. (2016, April). Co-chair of committee that organized a summit for Purdue University faculty and staff interested in partnering with P-12 groups. Purdue faculty and staff shared ideas on partnership and research through plenary speakers, breakout sessions, and poster sessions.

Purdue P-12 Networking Summit. (2015, April). Member of committee that organized a summit for Purdue University faculty and staff interested in partnering with P-12 groups. Purdue faculty and staff shared ideas on partnership and research through plenary speakers, breakout sessions, and poster sessions.

Indiana STEM Action Coalition. (2012 – 2014). Organized Indiana team to attend the Change the Equation Vital Signs meeting. Hosted meetings for STEM education stakeholders in higher education, K-12 education, business, and philanthropy to develop an action group to advance K-12 STEM education in Indiana. Indiana

STEM Action Coalition includes approximately 30 members advocating for advancing K-12 STEM education.

Indiana Primary Algebra Readiness Initiative. (2010, Summer and Fall). Statewide workshops supported by the I-STEM Resource Network with the Indiana Department of Education to prepare teachers to address problem solving, cognitive demand, generalization, number sense, relationships, operations, patterns, and functions.

Indiana Science Summit. (2010, February). Conference co-planned and supported by the I-STEM Resource Network with the Indiana Department of Education and Eli Lilly and Company to gain support for and to help progress the Indiana Strategic Plan for Science Education Reform. Attendees included 250 leaders from K-12 education, higher education, government, and not-for-profits. Indianapolis, IN.

Indiana Building Awareness for Science Education Symposium. (2009, October). Conference planned and hosted by the I-STEM Resource Network to build awareness for the need of reform in science education in Indiana. Attendees included 150 K-12 administrators, K-12 educators, business members, government officials, employees of not-for-profits, and higher education faculty and administrators. South Bend, IN.

Purdue Conference on Indiana P-12 Energy Education. (2009, September). Conference co-planned and co-hosted by Purdue University College of Education, Purdue University's Global Sustainable Future Initiative, Indiana Council for Economic Education, Ackerman Center for Democratic Citizenship, I-STEM Resource Network, and Purdue University Center for Research and Engagement in Science

and Mathematics Education to share with P-12 teachers and administrators a thematic treatment of energy in our schools. Attendees included 75 K-12 educators and higher education faculty. West Lafayette, IN.

Indiana Algebra Readiness Workshops. (2008, Summer). Workshops developed and organized by the I-STEM Resource Network included activities and information for teachers to address Cognitive Demand, Algebraic Habits of Mind, and Formative Assessment in their classrooms. Attended by 160 middle school mathematics teachers and Algebra I teachers. Indianapolis, IN; Evansville, IN; Fort Wayne, IN; and Merrillville, IN.

Indiana Algebra Readiness Conference. (2008, June). Conference co-developed and co-hosted by the I-STEM Resource Network for working with students potentially at risk of failing Algebra I and the Core 40 Algebra I End-of-Course Assessment. Attended by 200 middle school mathematics teachers, Algebra I teachers, and administrators. Indianapolis, IN.

Indiana Building Awareness for Science Education Symposium. (2008, April). Conference co-planned and hosted by the I-STEM Resource Network to build awareness for the need of reform in science education in Indiana. Attendees included 150 K-12 administrators, K-12 educators, business members, government officials, employees of not-for-profits, and higher education faculty and administrators. Indianapolis, IN.

K-12 PROFESSIONAL DEVELOPMENT PROGRAMS

Transitioning to Common Core State Standards for Mathematics. (2012-2013). Lafayette Catholic School System, Lafayette, IN. Meetings and workshops with 30 K-6 teachers of mathematics to incorporate CCSSM content and practice standards into classroom instruction.

Transitioning to Common Core State Standards for Mathematics. (2012-2013). Klondike Elementary School, West Lafayette, IN. Meetings and workshops with 5 mathematics education leadership team teachers to incorporate CCSSM content and practice standards into classroom instruction.

Standards-Based Integrated Instruction. (2009 – 2010). Purdue University. Consultant and Instructor for a $305,000 Indiana Commission for Higher Education Improving Teacher Quality Partnership program.

Enhancing Teacher Quality in Advanced Life Science. (2005 – 2008). Purdue University. Collaboration with College of Agriculture Department of Youth Development and Agriculture Education.

Implementing Inquiry-Based Instruction in the Classroom. (2005 – 2007). Shelbyville Central Schools. Program culminated with a school district elementary grades science expo in 2006-2007. Every elementary teacher of science and every elementary student in Shelbyville Central Schools completed an inquiry-based science fair style project.

Teaching Through Problem Solving. (2005 – 2006). Frankfort High School. Worked with all high school teachers on incorporating problem solving into classroom activities. Project was done as part of the school's professional development plan.

Standards-Based Integrated Science Instruction. (2004 – 2008). Purdue University. Consultant and Instructor for a six-year $900,000 Indiana Commission for Higher Education Improving Teacher Quality Partnership program.