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Teacher Perceptions of Professional Learning Communities' Impact on Math Critical Thinking Pedagogy

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This is to certify that the doctoral study by

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Walden University
2018

Abstract

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MA, Walden University, 2011

BS, Michigan State University, 1986

Proposal Submitted in Partial Fulfillment

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Abstract

U.S. educational leaders struggle with declining mathematics achievement among students as compared to other countries. The problem for this study was low standardized mathematics scores in one district in a major city in the Southwestern United States. The purpose of this sequential explanatory mixed method project study was to analyze the effectiveness of professional learning communities (PLCs) on the mathematics critical thinking pedagogy among teachers in 2 elementary schools. The conceptual framework focused on work by Olivier, Hipp, Huffman, and Hord on the efficacy of PLCs for improving teacher pedagogy. Research questions addressed in this study were designed to explore teachers' perceptions of PLCs according to Olivier, Hipp, and Huffman's 6 professional learning characteristics for improving math critical thinking pedagogy, as well as the efficacy of the structure of the PLCs. Data were obtained via open-ended interviews and focus groups, and employed descriptive analysis using grounded theory where conceptual categories emerged from the survey data. Likert scale data were also gathered via a survey, which was triangulated to form conclusions regarding the research questions. Key findings indicate that teachers perceive PLCs positively; however, they indicated the need for more time and administrative support for mathematics PLCs. The project that resulted from this research is a PLC professional development session that guides schools' mathematics PLCs and addresses critical thinking pedagogy and the need for school and district support for mathematics PLCs. Social change may result by improving teachers' mathematics critical thinking pedagogy and giving students mathematics instruction needed to compete in a global economy.

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Section 1: The Problem

The Program for International Assessment (PISA) is used to rank 64 countries every 3 years based on its collection of math test results (Organisation for Economic Cooperation and Development [OECD], 2016). According to the OECD (2016), the United States ranks below average in math among the world's most developed countries. According to Heitin (2017) results the math performance of U.S. students on the 2016 PISA remained stagnant as other nations surged ahead. In a global economy, employability is likely to depend on students' knowledge and problem-solving skills; thus, the poor math skills of U.S. students raise concerns among leaders regarding students' abilities to compete in a global job market (OECD, 2016).

Selling, Garcia, and Loewenberg Ball (2016) stressed that strong math content knowledge and instructional strategies that foster critical thinking are crucial to math teachers' effectiveness, and further described the immediate need for teachers to improve their mathematical knowledge because Common Core requires strong mathematical pedagogy, which elementary teachers often lack. Abdullah, Halim, and Zakaria (2014) explained that math teachers must understand instructional strategies to foster students' metacognitive problem solving and math skills. The purpose of the study was to analyze teachers' perceptions of the use of Professional Learning Communities (PLCs) to improve their critical thinking math pedagogies. PLCs consist of groups of teachers working together to strengthen their instructional strategies and improve student achievement by sharing best practices (Hord & Hall, 2014). I analyzed the effect of

PLCs on critical thinking pedagogy among elementary math teachers working in a Georgia school district. Specifically, I explored teachers' perceptions of the potential of PLCs to improve their pedagogy for teaching critical thinking skills through a sequential explanatory design, which allowed me to compare data from interviews, surveys, and focus groups. Participants included teachers involved in PLCs in two elementary schools in a district outside of a large city in Georgia. I also examined teachers' perceptions of the efficacy of the structure of their PLCs via responses on the Professional Learning Community Assessment.

Definition of the Problem

Teachers require solid pedagogical content knowledge to teach critical thinking skills. However, current methods of professional development do not address the intricate pedagogical content knowledge that teachers must have to improve students' critical thinking skills. PLCs enable teachers to obtain the critical thinking math pedagogy needed to raise students' thinking and achievement to the levels required to compete in a global society.

In 2014, educational leaders in Georgia developed and implemented an assessment called Georgia Milestones, a standardized assessment consisting of multiple choice and open-ended questions that require students to justify their answers in written form (GOSA, 2015). According to Herman and Linn (2014), Georgia Milestones integrates questions from the two highest levels of Webb's (1997) depth of knowledge: strategic and extended thinking. The higher levels of Webb's depth of knowledge require

students to use metacognitive skills to plan and solve problems on the Georgia Milestones assessment (Herman & Linn, 2014). Metacognition refers to higher order critical thinking and involves multiple levels of planning, evaluating, analyzing, and building awareness of the cognitive thought processes that occur during problem-solving (Vanderbilt University, 2016). Herman and Linn (2013) stated that advanced knowledge and skills, such as critical thinking capabilities, are essential to professional and academic success in the 21st century.

Students in the study site school district struggled on the Criterion Referenced Competency Test (CRCT), the standardized assessment that preceded the Georgia Milestones assessment. The pattern of low achievement continued with this assessment. Persistent low math achievement on the CRCT and Georgia Milestones indicates the need for pedagogical improvements. Poor performance on the Georgia Milestones test may indicate students lack the math skills necessary succeed in a global economy. Teachers in the district are not prepared to teach the types of critical thinking that will be assessed; therefore, PLCs in each school may improve teachers' critical thinking math pedagogy. I investigated whether the PLCs improved teacher pedagogy, which may increase students' academic performance in math.

The problem that prompted the study was low math achievement and weak critical thinking skills among math students in the study site school district. The Georgia Milestones assessment requires students to demonstrate math thinking in a logical and coherent manner. Students' math scores in the study site district indicate a lack of math

skills and underperformance compared to state averages. According to data from the Georgia Department of Education (2011), 73% of students in the study site district attained math proficiency, compared to the state average of 83%. In 2014, CRCT scores indicated average student proficiency in the state remained at 83%, while average student proficiency in the district fell to 71% (GaDOE, 2015). The district is below the state average in third and fourth grades in math. The average CRCT proficiency scores among third grade students in the study site district were 13% lower than the state average in 2014 (GaDOE, 2015). Scores among the district's fourth grade students in 2014 were 15% lower than the state average (GaDOE, 2015). The math portion of the Georgia Milestones exam requires a higher level of thinking and performance than the CRCT requires (GaDOE, 2015). Educational leaders in Georgia changed the test to better assess students' college and career readiness. The test assesses students' reasoning by requiring them to explain their thinking strategies (GaDOE, 2015). Table 1 provides a comparison of the CRCT test with the Georgia Milestones Test.

Table 1

Comparison of Sample Test Questions

CRCT Sample	Georgia Milestones Sample
Which fraction is largest? a) 1/4 b) 1/2 c) 1/3 d) 1/8	Hector is studying his multiplication facts through the product of 10 x 10 Part A Hector says that any multiple of 6 can be divided into 3 equal groups. Is Hector correct? Explain your answer using words, symbols, or pictures.

	Part B Hector finds the product of 4 and 7 by solving the expression 14 + 14. Explain how 14 + 14 can be used to find the expression of 4 and 7.

Note. Adapted from Georgia Office of Student Achievement. (2015). *Georgia Milestone: Georgia's new standardized test.* Retrieved from http://gosa.georgia.gov/georgia-milestones-Georgia's-new-standardized-test

The sample above indicates how the Georgia Milestones assessment measures a higher level of problem-solving. Students require more complex math skills to achieve high math scores on the assessment

Rationale

Leaders in the study site district have struggled to improve student achievement on standardized math tests for several years. In 2016, the state changed the standardized math tests to require students to exhibit higher order math skills, which are needed to perform well on state assessments. Teachers need to improve their critical thinking instructional strategies for students to obtain higher order math skills. There is room for improvement in math achievement among students at the study site district, as well as achievement compared to other countries.

Chia-Yi and Seokhee (2011) found that Japan, China, United States, and Korea measure critical thinking skills in math; however, international critical thinking assessments are rarely used in the United States. Georgia Milestones is a test that evaluates critical thinking skills. The district needs teachers with strong math critical thinking pedagogy to increase student achievement. Arne Duncan, former Secretary of

Education, stated that students need employable skills such as collaboration and critical thinking (USDE, 2013). Prior to the current investigation, the study site district had already implemented PLCs; however, research was lacking on whether the intended effects of those PLCs were achieved. The study site district could benefit from the study if results indicate PLCs improve teachers' math critical thinking pedagogy, which can increase student performance on state math exams.

Evidence of the Problem at the Local Level

In the study site district, student math scores on the Georgia CRCT were among the lowest in the surrounding metropolitan area. The math portion of the 2014 CRCT indicated the number of students with proficient math scores in the study site district was 14% below the state average for third graders, 12% percent below the state average for fourth graders, and 12% below the state average for fifth graders (GaDOE, 2015). On average, 83% of the elementary students in Georgia met or exceeded standards on the state math CRCT in 2014. However, during the same year, only 71% of students in the study site district met or exceeded math CRCT standards (GaDOE, 2015). In 2014, an average of 85% of students at the first study site school met or exceeded math CRCT standards (GaDOE, 2015). During the same year, just 73% of students at the second study site school met or exceeded those standards (GaDOE, 2015). Table 2 provides a comparison of CRCT and Georgia Milestones math scores for third, fourth, and fifth grade students at each of the study site schools, as well as district and state levels.

Table 2

Comparison of CRCT and Georgia Milestones Math Scores Developing Learner and Above

2015 Georgia Milestones	Fifth	Fourth	Third
State	75	79	79
District	63	65	65
School One	65	78	78
School Two	63	92	92
2014 CRCT	**Fifth**	**Fourth**	**Third**
State	88	83	80
District	76	68	68
School One	87	87	81
School Two	67	68	83

Note. Adapted from *The Georgia Department of Education*. (2016). Retrieved from https://www.gadoe.org/Curriculum-Instruction-and-Assessment/Assessment /Pages/CRCT-Statewide-Scores.aspx

Performance on the new Milestones assessment for the study site district was similar in 2014 and 2015. The schools in the study site district also underperformed on the new accountability assessment for the state of Georgia, the College and Career Reading Performance Index (CCRPI). The CCRPI is used to rate schools on a 100-point scale and is comprised of 60% school achievement, 25% progress from last year, and 15% achievement gap. Schools receive CCRPI achievement points for percent of students scoring at developing learner or above on the Georgia Milestones compared to last year in reading, math, science, and social studies. Georgia's average state CCRPI score of 83 out of a possible 100 points in 2014 (GaDOE, 2015). During that same year,

the score in the study site district was just 71 (GaDOE , 2015). The new calculations for the CCRPI have higher standards to encourage schools and districts to earn higher test scores (GaDOE, 2015). The CCRPI score includes state assessment scores (CRCT) as well as other school improvement and accountability factors (GaDOE, 2014).

The study site district is the third largest in the state of Georgia and has an enrollment of 98,700 students (GaDOE, 2016). The district has 77 elementary schools, and 71% of the student population is eligible for free or reduced lunch (GaDOE, 2016). There are 142 languages spoken in the district, and nonnative English speakers comprise 22% of the district's students (GaDOE, 2016). Large urban school districts have many challenges, including financial burdens, large student population, and diverse student needs. Socio-demographics significantly influence the performance of urban districts, as low student achievement is common in districts characterized by a low income population and diversity (Ahram, Stembridge, Fergus, & Noguera, 2016).

Evidence of the Problem from the Professional Literature

Sanchez and Summers (2014) indicated that college programs in education often fail to adequately prepare preservice teachers to teach math and science, focusing instead on reading. Leaders from the NEAAFT have also expressed concern over the ineffectiveness of teacher preparation programs (Sanchez & Summers, 2014). Sanchez and Summers (2014) further emphasized that colleges of education spend $6 billion a year on preservice education for teachers, yet few new teachers have the confidence

required to enter the classroom. Accordingly, teachers need continuous in-service professional development.

Former U.S. Secretary of Education Arne Duncan indicated that little is done to evaluate teacher preparation programs (NEA, 2014). Consequently, educators graduate from regional teacher education programs with varying levels of effectiveness. A study released by the National Council on Teach Quality (2014) reported that in half of the 907 elementary schools surveyed teacher education programs fail to ensure candidates are capable of teaching science, technology, engineering, and math. Teachers need professional development after their licensure programs to learn instructional strategies not developed during their preservice education.

Current textbooks do not provide detailed instruction and teachers do not create enough student math experiences to achieve mastery in math (Doabler, Fien, Nelson-Walker, & Baker, 2012). If students lack mastery of basic math concepts, it may be difficult for them to understand advanced math concepts and develop their critical thinking abilities. Thus, teachers need ongoing training, collaboration with peers, and professional learning opportunities to keep abreast of resources needed to consistently improve students' critical thinking skills in math. To add to the problem, standardized math assessments are becoming more challenging, requiring higher levels of cognition from students.

Herman and Linn (2014) indicated that state assessments are changing to evaluate higher order thinking. Leaders in the United States have invested in the PARCC

assessments that require students to use higher order thinking to justify answers to open-ended questions (Herman & Linn, 2014). Furthermore, state assessments will not only test content; they will also evaluate students' critical thinking skills (Herman & Linn, 2014). School leaders must concentrate on improving student learning to help U.S. students compete in international assessments with the highest performing countries (Herman & Linn, 2014).

Preparing for the assessments is often challenging for schools. For example, school districts in South Korea struggled to transition to higher order thinking; however, educators used characteristics of PLCs to improve their teachers' math pedagogy. The superintendent of the Seoul Metropolitan Office of Education initiated a transformation among schools into learning communities, which led to shared values and visions between teachers and administrators. Kyounghye and You_Kyung (2012) state that the superintendent required schools to designate time in to their schedules for PLCs so that teachers to learn instructional strategies from other teachers to improve the efficacy of teaching. As the Schools within the Seoul Metropolitan school district completed the required PLCs, the schools experienced unity building within the schools with shared goals for the school and students (Kyounghye & You-Kyung, 2012). The district obtained information and strategies from the teachers that was not unfolding in the prior culture of administrative directives. The transformation also created collaborative learning environments for teachers to share best practices and led to the nation's consistently high PISA math rankings (Kyounghye & You-Kyung, 2012).

Assessments that require students to explain their answers in writing can improve their critical thinking and problem-solving skills (Herman & Linn, 2014). In addition, data from higher order assessments can help teachers identify shortcomings in their pedagogy. However, even with the important insights offered through assessments such as Georgia Milestones, teachers may need professional development to learn new instructional strategies and increase their pedagogical content skills. Finding effective ways to implement professional development for pedagogy regarding math critical thinking skills is important for schools to be effective in the future.

Colleges of education have failed to adequately prepare teachers with math critical thinking pedagogy, resulting in teachers and students who lack the critical thinking strategies needed to compete in a global environment and perform adequately on new higher-level assessments. Schools must find cost-effective ways to continuously supply teachers with the professional development they need to meet these challenges. Therefore, the intent of the study was to investigate teachers' perceptions of improving their critical thinking math pedagogies through PLCs.

Definitions

The following terms were used in the study:

College Career Readiness Performance Index (CCRPI): CCRPI is a comprehensive school improvement, accountability, and communication platform for all educational stakeholders that will promote college and career readiness for all Georgia public school students (GaDOE, 2015). Leaders use the CCRPI to evaluate schools based

on parameters designed to prepare students to be college and career ready (GaDOE, 2015).

Criterion Referenced Competency Test (CRCT): A set of tests administered at public schools in the state of Georgia that are designed to test the knowledge of first through eighth grade students in reading, math, social studies, and science. The predecessor to the new Milestones test (GaDOE, 2015).

Critical thinking: Critical thinking describes the intellectual process of conceptualizing, applying, synthesizing, and evaluating information gathered from reasoning, observation, reflection, or communication (Critical Thinking Community, 2015).

Georgia Milestones Test: The Georgia Milestones Test is a new criterion-referenced test for Georgia public school students with extended response questions used to assess students' critical thinking skills in third through eighth grades in math, reading, social studies, and science (GaDOE, 2015).

Knowledge frameworks: Knowledge frameworks are tools used to classify teachers' knowledge of analysis and evaluation (Holmes, 2012). Knowledge frameworks allow for the discussion and adjustment of teachers' instructional strategies.

Math number talks: Math number talks are a 5- to 10-minute block of time that math teachers spend building students' mental math skills at the beginning of every math lesson. During math number talks, teachers create environments where students devise their own problem-solving strategies for math problems provided by the teacher.

Teachers allow students to share their math strategies with the other students. By encouraging students to find and share all possible strategies for solving equations, math teachers help students develop their math critical thinking strategies and learn new strategies from their peers (Parish, 2015).

Professional Learning Communities (PLCs): PLCs are groups of teachers working collaboratively to share best practices. In education, the goal of PLCs is to increase and widen teachers' instructional strategies through collaboration with peers, with the goal of increasing student achievement (Hord, 2013). The six aspects of PLCs are shared and supportive leadership, shared values and vision, collective learning and application, shared personal practice, supportive conditions and relationships, and supportive structures (Hord, 2013; Southeastern Educational Development Laboratory, 2015).

Professional Learning Community Assessment (PLCA): PLCAs (see Appendix D) are used to evaluate teachers' perceptions of school practices within a professional learning community (SEDL, 2015).

Significance

Studying teachers' perceptions of the effectiveness of PLCs for improving math pedagogy is significant for several reasons. PLCs may be a cost-effective way to develop teachers' math pedagogical content knowledge. Shulman (1986) emphasized the importance of developing teachers' pedagogical content knowledge, explaining that it was fundamental for improving student achievement. If leaders at the study site school

district desire to improve students' math achievement, they may need to increase their teachers' math critical thinking pedagogy. Therefore, the effect of PLCs on teachers' math pedagogy should be determined in the district, as it relates to critical thinking.

Determining if PLCs are an effective method of professional development will benefit the district, as it may change the current professional development strategy. As stated earlier, results from PISA assessments indicate that the math performance of U.S. students has remained stagnant as the scores of students in many other nations improve (Heitin, 2015). Because math achievement has remained stagnant in the study site school district, leaders need to act to address students' poor math achievement. The research results may encourage the district to offer more professional development and mandate the use of PLCs. Increasing teachers' abilities to help students think critically about mathematics may provide students with opportunities to compete in the future global economy (OECD, 2015).

Research Questions

The aim of the research questions was to determine if participating teachers perceived PLCs to be effective in improving their math critical thinking pedagogy. I gathered qualitative interview and focus group data (see Appendix G) on teachers' perceptions of the effectiveness of the PLCs. Specifically, I asked teachers questions about their perceptions of how PLCs affected their math pedagogy and if they believed the current structure of the PLCs were effective. I sent teachers the PLCA to examine their teachers' perceptions of the six professional learning characteristics. I analyzed

results of the PLCA and compared findings with the results of the teachers' focus groups and interviews. Quantitative data were collected via the Professional Learning Community Assessment. Focus groups and interview data were collected via the protocols authorized by Walden University and the school district under study.

Qualitative Research Questions

RQ1: What are teachers' perceptions of the effectiveness of PLCs for improving critical thinking pedagogy in mathematics?

RQ2: What are teachers' perceptions of how the structure of a PLC impacts its effectiveness, according to the six professional learning community characteristics?

Quantitative Research Question

RQ3: Is there a statistically significant difference in the mean score of the items on the six professional learning community characteristics on the PLCA and the teachers' responses?

H_A: There is a statistically significant difference between the mean score of the six professional learning characteristics on the PLCA and the teachers' responses.

H_o: There is no statistically significant difference between the mean score of the six professional learning characteristics on the PLCA and the teachers' responses.

Review of the Literature

The major themes in the review of the literature are constructivism, critical thinking, professional development, and PLCs. The literature analysis has two sections: A presentation of the study's conceptual framework of constructivism and a review of the

broader problems of professional development, critical thinking, and PLCs. I conducted a comprehensive search using Educational Resources Informational Center (ERIC), Education Research Complete, ProQuest, government agencies, professional math information, and various libraries. Search terms used to locate research for the section included *professional learning communities*, *collaboration*, *critical thinking*, *critical thinking pedagogy*, *professional development*, *professional learning*, *math pedagogy*, *knowledge frameworks*, *student achievement*, *school improvement*, *math achievement*, and *math improvement*.

Conceptual Framework

The conceptual framework for the study was based on Olivier et al.'s (2016) research regarding PLCs and school reform. The framework presents a new approach to assist leaders and external change agents in guiding schools toward maintaining high level PLCs. The conceptual framework evaluates PLCs with a Professional Learning Community Assessment helping school reform move from initiation to implementation, with the goal of high functioning PLC (Olivier et al., 2016). Olivier et al.'s (2016) PLC research follow's Hord's PLC studies regarding successful school reform using PLCs. Their research defined critical characteristics of effective PLCs. It is imperative that stakeholders implement these characteristics to foster efficient improvements in schools. The important PLC characteristics include shared and supportive leadership, shared values and vision, collective learning and application, shared personal practice, and supportive conditions (Olivier et al., 2016).

Senge (1990) developed a business approach to encourage people to work collaboratively on shared vision development, problem-solving, and collaborative learning. Senge's idea of collective collaboration made its way into the educational world. Shirley Hord built upon Senge's concept and applied it to education (Hord & Hall, 2014). Hord coined the term professional learning community to describe a process in which a school is structured into a culture in which staff work collectively to make efficient and significant school improvements (Hord & Hall, 2014). Hord's questionnaire had 17 descriptors and five categories designed to help schools define their PLCs based on five PLC characteristics. This led to the development of an improved survey that was better able to identify the effectiveness of PLCs within schools. This new survey was named the PLCA, which was used in the current investigation. The 46-question survey is used to identify stakeholders' perceptions of their school's PLC, based on six PLC characteristics. The PLCA was "developed to more accurately represent the phases of development from initiation to implementation to institutionalization" (Olivier et al., 2016, p. 69). The PLCA generates more comprehensive information than Hord's PLC questionnaire (Olivier et al., 2016).

The PLCA assessed teachers' perceptions of PLCs based on six key characteristics. The first PLC characteristic was shared and supportive leadership, which Hord and Hall (2014) defined as power, authority, and decision-making that should be shared and encouraged by stakeholders. The second critical component of a PLC is collective learning and application (Olivier et al., 2016). Hord and Hall (2014) defined

collective learning and application as the continuous collegial collaborative learning of school staff.

The next PLC dimension is shared personal practice (Olivier et al., 2016). Hord and Hall (2014) defined this as an environment that creates situations in which teachers can observe and learn from others. The fourth characteristic is supportive relationships which addresses teachers' level of collaboration and trust. The fifth PLC characteristics is supportive structure which provides schools with information related to time allocated for PLC meetings and teacher collaboration. The fourth and fifth PLC characteristic gives schools data related to school environments that "support staffs' organization of structure and relationships as a professional learning community" (Olivier et al., 2016, p. 22). The last critical aspect of a PLC is shared vision and values (Olivier et al., 2016). As Senge (1990) explained, "You cannot have a learning organization without a shared vision" (p. 209). The characteristic is defined as the development of a group of common goals and purpose for the school among stakeholders and will provide information related to shared school vision (Olivier et al., 2016).

The concept of PLCs is based on the constructivist theory because learning is done collaboratively and actively in social environments (Hord & Hall, 2014). The PLC framework relates to the constructivist theory that people make meaning of interaction between their experiences and their ideas (Piaget, 1968). The theory of collaborative learning allows teachers to build upon prior knowledge and sharing of ideas (Hord & Hall, 2014). Olivier et al. (2016) found that schools with staff who participated in

continuous reflection and inquiry formed highly functional PLCs that fostered constant improvement in teachers' performance. Learning that occurs in PLCs is based on participants' abilities to use prior knowledge to make effective changes and good decisions. PLCs build long-lasting, powerful ideas that participants can use to shift and grow as they encounter change. A review of the broader problem associated with critical thinking and PLCs are included in the sections that follow.

Review of the Broader Problem

The problem that prompted the study was low math achievement in the district under study. The low math student achievement in the district leads to a broader problem of poor math achievement in the United States compared to other countries. According to OECD (2017), the United States performed below average on the PISA in 2012 in math with a ranking of 26. The United States performance in math is comparable to Hungary, Italy, Norway, Portugal, and United Kingdom, and Viet Nam (OECD, 2016). Furthermore, the United States spends 62,000 more per student on education which is more than most countries which does not translate to higher performance (OECD, 2016). School districts are continually searching for cost effective ways to improve students' critical thinking skills. Students in the United States will not be able to compete in a global economy if their math critical thinking skills are not improved. PLCs are powerful tools that leaders can use to foster school reform.

Professional Learning Communities

PLCs foster teacher collaboration and improved focus on student and teacher

learning (Dufour, 2016; Hord & Hall, 2014; Olivier, Hipp, & Huffman, 2016; Thessin, 2015). In addition, PLCs embody social constructivism, as the social aspect of PLCs helps teachers learn from each other. Teacher collaboration leads to more effective instructional strategies because they allow teachers to share and learn best practices (DuFour, 2016; Hord & Hall, 2014; Olivier & Hipp, 2016; Owen, 2014). Hord and Hall (2014) further stated that PLCs' continuous cycle of data analysis, reflection, and action research improves student achievement. Improved school culture and student centeredness are byproducts of well-structured PLCs (Hord & Hall, 2014).

Senge (1990) introduced the term *learning community* to describe a continual way for people to learn how to learn and work together. His approach was to bring people together to discuss more effective ways of achieving defined goals. Senge's idea followed the constructivist belief that people learn efficiently when working in social settings. Senge (1990), Dufour, (2016), Hord and Hall (2014), and Olivier et al. (2016) all believed in collaboration as a means of improving learning and efficacy.

Professional development. Continuous professional learning in communities of co-workers, as recommended by Senge (1990) and Hord and Hall (2014) are especially important for new teachers. Senge (1990) and Hord and Hall (2014) recommended that new employees be aligned in ongoing PLCs to increase the learning curve for new employees through collaboration more experienced peers. Wells and Feun (2013) discussed the importance of using PLCs to reach a continuous state of professional development, which is consistent with Dewey's (1938) idea that learning is a lifelong

endeavor through social situations. Dewey (1938) believed that people learned best by doing things and being engaged with people while learning. Wells and Feun (2013) compared two school districts that used PLCs and found that sending teachers out of the building for professional development was ineffective. Wells and Feun's (2013) revealed that professional development teachers receive offsite did not pertain to their specific professional development needs. Also, teachers are sent out of the school for professional development and are expected to pass new information on to their colleagues without a clear structure for reteaching in their home school (Wells & Feun, 2013). External professional development is an aging model and district administrations need to act on research that indicates external professional development is ineffective. Providing continuous professional growth and development is important to improving teacher pedagogy and increasing student achievement. Dewey (1938); Hord and Hall (2014); Senge (1990); and Wells and Feun (2013) believed that learning should be integrated within a person's environment for an efficient lifelong way of learning.

Killion (2015) conducted an international comparison study over eight years, which indicated that math professional development improves teachers' instructional skills and drives student achievement. Killion's (2015) study compared student achievement and teacher self-reports of their math professional development. Killion (2015) found that in high performing teachers, the PLC holds each other accountable to ensure everyone is successful. States are developing new ways to provide teachers with opportunities for professional growth and evaluate the effectiveness of these learning

opportunities (U.S. Department of Education, 2014). The main objective of the new professional development systems is to support the continuous growth and development of each teacher (GaDOE, 2014).

Killion (2015) posited that professional development should be job-embedded and consist of continual collaboration. Other researchers (Hord & Hall, 2014; Killion, 2015; Senge, 1990; Wells & Feun, 2013) suggested that collaboration should occur between teachers teaching the same content. Olivier et al. (2016) discovered that teachers job satisfaction improved when PLCs were supported consistently by administration. PLCs can provide teachers with the continuous growth that states require, including enhanced critical thinking pedagogy.

New teachers need ongoing professional development which is often not provided in their preservice training. Choy and Pou San (2012) found that the preservice training new teachers receive does not include pedagogical content knowledge for math critical thinking skills. Steele, Brew, Rees, and Ibrahim-Khan (2013) found that preservice elementary teachers were apprehensive about teaching math. Crosswell and Beutel (2012) discovered an urgent need for professional learning programs for beginning teachers as they need more professional development that teaching programs encompass. New teachers, even those who are well prepared, often join the profession feeling the need for more professional learning. New teachers are often self-reflective, evaluate their own instructional strategy gaps, and seek professional development opportunities to

improve upon their weaknesses (Crosswell & Beutel, 2012). PLCs benefit new and experienced teachers.

PLCs focus on the pedagogy of critical thinking that might benefit new teachers as well as veterans of the profession. Most elementary teachers lack instructional strategies that target critical thinking skills in mathematics (Selling, Garcia, & Ball, 2016). Choy and Pou San (2012) surveyed 60 teachers in Malaysian institutions of higher learning and found that teachers did not reflect on their instructional strategies. The teachers analyzed whether they taught content but did not reflect critically on their instructional strategies. Although the study was small and findings are not generalizable to a larger population, it indicated a need for teachers to practice ongoing accountability and collaboration with peers, which PLCs typically provide. The results of the study emphasized continuous social learning and collaborative conversations which are key components of the constructivist view.

Choy and Pou San (2012) found that teachers wanted to be able to teach critical thinking strategies but lacked the instructional skills to engage students in critical thinking. According to Choy and Pou San (2012), district leaders must provide teachers with relevant professional development opportunities to improve upon these skills. Olivier and Huffman (2016) discovered that schools and districts can made improvements to instructional strategies with six key components of PLCs which are shared and supportive leadership, shared vision and values, collective learning and application, shared personal practice, and supportive relationships and structures. Olivier

and Huffman (2016) indicated that when district employees collaborated with school employees using six key characteristics, teacher quality and student performance were significantly enhanced. Schools in Shanghai and Japan provide the type of professional development necessary for continuous professional development (Salleh & Tan, 2013).

Collaborative learning. In Shanghai and Japan, PLCs are an effective collaborative structure that support new teachers. Salleh and Tan (2013) stated that educators in Singapore, Hong Kong, China, and Japan use collaboration to improve instructional practices. Salleh and Tan also indicated that new teachers in Shanghai and Japan received vital mentoring from learning communities at the beginning or their careers and are provided with extra professional development and time with an experienced teacher to help them learn effective teaching strategies. New teachers are guided through their first few years with collaborative help from other teachers. In addition, new teachers benefit from the Dewey's constructivist beliefs as well as the ideas that PLCs allow learning to be done socially, and learning is improved through collaborative inquiry (Dufour, 2016; Hord & Hall, 2014; Olivier et al., 2016). Salleh and Tan (2013) stated that collaborative work helps new teachers receive the support they need to teach effectively. Based on research, the National Commission on Teaching and America's Future made recommendations that new teachers become deeply involved in PLCs (National Commission on Teaching and America's Future, 2014). PLC characteristics draw upon previous research (Hord & Hall, 2014; Killion, 2015; Olivier & Huffman, 2016; Senge, 1990; Vygotsky, 1978) that promotes teacher collaboration to

share ideas and improve learning. Kyounghye and You-Kyung (2012) found that Korean teachers' use of PLC characteristics, such as collaborating on curriculum development, sharing best practices, and reviewing student data, helps Korea consistently place at the top of PISA math rankings (Kyounghye & You-Kyung, 2012). Korean teachers are taught to continuously monitor and improve their instructional strategies. Continuous self-evaluation and pedagogical improvement are consistent with PLC models. Similarly, Choy and Pou San (2012), Salleh and Tan (2013), and Kyounghye and You Kyung (2012) found PLC characteristics were effective for improving learning among teachers in Japan, Shanghai, and Korea. Attard (2012) and Owen (2014) also found that the traits of PLCs in Europe created effective professional development.

While most teachers value PLCs, researchers (Gray et al., 2014) indicate that some teachers have difficulties building trust in co-workers, which can impede collaboration. Attard (2012) conducted a 1-year study among seven teachers participating in a PLCs and found that teachers should have opportunities to participate in and benefit from PLCs. Attard observed that PLCs became a collaborative process among every member and involved sharing and analyzing new information. In another study, Leclerc et al. (2012) found that teachers took responsibility for becoming leaders, analyzing their pedagogy, and completing peer evaluations improved their pedagogy, which all align with the constructivist theory of social learning.

Owen (2014) conducted a study on 52 Australian teachers in three schools and found that 80% to 97% of teachers responded to questions regarding key PLC

characteristics with a 4 or 5 on a 5-point scale. An interesting aspect of the 1-year study was that schools increased school achievement by using key PLC characteristics (Owen, 2014). Australia ranked 17th out of 64 countries in math (OECD, 2015). Similar PLC components are used in Singapore, which along with Korea, also have high PISA rankings. According to Harion and Dimmock (2012), Singapore's use of PLCs contributed to the country's rank of second out of 64 countries in math achievement. An important aspect supporting PLCs, in Harion and Dimmock's research, was that Singapore's education administration respects the PLC model strongly enough to implement PLCs in an otherwise hierarchical atmosphere. Despite Singapore's strong top-down administrative culture, the importance of shared educational leadership and collaborative teacher learning are considered essential to leading the world in math education (Harion & Dimmock, 2012).

As outlined above, integrating the critical characteristics of PLCs is essential to collaborating for improved student performance and learning (Attard, 2012; DuFour, 2016; Harion & Dimmock, 2012; Hord & Hall, 2014; Leclerc et al., 2012; Olivier et al., 2016; Owen, 2014; Senge, 1990; Vogotsky, 1978; Wadsworth, 1996). Other countries such as Korea, China, Japan, Singapore, and Canada have all shown significant achievement on the PISA rankings (OECD, 2016). Embedding PLC characteristic of shared learning into schools helped provide substantial success for these countries (Choy & Pou San, 2012; Dimmock, 2012; Kyounghye & You Kyung, 2012; Owen, 2014; Salleh & Tan, 2013).

Thessin (2015) observed 28 teachers in a midsized urban school district and found that certain characteristics were critical to the success of PLCs. Thessin stated that high-performing PLCs had most of the PLC characteristics of collaborative work, shared vision, focus on improved student learning, shared leadership, and presence of certain cultural conditions. Thessin's research revealed that 78% of elementary teachers and 67% of middle and high school teachers established goals for every student to perform at a high level of achievement. Thessin's study can be compared to the PLC studies of other countries. According to Hord and Hall (2014), the PLC component of collaborative learning can increase student achievement in schools around the world. When schools use PLCs, they perform more efficiently, increase teacher pedagogy, and increase student achievement (Hord & Hall, 2014).

Teachers become more effective and student achievement improves when members of PLCs collaborate to compare student data and assist each other to improve instruction (DuFour, 2006; Hord & Hall, 2014; Olivier et al., 2016). Olivier and Huffman (2016) found that when school districts' central offices supported school PLCs to foster collaboration, student achievement increased. Professional learning communities allow teachers to share best practices and sharpen their instructional strategies (Hord & Hall, 2014). The PLC process improves teachers' pedagogy by allowing them to debate and challenge each other within their communities. Spirited conversations with peers who teach similar content can improve teachers' instructional practices and student achievement (Owen, 2014). Educators must work collaboratively

and assume joint accountability for student achievement (DuFour, 2016). Teachers' instructional strategies become more varied and more effective when collaborative professional learning takes place (Killion, 2014). According to Killion (2014), student achievement increases when teachers learn better instructional strategies.

Churchin (2013) revealed that increases in student achievement can occur when schools use PLCs as an intervention. A Texas school for at-risk students improved students' pass rates on standardized tests from 19% to 70% between 2002 to 2011 (Churchin, 2013). PLCs were an intervention the school emphasized to make gains in student achievement during that 9-year period. Implementing key PLC characteristics of teacher collaboration, shared vision and values, and shared leadership resulted in significant improvements to students' achievement.

The conceptual framework of improving pedagogy through PLCs is grounded in theories from Dufour (2016), Hord and Hall (2014), and Olivier et al. (2013). A review of the research indicated that PLCs improve the skills of new and experienced teachers, increase the rankings of countries that integrate PLCs into their schools, and improve teachers' instructional strategies with professional learning characteristics. Characteristics of PLCs that improved teachers' effectiveness are shared leadership, collaboration, shared vision, collective learning, shared personal practice, and supportive structures (Olivier et al, 2016). The next section provides professional literature with evidence of critical thinking math pedagogy as a problem.

Critical Thinking

The previous section included a review of PLCs as the most efficient way to improve teachers' pedagogy. The current research literature reviewed below relates to improving teachers' math critical thinking, and content knowledge pedagogy. A key concept of constructivism is that learning is constructed via by using prior knowledge to build new knowledge (Vygotsky, 1978), which connects to the conceptual theory of the current study on PLCs. PLCs create an environment in which the knowledge teachers have learned previously can be expanded upon via peer collaboration (Hord & Hall, 2014). In the next section, I discuss how critical thinking learning evolves in stages using Bloom's (1956) levels of intellectual learning.

Stages of critical thinking. Bloom (1956) organized knowledge into six levels, known as Bloom's Taxonomy, which range from simple to very difficult and requiring abstract thought. Bloom believed was that learning at high levels requires careful preparation and execution. Professional learning communities are based on the idea that prior knowledge and collaboration create new knowledge (DuFour, 2014).

The six categories of Bloom's (1956) framework include knowledge, comprehension, application, analysis, synthesis, and evaluation. Bloom's idea was that learning at a higher level was preceded by understanding knowledge of the higher domains. Bloom's intent on creating the domains was to motivate educators to reach higher domains and move students to higher levels of thinking. Teachers need ongoing professional development to understand the many angles of critical thinking that Bloom's

Taxonomy requires. Bloom and Webb (1997) both ranked types of thinking or learning by their difficulty.

Webb is a mathematics educator at the University of Wisconsin who leads reform on how mathematics and science are evaluated (University of Wisconsin, 2015). Most of Webb's research encompasses the evaluation of students' knowledge of math. Webb created four depth of knowledge categories that educators can use when striving to create more rigorous tasks for students. The categories, ordered from lowest to highest, include recall, skill/concept, strategic thinking, and extended thinking. Webb's Depth of Knowledge created common language to understand cognitive demand in assessment, curriculum, lessons, and tasks (Webb, 1997). Teachers need ongoing professional development to understand and integrate Webb's categories and to increase students' math critical thinking.

Piaget (1968) also believed thinking occurs in stages that become more sophisticated as people get older. Piaget (1968) identified four stages of cognitive development, which are categorized by age. The sensorimotor stage consists of birth to 2 years; preoperational occurs between the ages of 2 years and 7 years; concrete operational occurs between the ages of 7 years and 12 years, and formal operational occurs from age 12 and up (Piaget, 1968). Piaget's work indicated that humans have an innate need to develop critical thought to reason from many angles. If the critical thought process is cultivated early in the development of students' math knowledge, then math critical thinking can begin at an early age. Piaget's research falls within the theory of

PLCs, similar to work by Bloom (1968) and Webb (1997), as the new knowledge can be attained from prior knowledge with collaboration. Professional learning communities nurture teacher conversation and collaboration (Dufour, 2016; Hord & Hall, 2014; Olivier et al., 2016), and the collegial conversations that PLCs generate might help teachers understand the various stages and intricacies of critical thinking. Based on research that knowledge is built upon prior knowledge, Butera et al. (2014) discovered the need for teaching critical thinking skills at an early age.

Math critical thinking at an early age. Research indicates that critical thinking should be integrated early in the elementary curriculum (Butera et al., 2014). The United States Department of Education funded a 5-year study on 783 children in five states where the preschool curriculum included critical thinking in mathematics (Butera et al., 2014). Some students were given a traditional curriculum, while others were given curriculum comprised of continual critical thinking strategies and steps. Qualitative data were collected by case studies, collection of themes, cross site analysis, and across the years. Butera et al. found that the math critical thinking curriculum significantly improved math achievement, as compared to students who used the traditional curriculum. The study involved 45 classrooms and 33 teachers. Preschool students who were taught the more difficult curriculum possessed the critical thinking strategies to solve difficult situations. Butera et al. (2014) stated that the students who were not taught problem-solving skills could not complete difficult math equations. Early educators may lack deep mathematical content knowledge, which leads them to avoid teaching difficult

skills due to their own insecurities (Butera et al., 2014). Math professional development is often overlooked in early elementary grades (Butera et al., 2014). Butera et al. indicated that the process of teaching critical thinking should be done in stages and should start early in the elementary grades.

Teachers need ongoing professional development to understand math critical thinking strategies. Courey, Siker, and Paik (2012) also investigated critical thinking in the early grades and found that specific instructional strategies targeting critical thinking for third graders' improved students' mathematical problem-solving skills. The researchers analyzed 67 third grade students' critical thinking math strategies using real life math scenarios in conjunction with schema problem-solving strategies. The researchers discovered a significant improvement in math skills when students were taught using the critical thinking strategies along with real-world math problems. Higher order instructional strategies helped the students master their own critical thinking strategies. In addition, the critical thinking instructional strategies helped below level students catch up to the levels of their peers. Butera et al. and Courey et al. (2012) both posited that critical thinking should be taught at an early age.

Critical thinking pedagogy. Mulnix's (2014) research revealed similar results to that of Courey et al. (2012). Mulnix found that teaching critical thinking skills requires specific instructional strategies that are not fully embedded in current teaching methods. Mulnix stressed that overlooking the importance of improving critical thinking results in the neglect of students' essential skills. He further stated that professional development

for math critical thinking skills was increasingly central to education in the twenty-first century. Killion (2015) conducted an international comparison study over several years and found that math professional development improved teachers' critical thinking instructional skills and drove student achievement.

Taiwanese teachers changed the way they taught because of national curriculum reform (Leung, 2013). According to Leung (2013), teachers in Taiwan used PLC characteristics to pose problems, teach students to think critically, and solve problems using varied strategies in math. When teachers change their instructional strategies, they need professional development (Leung, 2013). Leung stated that further research was needed to determine the most effective strategies for implementing problem-solving and critical thinking tasks, which improve student performance on math problems that require higher order thinking. Nargundkar, Samaddar, and Mukhopadhyay (2014) concurred with Mulnix (2014), Leung (2013) and Killion (2015) regarding the importance of improving teachers' critical thinking pedagogy.

An important aspect of Nargundkar's et al. (2014) research was that teachers' abilities to provide students with strategies to think critically increased student achievement. Nargundkar et al. found that when high school students used critical thinking skills to solve problems, their scores on departmental final exams increased by an average of 24%. If students learn critical thinking skills during the early years of their education, they may be better equipped to compete in a global economy.

Sanchez and Pou San's (2012) research indicated the need for improved critical thinking pedagogy among teachers. They found that educators understood the importance of teaching critical thinking skills; however, they often lacked the instructional strategies to do so in mathematics. Teachers have had little success in developing students' critical thinking skills in the classroom using current methods. Sanchez and Pou San stated that teacher preparation programs and professional development opportunities must teach the pedagogy of critical thinking in mathematics. The scholars also referred to research conducted in June of 2014 by the National Council on Teacher Quality, which indicated that colleges of education fail to prepare students to teach math, reading, and science. Collaborating and sharing best practices through PLCs could help teachers understand improved instructional practices for math critical thinking.

Magee and Flessner (2012) also discovered the need for ongoing math critical thinking professional development. The scholars found that teacher educator programs may emphasize the importance of inquiry-based learning; however, university teacher education programs rarely educate students on the use of inquiry-based learning. Ongoing, cost-effective professional development is needed to help new teachers learn from veteran teachers. Magee and Flessner found that once teachers left their teacher educator programs, they were uncomfortable teaching inquiry-based learning. Leaders of universities in the study evaluated methods used in classes for new teachers and realized they had not developed environments for their students to learn inquiry-based teaching

practices. PLCs could be used to help new teachers learn inquiry-based instructional strategies. Butera et al. (2014) and Courey et al. (2012) emphasized the need for teaching critical thinking at an early age, and Killion (2015), Leung (2013), Mulnix (2014), and Nargundkar et al. (2014) stressed the importance of improving teachers' critical thinking pedagogy.

Content pedagogy. Holmes (2012) revealed that teachers should assess themselves and their peers regarding content pedagogy. Teachers need a deep understanding of mathematical concepts and the best ways to teach them. Holmes suggested that classroom teachers should be asked questions, such as, "At what depth is a mathematical concept displayed by the teacher in the classroom?" Holmes indicated that teachers' instructional strategies directly affect student achievement; therefore, instructional strategies should be improved and measured.

Selling, Garcia, Loewenberg, and Ball (2016) stressed the importance of measuring teachers' mathematical content knowledge. Selling et al. (2016) explained that teachers with high scores on their knowledge for teaching survey significantly predicted the amount of student achievement growth. In addition, the researchers all suggested how important it was for teachers to have mathematical content knowledge, as well as pedagogical content knowledge, to increase student achievement (Holmes, 2012; Selling et al., 2016).

Holmes (2012) described two types of teaching frameworks, including content knowledge and content teaching. Content knowledge frameworks include Bloom's

(1956) taxonomy, Skemp's (1976) instrumental and relational understandings, Hiebert and Carpenter's (1992) procedural and conceptual understandings, and Webb's (1997) depth of knowledge. Holmes (2012) further explained that content knowledge for teaching frameworks included Schulman's (1986) type of teachers' knowledge and Ball's (2000) mathematical knowledge for teaching. Selling et al. (2016) described mathematical content knowledge for teaching as knowledge teachers must have and understand to enable them to effectively teach math. Selling et al. further stated that teachers need to have skills to analyze not only what is conventional to all mathematicians, but also be able to correct student understanding and conceptually relate content in practice. Teachers can also use knowledge frameworks to evaluate themselves and their peers. Content knowledge frameworks can be used for peers to evaluate student work, lesson plans, and academic tasks. For example, Webb's depth of knowledge can be used to analyze the level of rigor that students acquire from an academic activity (Webb, 1997).

Content knowledge teaching frameworks can be used by peers to evaluate how a teacher explains and delivers concepts when teaching. Selling et al. (2016) conducted a study that indicated elementary teachers were unable to explain how to prove mathematical problems. Selling et al.'s study indicated a need for teachers to learn about their strengths and weaknesses to improve their instructional strategies. Shulman (1986) stressed that teachers must understand what makes certain content easy or difficult to learn. Shulman (1986) also emphasized the importance of pedagogical content

knowledge and the need for teachers to be reflective when teaching. Holmes (2012) stated that knowledge frameworks can be used to identify and monitor higher order classroom instruction.

Brodie (2013) discovered teachers can improve their math content knowledge via collaborative conversation with other teachers. Brodie found that intense collaborative conversations between teachers about learners' errors and teachers' math content knowledge lead to improved instructional knowledge for all teachers involved. Brodie further explained that the development of teachers' math pedagogical content knowledge was such that it could not have been taught in a classroom or lecture. PLCs mold experiences that are tailored to students and teachers involved in their unique, temporal instructional experiences. Therefore, students can reach higher levels of achievement because the instructional strategies are specific to their needs. Holmes (2012), Brodie (2013), Selling et al. (2016) and Shulman (1986) agreed on the importance that teachers evaluate their content knowledge for teaching to increase their instructional skills.

PLCs provide structure for teachers to use knowledge frameworks to learn and analyze each other's instructional strategies, student work, lesson plans, and academic tasks. Shulman (1986) emphasized the importance of teachers sharing what they know. Hord and Hall (2014) also stated that teachers should build on instructional strategies learned from their peers by participating in larger learning communities. PLCs also help teachers identify their weaknesses and allow other teachers to share their best practices. Continuous monitoring and fine-tuning of instruction encourages higher-order thinking

and increases student learning and achievement (Holmes, 2012). PLCs allow teachers to use knowledge frameworks to share, evaluate, and adjust higher-order instructional strategies. Knowledge frameworks help teachers discuss their content knowledge for teaching to improve instruction and student achievement (Selling et al., 2016). Holmes (2012), Hord and Hall (2014), and Shulman (1986) all agreed that teachers should share what they know with other teachers to increase pedagogical skills. Holmes (2012) also indicated that more research is needed about knowledge frameworks.

Holmes (2012) discussed the importance of using Bloom's taxonomy to evaluate teachers' content knowledge in mathematics. He indicated the importance of teachers knowing how to teach mathematics content, as well as critical thinking skills. Holmes emphasized the importance of assessing teachers' math content knowledge using Bloom's taxonomy and implied that higher levels of math and critical thinking content teaching knowledge is necessary to increase students' levels of higher order thinking in math. PLCs may help teachers to continuously monitor, evaluate, share, and learn effective critical thinking and math pedagogy, supporting beliefs of Hord and Hall (2016), Shulman (1986), and Holmes (2012), that teachers need to increase their critical thinking pedagogy.

Higher order math assessments. Herman and Linn (2014) indicated that state assessments are changing to evaluate higher order thinking. The United States has invested in the Partnership for Assessment of Readiness for College and Careers (Herman and Linn, 2014). According to Herman and Linn, the assessment requires students to use

higher order thinking to justify their answers to opened-ended questions. The authors explained that state assessments will not only test content but will also evaluate students' critical thinking skills (Herman & Linn, 2014).

Georgia has developed a new assessment called Georgia Milestones, which consists of multiple choice and open-ended questions that require students to justify their answers in written form (Georgia Department of Education, 2014). Herman and Linn (2014) stated that the new assessment will have more questions in the two highest levels of Webb's (1997) depth of knowledge, which are strategic thinking and extended thinking. The higher levels of Webb's depth of knowledge requires students to use metacognitive skills to plan and solve problems on the assessment (Herman & Linn, 2014). Herman and Linn assert how depth of knowledge capabilities are essential to success in the twenty-first century. Thus, educators must concentrate on developing deeper learning to help the U.S. students compete on international assessments with students in the highest-performing countries (Herman & Linn, 2014). Preparing for the new assessments will be challenging for schools. For example, Korea struggled to transition their educators to teaching higher-order thinking but used the characteristics of PLCs to improve teachers' math pedagogy. Pedagogical improvement helped Korea to consistently achieve high PISA math rankings (Kyounghye & You-Kyung, 2012).

Finding effective ways to implement professional development for pedagogy regarding math critical thinking skills is important for schools to be effective in the

future. Professional learning communities are a cost-effective way that schools can sustain ongoing professional development for math critical thinking pedagogy.

Implications

Without research on the effectiveness of PLCs, school districts cannot know if PLCs effect teachers' math critical thinking pedagogy. PLCs give teachers opportunities to collaborate and improve their pedagogy. If district leaders do not know if they are helping teachers with critical aspects of their pedagogy, such as math critical thinking, they will not know whether to continue to invest in PLCs. If the findings indicate that PLCs are effective in improving teachers' math pedagogy, then districts know to invest time, energy, and training in to PLCs in the district.

The project for my study will be a presentation that guides schools' PLCs and addresses math critical thinking content knowledge for teaching as well as math content knowledge. The data I obtained from the study may be used to help schools focus on how to integrate the PLCs and math critical thinking content knowledge in to the routine within their school. Initiating the PLC routine into schools will be done by incorporating the characteristics of PLCs which are: shared and supportive leadership, shared values and vision, collective learning and application, shared personal practice, supportive conditions and relationships, and supportive structures. The presentation could be a PowerPoint used to train PLC leaders in the building and help organize building level PLCs so that they address a deeper pedagogy such as math critical thinking.

The consequences of not conducting the study will be that the district of study w

not know if their PLCs are efficiently improving their teachers' math critical thinking pedagogy. If the study had not been conducted the district will not know if the PLCs are worth the time and energy they are putting in to them. Choosing to forgo the study, may have resulted in lost time and money for the district of study.

Summary

PLCs can be an effective strategy to improve teacher pedagogy (Hord & Hall, 2014). Key findings from research on professional development and PLCs indicate the importance of teacher collaboration to share, learn, and employ best practices to improve pedagogy. Researchers found teachers often lack the knowledge and skills to teach math critical thinking (Holmes, 2012). Research on students' math achievement and math pedagogy revealed that continually increasing teachers' pedagogical content knowledge is critical for improving student math achievement.

Qualitative research on the effectiveness of PLCs is abundant; however, research on math critical thinking pedagogy is scarce. Minimal research has been done on pedagogical content knowledge for teaching; thus, a gap exists on the effect that PLCs have on math critical thinking pedagogy. Previous researchers examined the effect of PLCs on student achievement but have not specifically analyzed critical thinking or math pedagogy. Therefore, a study that analyzed the effectiveness of PLCs' to improve math critical thinking pedagogy was warranted. The current study provided valuable information in the field of PLCs and math pedagogy.

In Section 1, I identified the problem of the study and provided a review of literature that included the conceptual framework of PLCs and the effect of PLCs on teachers' pedagogy. The review of literature provided evidence of the local problem, as well as evidence of the problem from professional literature. Section 2 includes an explanation of the mixed methods design and approach, qualitative and quantitative data collection strategies, and the setting and sample. A description of the data analysis process is also provided. Section 3 incorporates the project description, evaluation plan, and review of literature. In Section 4, I reflect on the importance of the research, provide directions for the future, and recommendations for alternative approaches.

Section 2: The Methodology

The purpose of the study was to analyze teachers' perceptions of PLCs' effect on math critical thinking pedagogy. I used the explanatory sequential mixed methods design to obtain rich focus group and interview data and triangulate with information from the PLCA. I used the PLCA to gather quantitative information on teachers' perceptions of their schools' PLCs and their effect on pedagogy, in terms of Olivier et al.'s six PLC characteristics. The sequential aspect of the study began with the PLCA and then moved to focus groups. Finally, I conducted individual interviews to gather more detailed information and expand upon the previous data. Follow-up questions during the interviews were tailored according to a combination of results from the PLCA data and the main interview questions.

Mixed Methods Design and Approach

I chose the mixed methods design to develop a rigorous study that allowed me to analyze qualitative data and create a rich narrative of teachers' perceptions of PLCs. The qualitative focus group data, along with the quantitative analysis of the PLCA's Likert data, provided insight into teachers' perceptions of how PLCs effect critical thinking math pedagogy. McKim (2015) found that graduate students regarded mixed methods studies to be more rigorous than quantitative or qualitative methods alone. Creswell (2012) asserted that the mixed methods design allows for the compensation of weaknesses of individual methods.

The quantitative data for the study was collected via an online PLCA, which

participating teachers responded to. The qualitative data consisted of two teacher focus groups comprised of six teachers from each school. There will be four teacher interviews, two from each school. The depth of interview and focus group data provided rich context for the information gathered from the PLCA. In addition, the increased number of teacher responses on the PLCA helped offset the limited responses acquired from the interviews and focus groups. Creswell (2012) indicated that mixed methods designs provide data with greater depth because they draw upon qualitative and quantitative methods rather than a single method. The mixed methods design also provides enhanced credibility because of the multiple types of data that are used (Lodico, Spaulding, & Voegtle, 2010). Therefore, I chose the mixed methods design that utilized the PLCA, interviews, and focus groups to increase credibility, improve rigor, and offset weaknesses of each individual method.

An explanatory sequential mixed methods design that provided two phases was the most effective research design for the study. Quantitative data were obtained first as a foundation for further analysis of the problem through qualitative data. Concurrent data collection would not have allowed for qualitative interview questions to be shaped by quantitative data; therefore, the use of a sequential explanatory mixed methods design that enabled qualitative questions to be shaped by quantitative data findings was appropriate. McKim (2015) analyzed students' perceptions of the value of methodological approaches and found that graduate students regarded mixed methods studies with more value. McKim (2015) states that the graduate students regarded a

mixed methods approach to have comprehensive information and a fuller view of a problem, opposed to data that is only obtained either from a descriptive detail of qualitative or numerical detail of quantitative information. Creswell (2012) stated that an explanatory design helps researchers analyze one layer of a multilevel system. In the current study, quantitative data provided broader information regarding teachers' perceptions of six professional learning characteristics. The survey data, in turn, allowed the qualitative data to reveal more comprehensive insights into teachers' perceptions of how PLCs affected their math critical thinking pedagogy. With the explanatory method, the quantitative information is obtained first to develop questions for the qualitative instrument. I chose the explanatory design because the comprehensive information from the PLCA was enhanced by data from interviews and focus groups.

Merriman (2009) and Lodico et al. (2010) stated that ethnographic analysis involves writing about cultural groups. I considered ethnographic analysis but did not choose the design because the study did not focus on the culture of a specific group, but on teacher pedagogy and the effect of PLCs. Instead, the mixed methods design was chosen to obtain quantitative and qualitative data from teachers regarding the effectiveness of Olivier et al.'s six professional learning characteristics. Merriam (2009) stated that narrative analysis is a design used to tell peoples' stories. I did not choose narrative analysis because stories were not the focus of the data collection. In summary, the sequential explanatory mixed methods design was the best design to analyze teachers' perceptions of the effect PLCs have on math critical thinking pedagogy.

The integration of multiple forms of data occurred in sequential order, beginning with the PLCA. The PLCA was introduced to teachers in a staff meeting. The teachers were then sent an invitation to participate in the survey. The email to the teachers included the PLCA link. The consent form is embedded in the beginning of the online survey. The PLCA was online, so data were generated and sent to me immediately after teachers completed the assessment. Next, I conducted offsite focus groups. I used results from the PLCA and focus groups to develop interview questions. I then performed offsite interviews and the results were coded into categories and themes. Finally, these data were triangulated to compare categories and themes from all three forms of data.

Setting and Sample

The study site district is a large district in a metropolitan area of Georgia. The total population of the school district is 816,000 students. The demographics in the district are 63% African American, 16% Hispanic, 11% White, 8% Asian, and 2% Other. The target population was elementary math teachers employed in the study site district. The principals are responsible for organizing and monitoring the PLCs. The selected schools had already implemented math PLCs. Part of the regular conversation regarding the math PLCs is sharing instructional strategies, including critical thinking instructional strategies. The math PLCs have been integrated into the two study site schools for at least 4 years. The math PLCs meet four times per year. The district math coordinator enhances the PLCs by including two math teachers from each school who attend quarterly math meetings. These meetings are designed to help school representatives

acquire new information and math strategies, which they then bring back to their schools. Critical thinking math strategies are discussed in these district meetings. To be eligible for the study, teachers must have taught math in one of the study site schools. The schools were chosen because they have similar demographics and have conducted math PLCs for at least 4 years. The elementary schools contained kindergarten through fifth grades. Participants were drawn from math teachers at the study site. I used a nonprobability convenience sample because I sought data from a small group of people and did not intend to generalize results to a larger population. Creswell (2012) stated that in convenience sampling, the researcher uses participants who are willing and available to participate. The PLCA survey was given to 51 elementary math teachers at two study site elementary schools. All the math teachers from both schools were asked to complete the PLCA. The large number of participants provided broad information regarding math teachers' perceptions of Olivier et al.'s six professional learning characteristics pertaining to the PLCA.

I used a purposeful sampling strategy to locate focus group participants from each of the study site schools. There was a pool of 51 elementary math teachers used in the study. There were two focus groups, one for each school. I selected one math teacher per grade level. The math teachers within each grade level were randomly chosen. Their names were drawn randomly. Six teachers from each school were asked to participate in each focus group, providing a total of 12 focus group participants. The teachers' experience ranged from 1 to 25 years. Fusch and Ness (2015) suggested that the size of a

focus group includes 6 to 12 participants, indicating that the sample size was large enough for a diverse group, yet small enough to allow group members to feel comfortable conversing with one another.

Purposeful sampling was also used to select two teachers from each study site school to be interviewed regarding their involvement in the focus groups. A total of four teachers were asked to participate in interviews after the focus groups were conducted. I selected teachers for these interviews based upon their active participation in the focus groups. A small number of participants in qualitative research can provide richer data (Lodico et al., 2010). I also used purposeful sampling to select the teachers for the PLCA.

The PLCs that have supported math teachers have been in place in the study site district for 4 years. The district math PLC representative attends quarterly meetings to obtain new math strategies to bring back to the school's math PLCs. The school principal organizes the PLCs, which take place four times per year.

To develop a good researcher-participant relationship, a study invitation and consent form preceded the PLCA. In the cover letter, I explained the purpose of the survey and described the importance of the potential subject's participation. The cover letter also explained that participation was voluntary, and that anonymity would be ensured to those who chose to participate. A consent statement was included at the beginning of the survey that indicated the study purpose and the participant requirements.

Ethical Treatment of Participants

I took precautions to protect study participants. Permission with approval number 12-06-16-0175019 was obtained from the Walden University's Institutional Review Board (IRB), as well as the study site district. The school district required complete approval from Walden University before the study was reviewed; thus, the study was approved by Walden University's IRB before the district reviewed the research. The district then granted study permission after an application was submitted the district (see Appendix G). Proper consent from the district involved obtaining completed consent forms from participants and the principals at each study site school. Walden University also required completed consent forms from the participants and school principals. Clear directions about the study were given to the participants prior to the consent forms being presented.

Conducting focus groups and interviews offsite helped differentiate my role as a teacher from my role as a researcher. In addition, focus groups and interviews were conducted outside of the schools to maintain participant confidentiality. I expressed respect for participants' time to build rapport. Prior to data collection, I obtained informed consent via signed consent forms.

Following interviews, participants reviewed transcripts to ensure accuracy. I also employed member checking to verify results of my analysis. I provided each participant with a draft of results so they could review my analysis for accuracy. Participants' names were coded to maintain confidentiality. I will keep all study-related data in a locked

filing cabinet in my home for a period of 5 years. The survey was distributed to the teachers via email using the SEDL PLCA online system, which allowed me to collect PLCA data, electronically and confidentially. The authors of the PLCA (Olivier et al., 2013) granted permission to use the survey for the research (see Appendix C). My professional role in the district as an instructional coach did not interfere with my research, as I was not in a supervisory role for any of the participants.

Data Collection Strategies

I employed interviews, focus groups, and the PLCA to examine teachers' perceptions of the effect of PLCs on their math critical thinking pedagogy.

Qualitative Data

Qualitative data were obtained via interviews and focus groups. Two focus groups were conducted, one for each school. Six math teachers participated in each of the focus groups. The pool of teachers from which final participants were chosen for the focus groups consisted of math teachers who taught kindergarten through fifth grade. One math teacher from each of the six grades was chosen and asked to participate. Teachers from grade levels that had more than one math teacher were randomly selected to participate by placing names in a jar from which one name was chosen. I obtained signed consent forms before conducting focus groups. The focus group questions were obtained from the dissertation of Rita Darlene Herrington of Walden University, who granted permission for me to use the questions in the current study (see Appendix F). The questions were adjusted to add math critical thinking elements. A total of seven

questions were presented to the focus groups. The focus groups were conducted outside the of study site schools and scheduled for approximately one hour. I recorded focus groups for accurate transcription. Focus group participants reviewed the transcripts for accuracy.

I conducted interviews after the focus groups took place, selecting interview participants based on their active focus group participation. I selected two teachers for the interviews from each school, making a total of four interview subjects. The interview participants were chosen based on their willingness to participate in the focus groups, with emphasis placed upon thought-provoking discussion leaders from whom others sought guidance and approval. I developed an interview protocol consisting of six questions (see Appendix H). Follow-up questions were added after I analyzed the PLCA and focus group results. The interviews were audio-recorded and then later transcribed using the software, Dragon Dictate. I scheduled interviews for 1 hour and conducted them off school premises. Saturation was achieved after four interviews. More interviews would have been scheduled if results did not indicate saturation. Fusch and Ness (2015) stated that saturation occurs when no new data is uncovered, and no new themes emerge. To ensure quality and trustworthiness of the data, I conducted transcript reviews and member checking. Then, I provided participants with copies of their interview transcripts and asked them to review for accuracy. Member checks and participants' review of data increase the credibility of qualitative research (Lodico et al., 2010).

I used data from the focus group and interviews to address the first research question:

RQ1: What are teachers' perceptions of the effectiveness of PLCs' for improving critical thinking pedagogy in mathematics?

The question generated narrative data regarding the teachers' perceptions of the effect of PLCs for improving their math critical thinking pedagogy. The focus group questions were adapted from Rita Herrington's interview questions to obtain deeper information regarding teachers' perceptions of PLCs' efficacy upon critical thinking math pedagogy. I developed the interview questions (see Appendix H), which aimed to expand upon the focus group questions and provide more specific information on teachers' perceptions of the effect of PLCs on their math critical thinking pedagogy. The questions from the interviews and focus groups created data that I used to address the second question.

RQ2: What are teachers' perceptions of how the structure of a PLC effects its effectiveness, and six professional learning community characteristics?

The focus group and interview questions targeted the six characteristics of PLCs described by Olivier et al. (2016), which included shared and supportive leadership, shared values and vision, collective learning, shared personal practice, and supportive conditions. The focus group questions produced in-depth details about Olivier et al.'s six professional learning characteristics, as well as insight into the structure of PLCs at the study site schools. There was sufficiency of data collection instruments in the interviews

and focus groups to answer the first two research questions. The focus groups lasted approximately 1 hour and took place outside of the schools. Interviews were conducted after completion of the focus groups. Two interviews were conducted with two teachers from each school, for a total of four interviews. Saturation was achieved with the initial four interviews. If saturation of the interview questions had not been achieved with four interviews, I would have conducted additional interviews.

I used a Word document to create a catalog system to track data and emerging themes and categories. The categories that emerged were identified, and the sources and corresponding data were entered in an Excel spreadsheet. Triangulation was integrated into the data analysis and collection process using the constant comparative method. Categories and themes were entered in to the Excel spreadsheet that contained all three sources of data, which were analyzed for reoccurring themes. Triangulation was a a natural process of the study, as the data was continuously compared.

The process of gaining access to the participants was achieved via email after proper authorization had been granted through Walden University, the school district, and the principals of both study site schools. Access to the district's employee email was made possible by my status as an employee of the district. The participants were emailed a Doodle link to establish a viable date for the focus groups to be conducted. The Doodle link allowed multiple people to agree on a date for their focus group by providing a chart that offered several dates for their consideration. After the dates of the focus groups had been decided upon, participants of the focus groups met outside of their respective

schools. The interviewees were contacted in the same manner via email after the focus groups had been completed.

My professional role in the district as an instructional coach did not interfere with my research, as I am not in a supervisory role for any of the teachers who participated in the study. I had no prior relationships with the teachers in either school. Further, I had never been employed at either of the two schools that were included in the study.

Quantitative Data

Quantitative data were collected through the PLCA survey (see Appendix B), which was designed to evaluate teachers' perceptions of the six PLC characteristics with regard toward their school's PLCs (SEDL, 2015). The questions for the quantitative portion of the study were taken from PLCA questions from Southwest Educational Development Laboratory (SEDL), an educational research organization. The PLCA is a Likert test containing four categories that represent the six dimensions of a PLC, as outlined by Olivier et al. (2016). There are 52 questions on the PLCA. The PLCA continues the work of a pioneer in the field of PLCs, Shirley Hord (Olivier et al., 2016). Olivier et al. designed the PLCA in 2013 to assess perceptions about the school's stakeholders related to six critical dimensions of a PLC (Olivier et al., 2016). The foundational framework for the study was based upon the work of Olivier et al. Therefore, it was appropriate to use their PLCA for the purposes of studying teachers' perceptions of their school's PLCs in relation to Olivier et al.'s six professional learning characteristics. Approval was granted to use the PLCA by Dr. Dianne Olivier (see

Appendix C).

The scores from the PLCA were calculated by SEDL and produced the mean and standard deviations of each question on the PLCA. The means were calculated using a scale of one through four with one indicating low agreement and four indicating high agreement. The standard deviation showed the variance of the scores. A subscale score of 3 or greater was indicative of a positive perception by teachers of the strength of practices of PLCs within the school. Therefore, a series of six 1-sample *t*-tests was performed, one for each subscale score, to see if any of the six subscale scores were significantly different from 3. R-v3.4 statistical software was used for the calculations and a 95% level of significance was set for the tests. The PLCA data revealed a broader perspective of teachers' perceptions of their school's PLCs.

Olivier et al. (2016) conducted rigorous field tests on the PLCA and determined it had sufficient internal reliability and validity. Cronbach's alpha internal consistency reliability coefficients were computed for six subscales of the measure that ranged from a low of .83 to a high of .93 (Olivier et al., 2016). The validity of the survey content was reviewed by 76 experts in the field, who analyzed the relevance of all 52 items on the instrument (Olivier et al., 2016).

Participating teachers received the survey through their schools' email systems. An email with a link to the survey was sent to all math teachers in the two study site schools. Teachers answered the survey questions using a 4-point scale reflecting their degree of agreement or disagreement with the question (SEDL, 2015). The SEDL system

automatically emailed survey results to me. The SEDL online survey calculated the raw data and provided the results in table format.

The PLCA data yielded numeric scores of Likert scale data related to the teachers' perceptions of the structure of PLCs and its effect on effectiveness related to Olivier et al. (2016) six professional learning characteristics. The survey was sent by email to kindergarten through fifth grade math teachers who participated in the study. Their permission to be surveyed was obtained in a consent form that was embedded before the PLCA.

I obtained permission from the school district to use the survey with participating teachers by submitting an application for approval to conduct research within the district. Once the study was approved by the district and Walden University's IRB, the survey was distributed to the teachers. I used the study site district's email system, as Walden University and the study site district required. The survey findings included means and standard deviations for each question. I was granted access to the data through SEDL after requesting it. The data was sent to me in a format by question, PLCA category, and summary. The raw data for the study is available by request from the researcher.

Research question three was answered by Olivier et al.'s (2016) PLCA survey information. Research question three is as follows: Is there a statistically significant difference in the mean score of the items on Olivier et al.'s (2016) six professional learning community characteristics on the PLCA and the teachers' responses? For question three, the means for the teachers' responses, and Olivier et al.'s (2016) PLCA

median were compared using a one sample *t*-test for each question. According to Fusch and Ness (2015), 95% of a normally distributed population is within 1.96 (95%) is within about 2 standard deviations of the mean. Therefore, a calculation can be done to determine an interval around the statistic of interest, which would contain the population parameter of interest for 95% of all possible samples.

Data Analysis

I conducted interviews and focus groups to collect the qualitative data to address research question 1, which explored the participants' perceptions of effectiveness of PLCs for improving critical thinking math pedagogy. Research question two was also addressed through use of interviews and focus group questions to establish the teachers' perceptions of the structure of PLCs in their schools. I used data from the PLCA to address research question three, which aimed at determining if a statistically significant difference existed between the mean score of the items on Olivier et al.'s (2016) six professional learning characteristics on the PLCA and teachers' responses.

The first step of data analysis was to identify data pertinent to the research questions. I used grounded theory to analyze the results and develop conceptual categories through which theories emerged from the data (Merriam, 2009). I then developed and organized categories to identify emerging themes. The transcript excerpts were coded and organized in Word documents and Excel spreadsheets to allow common themes to emerge. Fusch and Ness (2015) indicated that data saturation may be achieved in as few as six interviews, noting that striving for rich information instead of quantity is

ideal. Themes were tracked until it was determined that the interview data had produced a point of saturation. I also reviewed focus group data until it was evident that saturation had been reached. Creswell (2012) defined saturation as the "Subjective decision by the researcher that new data will not provide any new information for the developing of categories" (p. 433). Therefore, I determined that saturation had been achieved when no new information was obtained for the categories that were being tracked.

The systematic design of grounded theory involving three phases of coded data was utilized in the study (Creswell, 2012). Merriam (2009) contended that the process of assigning codes to data is how categories are established. Emphasis using codes analyzes the data in steps of open, axial, and selective coding (Creswell, 2012). Open coding is a process of making notes in the margins (Merriam, 2009). Accordingly, after I transcribed the interviews using Dragon Naturally Speaking software, I printed out the transcripts and made notes in the margins. Then, the codes were put into axial coding categories (Merriam, 2009). As the categories were formed, common themes emerged. Next, selective coding was achieved by organizing the common themes (Creswell, 2012). Merriam (2009) stated that the categories should be complete, mutually exclusive, conceptually congruent, and responsive to the research questions. I took care to ensure there was integrity within each category.

I analyzed categories from all data sets to identify larger themes that emerged. Trends, or lack of trends in the data, were analyzed to identify the teachers' perceptions of the effect of PLCs on their math critical thinking pedagogy. The triangulation of data

confirmed themes, trends, and patterns that emerged (Lodico et al., 2010). Triangulation was achieved by comparing themes from the results of the PLCA, focus groups, and interviews. Triangulation improves the accuracy and credibility of research results (Creswell, 2012).

The strategy for data collection was sequential. I first analyzed data from the PLCA using the PLCA online system, which totaled the data from the teacher surveys. Next, I conducted the two focus group discussions and analyzed resulting data prior to the individual interviews taking place. I adjusted follow-up questions according to the previous instruments' data. Finally, the interview and focus group data were coded and analyzed using the constant comparison method. Descriptive statistics were used with the PLCA by analyzing central tendency of mean and standard deviation. A subscale score of 3 or greater was indicative of teachers' positive perceptions of the strength of PLC practices within schools. I performed a series of six, 1-sample *t*-tests (one for each question on the PLCA) to see if any of the six subscale scores were significantly different from 3. I employed R-v3.4 software for the calculations. I analyzed variability by looking at standard deviations.

Creswell (2012) stated that interpretation of the findings involves making sense of the data by comparing it to previous studies and personal experiences. The interpretation revealed how the findings answered the research questions. It also analyzed limitations of the study, my reflections as the researchers, and contradictions or support as it related

to previous studies. The explanatory sequential design revealed teachers' perceptions of how PLCs effect math critical thinking pedagogy.

I improved the validity and reliability of focus group data by employing transcript reviews. Member checking was also employed, which improved the credibility of the focus group data. The PLCA was field tested to support its validity and reliability and has been used in numerous studies since 2003 (Olivier et al., 2016).

I integrated qualitative and quantitative data via an Excel spreadsheet. After the qualitative data were coded, I entered data into categories on the spreadsheet. The preliminary themes were carefully analyzed by reviewing each of the focus group and interview questions and responses and classifying all relevant information. The final themes emerged from constant comparison of data review and the classification process. The process of comparing categories of information is called constant comparison (Creswell, 2012). I conducted a constant comparative analysis on focus groups and interview data. The information obtained from the quantitative and qualitative findings were then used to address the four research questions of the study. The explanatory sequential analysis was conducted to explain the results of the PLCA and the themes from all focus groups and interviews. I then compared and triangulated data to determine if similar trends were revealed. Careful analysis was performed on all data to arrive at a summary of the findings.

Assumptions and Limitations

A limitation to the study was that it only involved two schools in the district. Due to the small number of schools and participants in the study, results cannot be generalized to all elementary math teachers. Also, the research was conducted in one district, preventing the generalization of study results to other populations. I was the only researcher interpreting data in the study among a small number of participants. Another limitation was time. The study was conducted during a single school semester. A longitudinal study may produce more information as to the keys toward developing effective PLCs for math achievement.

Data Analysis and Results

The following section is divided into four sections (a) structural approach and sequence of data collection, (b) quantitative analysis and findings, (c) qualitative analysis and findings, and (d) summary of outcomes as relates to the research questions and tests of hypotheses, as well as the larger body of literature and the conceptual framework of the research.

Structural Approach

The structure of the study was a mixed methods sequential design that allowed the data to evolve in stages from previous information for an exhaustive analysis of the problem. The sequential order of the data collected allowed for a thorough understanding of teachers' perception of PLCs effect on teachers' math critical thinking pedagogy. Three sequences of data collection were incorporated. First, quantitative data were

collected with the administration of the PLCA survey to $N = 22$ teachers from both schools. The second step in the sequence involved collecting qualitative information from two focus groups of mathematics teachers, one focus group at each school. The third and final step in the sequence involved qualitative data collection from four separate teacher interviews, in which two teachers from each of the two schools participated.

Quantitative Analysis and Findings

PLCA instrumentation. The PLCA survey was emailed with a cover letter and consent form to a convenience sample all elementary math teachers at two elementary schools in the school district who fit the inclusion/exclusion criteria of the study ($N = 52$ teachers). The survey was distributed to the teachers through email using the SEDL PLCA online system which allows PLCA data to be collected electronically and confidentially. Twenty-two anonymous responses to the surveys were returned and included in the study, a response rate of 42%.

The PLCA is comprised of six subscales: (a) shared and supportive leadership (SSL), (b) shared values and vision (SVV), (c) collective learning and application (CLA), (d) shared personal practice (SPP), (e) supportive conditions–relationships (SCR), and (f) supportive conditions–structures (SCS). The two supportive conditions factors of the PLCA (SCR and SCS) are sub-scales which assess Hord's (2014) single dimension of supportive conditions. The items and scoring for the six factors of the PLCA follow. For all six subscales, Olivier, Hipp, and Huffman (2016) state that PLCA subscale scores of 3 and 4 indicate a positive perception by teachers of the strength of practices of PLCs

within the school.

I chose the PLCA for my study due to the comprehensive nature of the data it produced. The PLCA teacher responses provided data directly aligned with Olivier, Hipp, and Huffman's (2016) six professional learning characteristics. Research question 3 inquired if there was a statistically significant difference in the median of the items on Olivier, Hipp, and Huffman's (2016) six professional learning characteristics on the PLCA and the teachers' responses. The PLCA generated the mean of teacher responses for every question on the PLCA that was contained within the six PLC characteristics. Therefore, Olivier, Hipp, and Huffman's (2016) PLCA provided data that directly aligned to research questions 1 and 2. The next section is a report of the quantitative data by theme.

Shared and supportive leadership (SSL). SSL was measured by PLCA items 1 through 11. SSL is a measure of how teachers perceive school administrators' willingness to share power, authority, decision-making and promote and nurture leadership among staff. Each of the items of the SSL construct was scored on a 4-point Likert-based scale from 1 = strongly disagree to 4 = strongly agree. Scores of the 11 items were then averaged for each teacher. The possible range of scores for the SSL construct are thus 1to 4, with higher scores indicative of a teacher's more favorable perception of the SSL attributes listed at the beginning of the paragraph.

Shared values and vision (SVV). SVV was measured by PLCA items 12 through 20. SVV is a measure of how a teacher perceives staff willingness to share visions for

school improvement and support norms of behavior. Each of the items of the SVV construct was scored on a 4-point Likert-based scale from 1 = strongly disagree to 4 = strongly agree. Scores of the nine items were then averaged for each teacher. The possible range of scores for the SVV construct are from 1to 4, with higher scores indicative of a teacher's more favorable perception of the SVV attributes listed at the beginning of the paragraph.

Collective learning and application (CLA). CLA was measured by PLCA items 21 through 30. CLA is a measure of how a teacher perceives staffs' willingness to share information and work collaboratively to plan, solve problems, and improve learning opportunities. Each of the items of the CLA construct was scored on a 4-point Likert-based scale from 1 = strongly disagree to 4 = strongly agree. Scores of the 10 items were then averaged for each teacher. The possible range of scores for the CLA construct are 1to 4, with higher scores indicative of a teacher's more favorable perception of the CLA attributes listed at the beginning of the paragraph.

Shared personal practice (SPP). SPP was measured by PLCA items 31 through 37. SPP is a measure of how a teacher perceives peers' willingness to offer encouragement and provide feedback on instructional practices. Each of the items of the SPP construct was scored on a 4-point Likert-based scale from 1 = strongly disagree to 4 = strongly agree. Scores of the seven items were then averaged for each teacher. The possible range of scores for the SPP construct are from 1to 4, with scores above higher

scores indicative of a teacher's more favorable perception of the SPP attributes listed at the beginning of the paragraph.

Supportive conditions - relationships (SCR). SCR was measured by PLCA items 38 through 42. SCR is a measure of how a teacher perceives relationships between students, teachers and administrators. Each of the items of the SCR construct was scored on a 4-point Likert-based scale from 1 = strongly disagree to 4s Strongly agree. Scores of the six items were then averaged for each teacher. The possible range of scores for the SCR construct are from 1 to 4, with higher scores indicative of a teacher's more favorable perception of the SCR attributes listed at the beginning of the paragraph.

Supportive conditions - structures (SCS). SCS was measured by PLCA items 38 through 42. SCS is a measure of how a teacher perceives the structure of the school, (i.e. size, proximity of staff, communication systems, etc.). Each of the items of the SCS construct was scored on a 4-point Likert-based scale from 1 = strongly disagree to 4 = strongly agree. Scores of the six items were then averaged for each teacher. The possible range of scores for the SCS construct are from 1 to 4, with higher scores indicative of a teacher's more favorable perception of the SCS attributes listed at the beginning of the paragraph.

The data were retrieved from the SEDL PLCA online system in summary form. Thus, only the mean and standard deviation for each of the 52 PLCA items and each of the six subscales, and the frequency counts of the item responses for each of the 52 PCLA items were available for analysis. Some subjective comments were also recorded

with the summary data. However, measures of internal consistency reliability, score ranges, and medians could not be computed for the collected data.

Table 3 includes the means and standard deviations for each of the 52 items and the six PLCA subscale scores. A subscale score of 3 or greater is indicative of a positive perception by teachers of the strength of practices of PLCs within the school (Olivier, Hipp & Huffman, 2016). Therefore, a series of six 1-sample *t*-tests was performed, one for each subscale score, to see if any of the six subscale scores were significantly different from a score of 3. R-v3.4 statistical software was used for the calculations and a 95% level of significance was set for the tests.

None of the six 1-sample *t*-tests, comparing the PLCA subscale scores to the value of 3 were statistically significant at the $p < .05$ level (see Table 3). Therefore, it was determined that the 22 teachers had positive perceptions of the strength of the practices of PLCs within their schools. The subscale score of SCR had the highest mean score ($M = 3.15$, $SD = 0.62$). The lowest mean was for the subscale of SCS ($M = 2.89$, $SD = 0.73$).

The individual items for each of the six PLCA subscales were checked for minimum and maximum mean scores. Statistical tests were not performed on the individual items scores for comparative or predictive purposes. Thus, only the descriptive information, namely the mean value, of each PLCA item was used to determine the minimum and maximum item scores for each of the six PLCA subscales. The items were scored such that higher means were associated more positive perceptions towards an item.

The minimum item score for the PLCA subscale of SSL ($M = 2.68$, $SD = 0.72$) was Item 1, "Staff members are consistently involved in discussing and making decisions about most school issues." The maximum item score for the PLCA subscale of SSL ($M = 3.55$, $SD = 0.51$) was item 11, "Staff members use multiple sources of data to make decisions about teaching and learning."

The minimum item score for the PLCA subscale of SVV ($M = 2.86$, $SD = 0.89$) was Item 17, "School goals focus on student learning beyond test scores and grades." The maximum item score for the PLCA subscale of SVV ($M = 3.36$, $SD = 0.58$) was item 15, "Decisions are made in alignment with the school's values and vision."

The minimum item score for the PLCA subscale of CLA ($M = 2.91$, $SD = 0.81$) was Item 27, "School staff members and stakeholders learn together and apply new knowledge to solve problems." Two of the items tied for the maximum item score for the PLCA subscale of SVV; Item 28 ($M = 3.32$, $SD = 0.65$), "School staff members are committed to programs that enhance learning," and Item 30 ($M = 3.32$, $SD = 0.57$), "Staff members collaboratively analyze student work to improve teaching and learning."

The minimum item score for the PLCA subscale of SPP ($M = 2.82$, $SD = 0.80$) was Item 32, "Staff members provide feedback to peers related to instructional practices." The maximum item score for the PLCA subscale of SPP ($M = 3.55$, $SD = 0.51$) was item 33, "Staff members informally share ideas and suggestions for improving student learning."

The minimum item score for the PLCA subscale of SCR ($M = 2.95$, $SD = 0.72$)

was Item 40, “Outstanding achievement is recognized and celebrated regularly in our school.” The maximum item score for the PLCA subscale of SCR (*M* = 3.41, *SD* = 0.50) was item 38, “Caring relationships exist among staff and students that are built on trust and respect.”

The minimum item score for the PLCA subscale of SCS (*M* = 2.59, *SD* = 0.96) was Item 48, “The school facility is clean, attractive and inviting.” The maximum item score for the PLCA subscale of SCS (*M* = 3.14, *SD* = 0.83) was item 49, “The proximity of grade level and department personnel allows for ease in collaborating with colleagues.”

Thus, the lowest mean item score of the PLCA survey for the 22 teachers sampled was Item 48 (*M* = 2.59, *SD* = 0.96), “The school facility is clean, attractive and inviting.” And the highest mean item score of the PLCA survey for the 22 teachers sampled was a tie between Item 11 (*M* = 3.55, *S*D = 0.51) “Staff members use multiple sources of data to make decisions about teaching and learning,” and Item 33 (*M* = 3.55, *S*D = 0.51), “Staff members informally share ideas and suggestions for improving student learning.

Table 3

Means and Standard Deviations of the Professional Learning Communities Assessment-Revised (PLCA), for Each Survey Item and the Six Professional Learning Characteristics Subscales (N = 22)

Subscale/Survey	*M*	*SD*	*p*-value
Shared and Supportive Leadership	2.98	0.74	0.900
1. Staff members are consistently involved in discussing and making decisions about most school issues.	2.68	0.72	
2. The principal incorporates advice from staff members to make decisions.	2.86	0.71	
3. Staff members have accessibility to key information.	3.18	0.50	
4. The principal is proactive and addresses areas where support is needed.	2.91	0.81	
5. Opportunities are provided for staff members to initiate change.	2.82	0.80	
6. The principal shares responsibility and rewards for innovative actions.	3.05	0.90	
7. The principal participates democratically with staff sharing power and authority.	2.91	0.75	
8. Leadership is promoted and nurtured among staff members.	2.95	0.84	
9. Decision-making takes place through committees and communication across grade and subject areas.	3.18	0.50	
10. Stakeholders assume shared responsibility and accountability for student learning without evidence of imposed power and authority.	2.73	0.70	
11. Staff members use multiple sources of data to make decisions about teaching and learning.	3.55	0.51	
Shared Values and Vision	3.13	0.66	0.366
12. A collaborative process exists for developing a shared sense of values among staff.	3.09	0.53	
13. Shared values support norms of behavior that guide decisions about teaching and learning.	3.09	0.68	
14. Staff members share visions for school improvement that have and undeviating focus on student learning.	3.18	0.59	
15. A collaborative process exists for developing a shared vision among staff.	3.18	0.59	
16. School goals focus on student learning beyond test scores and grades.	2.86	0.89	
17. Policies and programs are aligned to the school's vision.	3.18	0.59	
18. Stakeholders are actively involved in creating high expectations that serve to increase student achievement.	2.95	0.72	
19. Data are used to prioritize actions to reach a shared vision.	3.27	0.63	
Collective Learning and Application	3.16	0.62	0.240
20. Staff members work together to seek knowledge, skills and strategies and apply this new learning to their work.	3.14	0.56	
21. Collegial relationships exist among staff members that reflect commitment to school improvement efforts.	3.18	0.50	
22. Staff members plan and work together to search for solutions to address diverse student needs.	3.18	0.59	
23. A variety of opportunities and structures exist for collective learning through open dialogue.	2.95	0.49	
24. Staff members engage in dialogue that reflects a respect for diverse ideas that lead to continued inquiry.	3.05	0.72	
25. Professional development focuses on teaching and learning.	3.27	0.55	
26. School staff members and stakeholders learn together and apply new knowledge to solve problems.	2.91	0.81	
27. School staff members are committed to programs that enhance learning.	3.32	0.65	
28. Staff members collaboratively analyze multiple sources of data to assess the effectiveness of instructional practices.	3.27	0.63	
29. Staff members collaboratively analyze student work to improve teaching and learning.	3.32	0.57	

(*table continued*)

Subscale/Survey	*M*	*SD*	*p*-value
30. Staff members provide feedback to peers related to instructional practices.	2.82	0.80	
31. Staff members informally share ideas and suggestions for improving student learning.	3.55	0.51	
32. Staff members collaboratively review student work to share and improve instructional practices.	3.09	0.68	
33. Opportunities exist for coaching and mentoring.	3.00	0.69	
34. Individuals and teams have the opportunity to apply learning and share the results of their practices.	3.09	0.53	
35. Staff members regularly share student work to guide overall school improvement.	2.91	0.75	
Supportive Conditions- Relationships	3.15	0.62	0.269
36. Caring relationships exist among staff and students that are built on trust and respect.	3.41	0.50	
37. A culture of trust and respect exists for taking risks	3.23	0.53	
38. Outstanding achievement is recognized and celebrated regularly in our school.	2.95	0.72	
39. School staff and stake holders exhibit a sustained and unified effort to embed change into the culture of the school	3.00	0.69	
40. Relationships among staff members support honest and respectful examination of data to enhance teaching and learning	3.18	0.59	
Supportive Conditions- Structure	2.89	0.73	0.488
41. Time is provided to facilitate collaborative work.	2.91	0.68	
42. The school schedule promotes collective learning and shared practice.	2.91	0.68	
43. Fiscal resources are available for professional development.	2.77	0.69	
44. Resource people provide expertise and support for continuous learning.	2.77	0.61	
45. The school facility is clean, attractive, and inviting.	2.59	0.96	
46. The proximity of grade level and department personnel allows for ease in collaborating with colleagues	3.14	0.83	
47. Communication systems promote a flow of information among staff members.	3.00	0.69	
48. Communication systems promote a flow of information across the entire school community including: central office personnel, parents, and community members.	2.95	0.65	
49. Data are organized and made available to provide easy access to staff members.	3.00	0.69	

Note. *p*-value is for a one sample t-test comparing the mean of the subscale score to a value of 3. A subscale score value of 3 is indicative of a positive perception by teachers of the strength of practices of PLCs within the school. None of the six subscales significantly differed from a value of 3 at the $p < .05$ level. Item Rating Scale Range: 1-4, 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree.

Qualitative Analysis and Findings

The focus group data collection, interview data collection, and data reduction and classification are described in the following section. Table 5 describes the demographic

and descriptive information for the teachers who were included in the focus groups and interviews, according to each school.

The interview and focus group questions addressed research questions 1 and 2. Research question one asked teachers' perceptions of the effectiveness of PLCs for improving critical thinking pedagogy in mathematics according to Olivier, Hipp, and Huffman's (2016) six professional learning community characteristics. The questions in the interviews and focus groups generated data that described teachers' perceptions of PLCs and how the PLCs addressed their critical thinking pedagogy in mathematics. Research question number two provided information that described teachers' perceptions of how the structure of a PLC alters its effectiveness according to Olivier, Hipp, and Huffman's (2016) six professional learning community characteristics. I used the focus group and interview questions to ask about teachers' perceptions of how the structure of a PLC changes Olivier, Hipp, and Huffman's (2016) six professional learning community characteristics. The qualitative questions were aligned carefully with research questions one and two and the data obtained was effective in addressing both research questions.

Focus group data collection. After the quantitative data was collected, two focus groups were conducted to obtain qualitative data. One focus group was conducted for the teachers at each of the two schools. Math teachers from each grade level at each of the two schools were prospectively selected and invited to participate in the voluntary focus groups. Teachers who agreed to participate were given a consent form. The focus group discussions were conducted offsite and were recorded. The focus group data were

transcribed using Dragon Naturally Speaking. The data were saved on my personal computer with letter codes assigned for the teachers' names. The codes and transcriptions were saved on a flash drive and are be kept in a locked filing cabinet and will be destroyed after five years.

Interview data collection. Individual interview questions were refined after the data from the surveys and focus groups were collected and reviewed to structure questions to better obtain deeper information regarding the teachers' math critical thinking pedagogy. Two teachers from each focus group, (four teachers in total) were asked to volunteer for individual interviews. I spoke with each of the four participants individually and explained their role in the process of the study. The participants were given clear explanation about their voluntary role, their right to withdraw from the study at any time, and the nature of anonymity of their responses. The four teachers that accepted the invitation to participate were emailed consent forms and given a date that they were to be returned to me. After the signed consent forms were received, the interviews were conducted offsite and individually to maintain anonymity. The interviews were recorded and transcribed. Again, the data were saved on my personal computer with letter codes assigned for the teachers' names. The codes and transcriptions were saved on a flash drive and will be kept in a locked filing cabinet and destroyed after five years.

Table 4 presents descriptive findings for the individual teachers who are included in the narrative of the qualitative findings, grouped by school. A separate focus group was conducted for each school. After the focus groups, four teachers were asked to

participate in individual interviews. Teachers A, B, AA, and AB were included in both the focus groups and individual interviews. A majority of teachers were female (66.7%). Fifty-eight percent of the teachers were African American. The years of teaching experience ranged from three to 25 years (M = 10.92 years, SD = 6.43 years).

Table 4

Demographic and Descriptive Information for Teachers Included in the Focus Groups and Interviews, According to School (N = 12)

School/Teacher	Gender	Years of teaching experience	Grade Level Currently Teaching
School 1			
Teacher A	Male	15	5th grade
Teacher B	Female	12	3rd grade
Teacher C	Female	3	2nd grade
Teacher D	Male	25	5th grade
Teacher E	Female	11	4th grade
Teacher F	Female	5	1st grade
School 2			
Teacher AA	Male	13	2nd grade
Teacher BB	Female	11	3rd grade
Teacher CC	Male	18	4th grade
Teacher DD	Female	7	3rd grade
Teacher EE	Female	3	1st grade
Teacher FF	Female	8	Kindergarten

Note. All teachers were mathematics teachers in K-5 elementary schools.

Data reduction and classification. Reduction of the qualitative data collected from the survey was performed manually. Interviews were then transcribed from the audio recordings into individual Word documents. The participants in the study were given the opportunity to review the transcripts from their interviews to ensure accuracy.

The qualitative responses from the transcribed Word documents were manually sorted and coded, with the focus shifting between the key responses of the teachers to interpretations of the meaning of those responses. I then reviewed each interview question node and performed a preliminary grouping of every expression relevant to each interview question and the research questions of the study. The preliminary grouping was performed by reviewing each of the focus group and interview questions and classifying all relevant information. Additional groupings were constructed as themes emerged from the data review and classification process. Qualitative data should be constantly compared and analyzed during the coding process until strong themes and categories develop (Larkin, Watts, & Clifton, 2006). Reduction and elimination of unrelated text was then performed. I investigated each grouping and aggregated them if they were similar in context, thus clustering similar categories by grouping clusters into core themes. The themes were then cross-referenced with each teacher's focus group or interview record to create a textual structural description of the perceptions and essence of the teacher's experience with the structure and effectiveness of the PLC on the teacher's math critical thinking pedagogy. Each expression relevant to each teacher's experience was checked for its relationship to similar categories, purpose statement, and the research questions of the study. The process of comparing expressions to categories, purpose and research questions led to the identification and final determination of the themes of the study.

Table 5 presents the themes derived from the qualitative data analysis as it relates to the six professional learning community characteristics.

Table 5

Qualitative Findings: Emerging Themes According to the Six Subgroups of the PLCA

Dimension	Theme	Description
Shared and supportive leadership	Collaboration	PLC meetings allowed for collaboration between teachers.
Shared values and vision	Deliberate focus on subject matter	Teachers felt the PLC meetings were more focused on math pedagogy than traditional meetings or grade level planning meetings.
	Student-Centric	Teachers commented that the information and techniques shared in PLC meetings were centered on improving students as individuals and as a class.
Collective learning and application	Professional development	The teachers felt that the concepts and lessons learned from participation in a PLC enhanced their critical thinking, depth of knowledge in pedagogy, and contributions to grade level collaborative planning.
	Problem solving	The focus and collaboration elements of PLC meetings enhanced problem solving of the teachers. Teachers could troubleshoot and assess.
Shared personal practice	Open environment	Emerging problems and trends. Administration's support of, and the collaborative environment of, the PLC framework gave teachers the ability to share ideas and opinions in the hallways, each other's classrooms, and at other schools.
	Vertical thinking	Teachers felt the collaborative environment of PLCs trained them to think "vertically" for their students so that the teachers focused instruction with the students' next steps for learning in mind.
	Camaraderie	PLCs enhance a sense of community between the teachers and allows for impromptu discussions and planning outside of the meetings.

(*table continued*)

Dimension	Theme	Description
Supportive conditions – structures	Administrative Support	When administration was focused on math PLC's they provided the resources to allow ample opportunities for teachers to attend conferences and meetings. However, when administration was not focused on math PLC's, the support was not as readily available to teachers.
	Time	Many teachers expressed that more time should be allocated for PLC meetings. The meetings should be more often and for at least ½ of a day.
Supportive conditions – relationships	Trust	Teachers commented that the open environment that evolves from attendance and collaboration at PLC meetings creates an environment of transparency and trust.
	Camaraderie	PLCs enhance a sense of community between the teachers, and this camaraderie allows for impromptu discussions and planning outside of the meetings.

Findings to Support Thematic Analysis

As I reviewed the transcripts and sorted the themes, I noticed a difference in the resonses of the teachers at School 1 when compared to School 2. The teachers at School 1 mentioned that administrators at the district and school level were more focused in the current school year with Leveled Literacy and the Lucy Calkins writing programs. The administrators had been more focused on mathematics in the prior year and therefore were more supportive of the math PLCs. But the interest had waned in the current year. The responses of the teachers in School 1 reflected teachers' perceptions of lowered interest and focus of the administrators for the math PLCs. Conversely, the teachers in School 2 were actively involved in math PLCs and felt they had full support of the

administration. The main complaint of teachers in School 2 was that there was not enough time available for full involvement in the math PLCs. Given the dichotomy of responses from the teachers, I have made my best attempt to incorporate both the positive and negative aspects of each theme, when observed, from the transcripts and my notes.

Shared and supportive leadership. Shared and supportive leadership is shared power and broad-based decision making that reflects commitment and accountability (Olivier et al, 2016). Collaboration was a theme that emerged within the shared and supportive leadership PLC characteristic.

Collaboration. Teachers in both schools felt that math PLCs allowed for greater collaboration between teachers. But for the most part, the administration, when involved, provided access to time and resources so the teachers could attend meetings and conferences. Administration was not a shared partner in the PLC's lesson planning or direction. Teacher BB, from School 2, stated:

> The math PLCs are more collaboration and sharing for us [teachers]. We can discuss issues we are having with math and figure out solutions for them whether it is more training, or some students get more tutorial, or more ESOL help, etc. It is usually a place where all of that stuff is talked about.

PLCs were also seen as a method to enhance critical thinking and to collaborate on instructional strategies. Teacher BB mentioned that the principal had made critical thinking strategies a priority. The focus on critical thinking strategies directed the teachers to focus on math exemplars and number talks for critical thinking and

encouraged the teachers to research the resources on the strategies for teaching students critical thinking skills. Teacher AA stated, "We learn from each other all of the time." Teacher CC mirrored teacher AA stating, "I feel like we are constantly sharing and learning from each other, mostly in our math PLCs or in our grade level planning meetings. We are always talking and sharing." Teacher FF added, "We also went to another school to get ideas from them. Then we came back and talked about what we saw and how we could use it here." Teacher E, from School 1, said the administration was supportive in the previous year, stating, "…last year they [administration] brought us in for meetings and talked a lot about "math talks" and gave us a book to read." Other teachers in the School 1 focus group noted that in the previous year administration encouraged teachers to go to other schools to fact find and bring back information to share with the other teachers. Teacher D described the process in more detail:

> "Focus walks" is what they [administrators] called them…we could go with our region cluster to see other teachers doing a good job with "math talks". Then we have had more with the Leveled Literacy and reading for focus walks and have not had as many [math focus walks] this year.

Although teachers in the School 1 focus group felt that there was more administrative support in the prior year, they still felt the math PLCs were viable and incorporated the collaborative elements into the reading program and other school work. Teacher C also noted that the shift from math to reading was more of a "county thing" rather than at the school level. Teacher A noted, "The administration asks us to go to

math trainings in the summer as well. So, I went to a good math training in the summer last year as well."

Teacher F also gave support for the principal, saying:

> Our grade is working on math constructed response right not so at our grade level meetings we talk with the writing teachers and they help [the math teachers] put in math constructed response [into the writing lesson plans]. So, it is in the writing as well. [The principal] is good about that and the kids need help with [both math and writing] for testing.

Teacher A described effective collaboration via the PLC when asked to describe his math critical thinking learning in his interview:

> I would say right now, I get most of it by talking to teacher B and Teacher C, we always are sharing stuff we find. I get the most from talking and working with them. We just come in to each other's rooms and share stuff. Last year's math talks were a great thing. I mean I learned a lot and practiced and tried different ways to teach the kids critical thinking strategies. But this year it has been more on my own. Finding math stuff and talking about it with the other math teachers.

Eight teachers mentioned collaboration as an important aspect of participating in a PLC.

Shared values and vision. Shared values and vision is a PLC characteristic that focuses on student learning, high expectations and shared visions guiding teaching and learning (Olivier et al, 2013). There were two themes that evolved from the shared

values and vision dimension. The two themes were deliberate focus on subject matter, and student-centric.

Deliberate focus on subject matter. Teachers in both schools felt that the PLC meeting allowed for a greater emphasis on math pedagogy than traditional meetings or grade level planning meetings. Teacher AA stated,

> Traditional Meetings are less focused and contain a whole lot of topics whereas PLC meetings are more focused and there is usually something specific to talk about and analyze. There may not be a specific agenda per say because the conversation can go off in so many different ways. But there is usually some aspect of math we are tackling whether it be data or a new math teaching strategy.

Teacher's AA and CC noted that the higher level critical thinking strategies for math are planned in the PLC meetings. Teacher BB noted in her interview that shared math values can be observed by visiting the individual classrooms,

> If you came to our grade level meetings you would see [the shared focus on math subject matter]. Or, you would also see it if you walked to the other rooms form math at the same time or day, you would see the same activities to show we plan together.

Teacher A, from School 1, also discussed the singular focus of math PLCs:

> The math PLCs are usually about one topic. We get trained on something like math talks, and then we talk about how to use them in the classroom. These meetings involve only the math teachers. Opposed to grade level meetings that

> focus on schedules and upcoming events in the school, grade level issues, um things like that.

However, teacher D, from School 1, stated that he felt "we aren't that uniform" when discussing shared visions in the focus group. He stated, "We can pick and choose our own strategies. Like for word problems, there is not a structure that we all follow, we can choose how we teach it." He then added, "But the number talks was not something that we had a choice [*sic*]. We all had to do them and share about them." Several teachers expressed how PLCs helped them acquire pedagogical content knowledge.

Student-centric. When I asked the focus group of teachers in school 1 to elaborate on structured critical thinking math discussions, the teachers commented on the use of data and goal setting to improve students on the individual and class level. Teacher A commented:

> I guess you would say [structured critical thinking math discussions] are what happen in math PLCs. They are like, we have a topic like math number talks and then we might like see a video and then we talk about it and discuss how we can implement the strategy in our classrooms.

Teacher C added, "Or we will look at MAP scores and talk about the hot spots where we need to emphasize, or where students may need more assistance. That kind of talk, analyzing student data I guess you could say." Teacher E noted that many of the structured math conversations involved focusing the lesson plans and discussions on a specific set of students.

The teachers in School 2 also mentioned focus on the students when asked about the structured match critical thinking discussions. Teacher AA commented that the math PLCs are, "…where more of the learning of new critical thinking strategies come in to play." Teacher AA noted that these discussions often carry over into the grade level planning meetings, "…when we talk about the different activities for the students and how to get them to learn more effectively or at a higher level, or to teach the lower level students the higher level critical thinking strategies." Teacher CC noted, "The discussions are helpful because everyone is sharing and learning and asking questions and trying to come up with the most effective way to teach higher level strategies not only to high level students, but all the students." Teachers found PLCs a way to craft student-centered lessons.

Collective learning and application. Collective learning and application is working collectively to plan, solve problems, and improve learning opportunities (Olivier et al, 2013). There were two themes within the collective learning and application PLC dimension. Professional development and problem solving were themes that emerged within the collective learning and application PLC characteristic.

Professional development. The teachers felt that the concepts and lessons learned from participation in a PLC enhanced their critical thinking, depth of knowledge in pedagogy, and contributions to grade level collaborative planning. The collaborative elements of the PLC were very helpful in knowledge transfer. When I asked the focus group at School 1 "How do you collectively learn from each other?" Teacher A

responded, “Usually when we collaborate together like, when, like I have two other teachers in my grade level who teach math and we get together during planning. So our grade level planning time.” He also noted, “The ideas I have gotten from, like, teacher B, and then use or change have helped me learn from someone who has taught math for a lot longer amount of um, time. So it helps, really helps.”

Teacher D elaborated more on the topic:

> We definitely are always learning and sharing with each other. It’s the best way to see if you are analyzing the standard the right way, or have the best math strategy to teach something. Sometimes we will share a strategy, and some will like it and others won’t. But we’ve talked it out and looked at it from different angles. And we understand it better. Then, sometimes we agree to all use the same strategy, other times we go off and do the one we like. But we have challenged ourselves and that doesn’t happen when you work alone.

Teacher B commented that she liked to see someone else teach, even if only in a video, and that helps her to have a better understanding to apply what she learns. Teacher C also said that she learned the most from watching other teachers in their classrooms and by asking teachers questions.

The teachers in School 2 mirrored those in School 1. Teacher FF stated, “When we were having Study Island problems and not understanding how to use it, teacher AA helped me assign students to different projects. He said he would be not be “Anywhere

near as good" as he is without the conversations and input from coworkers. Teacher DD elaborated further,

> If teachers didn't get together and talk about how they were teaching math and they weren't talking about it, I feel like it wouldn't be anywhere as good. I learn so much from our conversations I can't imagine not sharing and talking about math and how we are going to approach it. I wouldn't have nearly the resources and knowledge that I do because we collaborate all the time.

Many teachers noted how their peers contributed to their professional development by helping solve problems and answering questions.

Problem solving. The teachers in both schools felt that the focus and collaboration elements of PLC meetings enhanced their problem-solving capabilities and allowed them to troubleshoot and assess emerging problems and trends. Teacher DD said. "[The PLC] is a place you can say, 'I am having trouble with this.' And it is discussed and the solution is discussed." Teacher BB stated that the PLCs have enhanced the openness needed in stating the problems that require help,

> In this school a few years ago, there wasn't as much openness about going out and getting the math critical thinking professional development you wanted or needed as there is now. Now you can say, "I need to work on this" and not feel bad about it and go get professional development for it.

Teacher C also noted that the "supportive conditions" of PLC meetings allowed for teachers to be open and to share approaches to problem solving.

Shared personal practice. Open environment and vertical thinking were two themes that evolved from the shared personal practice PLC trait. Shared personal practice includes dimensions of peer observations, coaching, and feedback to improve performance (Olivier et al, 2016).

Open environment. The teachers in School 2 mentioned that administration's support of the math PLC, and the collaborative environment of, the PLC framework, gave teachers the ability to share ideas and opinions not only in the PLC meetings, but in the hallways, each other's classrooms, and at other schools. Teacher AA stated,

> The math PLC experiences at our school are good in that administration lets us to what we want to and what we need to with PLCs. They do not control what we talk about. We can determine how our time in a PLC is used and make it effective for our needs, and I like that.

Teachers DD and FF also commented on administration support as an enhancement to the PLC structure. Teacher DD stated, "I think administration creating the culture of the importance of the collaboration and the depth of discussion to getting at the critical thinking talk. That emphasis or priority keeps it sustainable." Teacher FF agreed and added, "I also think that if we weren't encouraged to go out to each other's rooms to learn from each other and share, then the importance of collaboration would dissipate, and then the PLC wouldn't be important."

The teachers in School 1 also mentioned the freedom to collaborate outside of the PLC meetings with informal discussions and by visiting each other's classrooms.

Teacher A noted, "I guess, you could say we don't always plan the structured conversations but they happen formally and informally all the time. We constantly are sharing so the conversations happen. [The conversations are] not always planned." However, the teachers in School 1 noted that the administration's focus within the year was on the reading program.

Vertical Thinking. Teachers felt the collaborative environment of PLCs trained them to think "vertically" for their students so that the teachers focused instruction with the students' next steps for learning in mind. Teacher B noted in her interview that professional development training gave her the tools to help her to help the students in her multi-grade classroom. She was also able to present the information to others in the PLC meetings so they could prepare their students for the next steps in learning:

> This summer I went to math professional development that was geared toward fourth and fifth grade students so I could understand where the students were coming from in fourth grade. So it was helpful because with our kids already behind, it helped me know where they were coming from and what I needed to do to fill in gaps and help them with their math strategies. So it helped me go multi-level with the fourth and fifth grades students. When I was done with the professional development it conferred with fourth grade teachers and helped them understand what they were moving up to and what deficits I was seeing and that they can work on in fourth before they come to fifth to see me.

Teacher B also gave some examples of how the use of data and collaboration within the

PLC environment enhances the vertical movement of students to the next level of learning:

> We do try to share ideas and data to try to move the students in to higher levels of thinking by their levels. For example, some of us got together recently to share the IReady data and look at it. I am now gearing my full lesson in math toward information we looked at. My small group lessons are toward things I found they are lacking, or looking at data they are lacking. All the came from conversations started with other teachers seeing how they were looking at the IReady information and what strategies they were using. But we try to talk about each academic level and discuss how we are going to move them to a higher level. Even using other diagnostic tests to see what they need at the different levels.

Teacher B also noted that she would like more time from administration to discuss and implement the strategies.

The focus group of School 2 mentioned vertical thinking strategies often during the discussion. The teachers of School 2 also had vertical math meetings planned by the administration. According to Teacher BB, the vertical math meetings were a place to "Talk about the progression of math skills and critical thinking." Teacher EE noted:

> The math vertical meetings were so helpful for me because I hadn't taught math before and it gave me a better understanding of the critical thinking I need to prepare my students for so that when they go to fourth grade they have the fundamentals and the critical thinking strategies they need.

Teachers at both schools appreciated vertical math meetings as PLC groups as the meetings helped inform practice.

The teachers in the School 2 focus group also agreed that common learning strategies such as CUBES helped in the vertical growth of students. CUBES is an acronym math teachers give students to support their math problem solving skills. The acronym stands for: circle the important numbers, underline the question, box the action words, evaluate the steps to take, solve and check the equation. The math teachers in school were all required to use CUBES so that when students moved up to the next grade level the teachers were using the same math strategies such as CUBES.

Supportive conditions – relationships. Supportive conditions are divided in to two sections which are relationships and structures. Supportive conditions regarding relationships includes trust, risk taking, and respect (Olivier, 2016). Two themes emerged from this PLC characteristic. Trust and camaraderie were the two themes within supportive conditions PLC dimension related to relationships.

Trust. Teachers commented that the open environment that evolves from attendance and collaboration at PLC meetings creates an environment of transparency and trust. When I asked the focus group at School 1, "How do you describe the level of trust among staff members at your school?" the response was positive. Teacher D said he felt that he trusted his colleagues and could express himself with them and added, "We have to trust each other if we are going to work closely together and help each other." Teacher A mentioned that there had been times when he worked with colleagues who

didn't trust each other and only a couple of teachers would work together. He then added, "But we have so much to do we need to work together to get it all done." Teacher C agreed saying, "We don't have time not to trust each other. There is too much to do!" Teacher E agreed that if they didn't trust each other, not much would get done.

I also asked the teachers in the focus group at School 2 to describe trust amongst staff members. The dialogue was as follows from Teacher AA: "[The trust among the teachers is] great , I mean I feel like we all share stuff and ideas, and uh everyone is willing to help each other out." Teacher DD: "Ya, and if you have a problem figuring something out you don't feel dumb, you just ask and you don't feel like you are being judged." Teacher BB: "It wasn't always this way. It used to be that everyone stayed in their rooms and didn't share things and wanted to be the best at everything. But it's not that way now." Teacher AA: "I feel like there is really good trust among teachers. There may be little problems with some teachers, but for the most part everyone has trust and helps each other out." Teacher EE: "I would agree with that." Teachers felt PLCs increased trust amongst faculty.

Camaraderie. Building further on trust and an open environment, PLCs enhanced a sense of community between the teachers, and the camaraderie allowed for impromptu discussions and planning outside of the PLC meetings. The sense of camaraderie was explicit for the teachers in School 1. When asked to describe the relationship between math PLCs and critical thinking math pedagogy Teacher A said, "That is where I get most of the higher level strategies is at the math PLCs. Um, from

other teachers sharing. Like the stuff that would come from the district. But also the sharing with other teachers. Even in the hallways, on the run, um quickly."

Teacher B added,

> We can share things we've gotten [to understand] in a quick conversation in the hallway. But the more difficult strategies I think, for me also come from the professional development I go to and learn from. Sometimes for the harder strategies you have to learn on your own to make them work. But I have learned a lot too from watching other teachers.

Teacher B, during her interview, also elaborated more on the camaraderie and the benefits of the ability to strike up conversations informally:

> Well, there had been more time to collaborate last year. But we try to catch each other in the halls or whenever to talk about things. Sometimes in by the copier, sometimes it is in the hallway, sometimes it's when I am sitting at my desk after school. We do try to share ideas and data to try to move the students in to higher levels of thinking by their levels. For example, some of us got together recently to share the IReady data and look at it. I am now gearing my full lesson in math toward information we looked at.

Camaraderie developed throughout each building as teachers shared information about teaching mathematics.

Supportive conditions – structures. The supportive conditions PLC trait with regards to structures includes time, money, people, and communication systems (Olivier

et al, 2016). There were two themes evolving within this PLC subscale. The two themes were administrative support and time.

Administrative support. Differences between the teachers in the two schools were most evident when it came to their perceptions and experiences with the administration's support (or lack of support). When administration was focused on math PLC's, as was the case in School 2, they provided the resources to allow ample opportunities for teachers to attend conferences and meetings. However, when administration was not focused on math PLC's, as was the case in School 1, the support was not as readily available to teachers.

When asked for evidence that the school had supportive conditions, the teachers in School 1 spoke affirmatively about PLCs, but felt the administration was not as supportive. The teachers mention more focus on the Lucy Calkin's writing program which was a writing initiative the district under study implemented the same year as the study. Teacher E said,

> I think any of the planning meetings you could go in to see teachers planning and working together. And of course our Math PLCs, I wish we did that more this year because they were the most, I mean the best for, um understanding things or even solving math issues. I wish it were built in. I mean you know so that it was regular, learn something new this year for math. Like I don't do Lucy Calkins, so there is a lot of time put in to it. I get it because it is important. But I feel like the

> district needs to also have a math initiative too. Like at the same time, so we can keep the math going.

Teacher A felt the support needed to come from higher up in the administration:

> It's just the district doesn't always support us. Like this year. Not much math, but previous year someone goes to district math meetings and brings back information. That part isn't happening, not like I mean our school isn't dropping the ball, well maybe a little for math. But the district doesn't always support the schools, I think, the way they should.

Teacher B felt that the principal of the school did support the math PLCs, "I think our principal has supported us with more math resources and the idea of math PLCs. We didn't have math PLCs before, so we were on our own to talk about math within our grade level and not as a school." Multiple teachers mentioned how math PLCs lacked administrative support.

Teachers in the School 2 focus group also felt that involvement of the principal and school level administration was important for the success of a PLC. Teacher AA said that in another school where he worked, there was not any collaboration and the teachers kept to themselves. Teacher DD responded, "[Collaboration] hasn't always been this way at this school [*sic*]. But now math is emphasized by administration. I don't think the previous administration was as comfortable with math." Teacher BB mentioned that the principal had made critical thinking strategies a priority and this priority was seen in the math PLCs and number talks.

Teachers in the focus group for School 2 also mentioned the administration supports of planning time as well as time for the PLC meetings. Administration gave one day a week to the teachers for collaborative planning and sharing, and met with the teachers each Thursday to discuss math strategies and goals.

Time. Many teachers expressed that more time should be allocated for PLC meetings. The meetings should be more often and for at least ½ of a day. School 1 was departmentalized by grade level, and so time was more difficult to find for PLC meetings between grade levels. Teacher A said that the teachers had to find time during the week to talk to other grade levels about math and that it often was at the level of "catching each other in the hallways." Teacher B said things were better in the previous year when the administration was focused on math PLCs. When asked, "What do you think threatened the sustainability of your math PLC?" he responded, "Having time to get together. Sometimes, like last year we had more time to get together. This year, it seems we have to find more time to get together." Teacher E then said, "Or we don't get together as much. And it's not as good [as last year]. We don't have time to share things and talk." Other teachers mentioned lack of time to share ideas as well.

Teacher F noted a lack of planned times for math PLC meetings and the increased focus on the writing program affected her critical thinking pedagogy:

> Other meetings have taken time away from our math PLCs. More time has been for writing it seems like, and um, not as much time to meet for our math PLCs. We still meet, it's just more on the run, or we have to set it up. But definitely, the

> math PLCs is where I get the most for my critical thinking pedagogy. Or trainings that I or, um others have gone to and then come back and share and talk about them. But there needs to be more time for that stuff. More planned time so it happens.

The teachers in School 2 also gave the general answer of "not enough time" when asked, "What do you think threatens the sustainability of your math PLC?"

Teacher AA responded:

> Time. So it's time. We get interrupted with meetings that take time away from the time we planned for our math PLC. It is frustrating to always be in meetings and not have enough time to collaborate and share instructional strategies, talk about critical thinking and work. Our PLCs for math seem to be the meetings that get interrupted and they are the most important ones.

Teacher DD: "For sure, time. The half day math PLCs are so valuable. The shorter meetings aren't as effective, not at all. They go by too fast, just when you are learning something or trying to figure something out." Others agreed with teacher DD that extended time was more useful that shorter meetings.

When I asked the teachers, "What do you think you need to make your math PLC stronger?" teacher AA said:

> Time. More time and extended time to talk about strategies and look at student data. It seems we always have to watch the clock and may be in a great discussion and have to stop because our 45 minutes are up. We need more

> extended time within the year to have deeper conversations about math critical thinking. For example, we had to take a personal day to have enough time to look at new student data that had just come in. It was too important not to take the time we needed to look at all of it. We needed to take time to look at the standards they needed to get more in depth with or reteach. It was really helpful, but it did take time and it did take uninterrupted time to look at all of it and really understand it and plan for instruction and higher-level thinking. Like when we came in on a Saturday, we were there for just a couple of hours and it was uninterrupted and we were able to get so much accomplished together. We could focus and stop when we had finished discussions, not when we had to get the kids from lunch.

Teachers BB, DD: "Agreed!" Extended time for deep conversations and data analysis would be appreciated by many teachers.

Integration of Quantitative and Qualitative Findings

Lodico et al. (2010) suggested that researchers collect multiple resources of information that should be compared through triangulation to validate the researcher's interpretation of the findings. The data from the study were triangulated using quantitative surveys, focus groups, and interviews.

I collected quantitative data with Olivier, Hipp, and Huffman's (2016) PLCA survey. The sample size for the quantitative analysis was 22 participants. The survey data were retrieved from the SEDL PLCA online system in summary form. Thus, only

the mean and standard deviation for each of the 52 PLCA items and each of the six subscales, and the frequency counts of the item responses for each of the 52 PCLA items were available for analysis. Some subjective comments were also recorded with the summary data. However, measures of internal consistency reliability, score ranges, and medians could not be computed for the collected data.

A series of six 1-sample *t*-tests were performed, one for each subscale score, to see if any of the six subscale scores were significantly different from 3. R-v3.4 statistical software was used for the calculations and a 95% level of significance was set for the tests. None of the six subscales significantly differed from 3 (see Table 3). Therefore, it was determined that the 22 teachers had positive perceptions of the strength of the practices of PLCs within their schools. The subscale score of SCR had the highest mean score ($M = 3.15$, $SD = 0.62$). The lowest mean was for the subscale of SCS ($M = 2.89$, $SD = 0.73$).

Qualitative information was obtained through focus groups and individual interviews. Four teachers were interviewed. Creswell (2012) states that saturation is a decision a researcher makes when they feel new data will not provide any more detail for the categories. The decision to stop at four interviews was done due to saturation of data that was occurring during the last interview. Each of the four teachers were interviewed individually offsite to maintain confidentiality of the participants. The focus group and interview data were analyzed and grouped thematically according to Olivier, Hipp, and Huffman's (2016) six PLC characteristics. All focus groups and interviews were

recorded and transcribed using the computer software Dragon Naturally Speaking. Member checks were done with the interviews and focus groups to ensure the transcriptions were accurate. The participants were given a copy of their transcription and identified any discrepancies between the transcription and their feedback. Member checking ensured that the researcher's bias was not interwoven in to the data (Lodico et al, 2010). The theoretical framework and the research questions helped to guide the data collection process, in that the six characteristics of Olivier, Hipp, and Huffman's (2016) professional learning characteristics and the research questions were references continuously during data analysis. The triangulation of the surveys, focus groups, and interviews helped determine the teachers' perceptions of PLCs for improving their math critical thinking pedagogy according to Olivier, Hipp, and Huffman's (2016) six professional learning community characteristics.

The information obtained from the quantitative and qualitative findings were then used to address the four research questions of the study. Research Questions 1 and 2 are addressed with the qualitative findings from the focus groups and interviews. Research Question 4, and the associated statistical hypotheses, are addressed with the quantitative findings from the PLCA survey. The data and conclusions from the data analysis are presented according to the research questions.

RQ1: What are teachers' perceptions of the effectiveness of PLCs' for improving critical thinking pedagogy in mathematics?

Teachers perceived the PLCs positively. Teachers in both schools felt that the PLC meetings were singularly focused on improving math pedagogy and critical thinking, more so than traditional meetings or grade level planning meetings. The PLCs were centered on improving students individually and as a group. The teachers gave many examples of how the collaboration between teachers and grade levels fostered a vertical thinking of teaching students. Instruction was focused on student achievement at the current grade level and on moving the students to the next level of learning.

PLCs were also effective at enhancing the teachers' professional development and problem-solving skills. The collaborative environment of the PLCs encouraged a place of trust and openness between the teachers. The camaraderie between the teachers in the PLC allowed teachers with problems or questions to feel free in asking for help without feeling judged by their peers. The teachers also felt that the ability to visit each other's classrooms and share resources made them better than they would be alone.

The qualitative data findings indicated that teachers felt PLCs were important, there wasn't enough time dedicated for them to be as effective as they should be. Teachers feedback suggested that inconsistency with the county and school administration focus on content other than math obstructed the consistency and importance for math PLC collaboration and meetings. Many teachers responded that they felt frustrated there weren't math PLCs more often and were finding when math PLCs weren't a priority teachers had to "catch each other in the hallways" to collaborate about math. Moreover, teachers felt as though the instructional strategies that were integrated in

to PLCs were beneficial in improving their critical thinking pedagogy, however infusing the math strategies in the math PLCs should be more consistent. Teachers replied that time for PLCs was a problem and the biggest threat to the sustainability of math PLCs.

RQ2: What are teachers' perceptions of how the structure of a PLC impacts its effectiveness, according to six professional learning characteristics?

The teachers spoke often about the collaborative nature of the math PLC's and the sense of community collaboration engendered. Themes of camaraderie, trust, and an open environment indicated that the community structure of a PLC enhanced both the professional development of the teachers as well as the transitioning of students through grade levels.

The theme of collaboration was important to the effectiveness of all six of the professional learning characteristics. Shared and supportive leadership requires the support of teachers for each other, and the support of the administration, especially in resources and time, to implement the PLC well. The themes of deliberate focus on subject matter and student-centric were important elements of the professional learning characteristic of shared values and vision. Collective learning and application was noted in the teachers' discussion of how the PLC enhanced their professional development and problem-solving skills. The supportive conditions of the PLC resulted in trust and camaraderie among teachers. When the administration supported the PLC structure, an open environment of information sharing allowed the teachers to collaborate in to move the students vertically through the grade levels and to become more proficient at math.

Conversely, when administration in either the school or district lost sight of making math PLCs a priority, teachers felt as though the effectiveness of the math PLC deteriorated.

Administrative support was very important to success of the PLCs and there was inconsistency in the support at the two schools. The administration of School 1 was more focused on reading and writing and the teachers missed the collaboration, personal development, and structures of the PLC in the current school year over the previous year. The administration of School 2 was focused on the math PLC and the teachers were given the support, mostly in time for meetings and planning, that the other school no longer experienced. Teachers in both schools mentioned the problem of inconsistent district support for math, and math PLCs. Teachers felt that when the district administration made other content areas such as writing a priority, the administration in the schools found less time for the math PLCs.

RQ3: Is there a statistically significant difference in the mean score of the items on Olivier et al.'s (2016) six professional learning characteristics on the PLCA and the teachers' responses?

H_A. There is a statistically significant difference in the mean score of the items on Olivier et al.'s (2016) six professional learning characteristics on the PLCA and the teachers' responses?

H_o. There is no statistically significant difference in the mean score of the items on Olivier et al.'s (2016) six professional learning characteristics on the PLCA and the teachers' responses?

Table 3 includes the means and standard deviations for each of the 52 items and the six PLCA subscale scores. A subscale score of 3 or greater is indicative of a positive perception by teachers of the strength of practices of PLCs within the school (Olivier, Hipp & Huffman, 2016). The subscale score of 3 was therefore used as the "mean" score for comparison with the subscale scores computed from the survey responses.

A series of six 1-sample *t*-tests were performed, one for each subscale score, to see if any of the six subscale scores were significantly different from 3. R-v3.4 statistical software was used for the calculations and a 95% level of significance was set for the tests. None of the six subscales differed significantly from 3 (see Table 3). However, the subscale of Supportive Conditions and Structure had the lowest score with a mean of 2.89 (see Table 3). Therefore, it was determined that the 22 teachers had positive perceptions of the practices of PLCs within their schools with supportive conditions being and area within the schools' PLCs that could be improved to make them stronger.

Conclusion. Do not reject the null hypothesis. There is no statistically significant difference in the mean score of the items on Olivier, Hipp, and Huffman's (2016) six professional learning characteristics on the PLCA and the teachers' responses.

Evidence of Quality

Lodico et al. (2010) suggested that researchers collect data from multiple information sources that can be compared through triangulation to validate interpretations of findings. Data from the study was triangulated using quantitative surveys, interviews, and focus groups.

I collected quantitative data via Olivier et al.'s (2016) PLCA survey. Cronbach's alpha internal consistency reliability coefficients were computed for the subscales of the survey, which indicated satisfactory internal consistency reliability (Olivier et al., 2016). A sample size of 15 participants within each group would be considered appropriate for accurate *p* values (Salkind, 2017). The sample size of the PLCA surveys was 22 participants. I calculated the means and standard deviations for each of the 52 items, as well as the six PLCA subscale scores. A subscale score of 3 or greater indicated positive perceptions of the strength of practices of PLCs within the school (Olivier et al., 2016). I performed a series of six 1-sample t-tests (one for each subscale score), to see if any of the six subscale scores were significantly different from 3. A 95% level of significance was set for the tests.

I obtained qualitative data via focus groups and individual interviews. Four teachers were interviewed. Creswell (2012) stated that saturation occurs when new data will not provide any more detail for the categories. I stopped collecting interview data after four interviews because saturation was indicated. I interviewed each interview participant individual, off school premises to maintain participant confidentiality. Once completed, I analyzed and triangulated focus group and interview data. All focus groups and interviews were recorded and transcribed using the computer software Dragon Naturally Speaking. The participants were given a copy of their transcripts and they identified any discrepancies between the transcription and their feedback. There were no changes made to the transcriptions after the participants reviewed them. Member

checking helps ensure that a researcher's bias does not influence data (Lodico et al, 2010). The participants were given the findings and reviewed them for accuracy. There were no changes or further review needed after member checking was conducted. The theoretical framework and the research questions helped guide the data collection process. The six PLC subscales of Olivier et al.'s (2016) Professional Learning Characteristics and the research questions were used continuously during data analysis. The process, with the triangulation of the surveys, focus groups, and interviews helped determine teachers' perceptions of the effect of PLCs on their math critical thinking pedagogy according to Olivier et al.'s six professional learning community characteristics.

Summary

Math achievement in the district under study is low and needs improvement. Therefore, the effectiveness of the PLCs in relation to teachers' critical thinking math pedagogy is important to understand. Research question one analyzed teachers' perceptions of the effectiveness of PLCs for improving critical thinking pedagogy in mathematics. Hord (2012) and Olivier, Hipp, and Huffman (2016) defined PLCs as teachers' learning together to improve student learning. Students will need math critical thinking skills in the future to compete in a global economy. Critical thinking contributes to career and educational success. In research conducted for the Bill and Melinda Gates Foundation, University of Oregon professor David T. Conley adds that "habits of mind" such as "analysis, interpretation, precision and accuracy, problem solving, and reasoning"

can be as or more important than content knowledge in determining success in college courses (National Education Association, 2017, p. 8).

An outcome of my study indicated that teachers perceived PLCs positively improving their math critical thinking pedagogy. However, the data revealed that teachers felt that PLCs needed to be scheduled more often. Abdullah, Halim, and Zakaria, (2014) stated that math critical thinking strategies evolve and change quickly, and teachers need to regularly keep up with the new critical thinking instructional methods. Teachers' responses revealed a strong feeling about the effectiveness of math PLCs improving their critical thinking pedagogy. Three out of four teachers interviewed replied that the math PLCs helped their math critical thinking pedagogy. However, there was a consensus in the teacher interviews and focus groups that the math PLCs needed to happen regularly to be effective and not overshadowed by other district initiatives.

The teachers' responses from the focus groups also indicated that critical thinking strategies come from conferences, workshops, and district professional development. Interview participants described opportunities they had for improving their math critical thinking pedagogy, and three of the four mentioned conferences, workshops, and external professional development also contributed to their math critical thinking pedagogy.

Time was another theme that arose from the data. During interviews and focus groups, teachers described not having adequate time to improve their math critical thinking pedagogy. PLCs were not often held often enough for teachers to benefit from them. Also, PLCs had to be cut short due to schedule restraints.

Research question 2 explored teachers' perceptions of how the structure of a PLC effects its effectiveness, according to Olivier et al.'s (2016) six professional learning community characteristics. An outcome of the interviews and focus groups indicated that teachers perceived leadership needed to prioritize math PLCs. Olivier et al. indicated that principal leadership was a key factor in the success of PLCs. The qualitative data further indicated that teachers perceived the structure of PLCs to be in place; however, they felt PLCs needed to be scheduled more often and include administrative support. A common theme throughout the interviews and focus groups was that the math PLCs were more effective when they were regularly scheduled. The teachers perceived that their math critical thinking pedagogy improved more when math PLCs were scheduled more often.

Another outcome related to research question 2 was regarding teachers' perceptions of PLC relationships structure. An outcome revealed that there was a culture of trust and among staff that enhanced teaching and learning. Teacher A commented that "We help each other out all of the time." The teachers in focus group two responded that the culture of respect for one another helps each other out.

Question 3 sought to see if there was a statistically significant difference in the median score of the teacher responses to the items on Olivier et al.'s (2016) six professional learning characteristics on the PLCA. The outcome of the 1-sample *t-test* indicated not to reject the null hypothesis. Therefore, there was no statistically significant difference in the mean score of the items on the PLCA and the teachers' responses. However, the subscale of supportive conditions – structures had the lowest

mean of the six categories. The information aligns with the qualitative data which indicated that teachers felt math PLCs needed to have more time devoted to them.

In summary, I used a sequential mixed method approach to analyze teachers' perceptions of how professional learning communities' impact improving math critical thinking pedagogy. I used Olivier et al.'s (2016) PLCA Likert scale assessment to obtain teachers' responses to six PLC characteristics, which were shared and supportive leadership, shared values and visions, collective learning and application, shared personal practice, supportive relationships, and supportive conditions. The mean scores of the survey respondents were compared to the value of 3 for each of the six subscales via a 1 sample *t*-test. The results of the teacher responses on the PLCA revealed no significant differences from the value of 3, indicating that teachers perceived math PLCs favorably. The qualitative findings supported the quantitative findings as the teachers perceived PLCs positively, however a significant problem was revealed as the teachers were frustrated with support and structure of the math PLCs within the school and the district. The qualitative results indicated that even though the teachers had a positive perception of math PLCs improving their pedagogy, they felt the administrative support for math PLCs in the school and district were lacking, critical thinking instructional strategies integrated within the math PLCs was inconsistent, focus on math was inconsistent, and not enough time was dedicated to math PLCs. The information coincides with the quantitative data as supportive conditions and structures on the PLCA was ranked lowest by the teachers. The next section describes the project that was derived from the findings.

Section 3: The Project

Teachers in the study perceived they need more consistency in their math PLCs to affect their math pedagogy. As the district rolled out new initiatives, the focus moved from math PLCs to the new writing initiative. Moreover, qualitative data indicated teachers within the two Georgia schools of the study felt there were inconsistencies with critical thinking strategies being integrated within the math PLC meetings, and math PLC meetings were held inconsistently. Teachers stated they needed more time, consistency, and collaboration within math PLCs. The project was derived from the findings of the quantitative and qualitative data which indicated that teachers' perceptions of PLCs were favorable. However, comments about substantial frustration within the qualitative teacher feedback indicated that the administration within the schools and district did not consistently support math PLCs. Teachers were committed to the math PLCs and found them to be helpful in supporting their critical thinking pedagogy. But erratic focus on math PLCs, lack of time for collaboration, lack of regularity in math PLC meetings being held, and fluctuating math critical thinking strategies integrated in the math PLCs left teachers frustrated as the inconsistency in the PLC focus reduced the math PLCs' effectiveness. The qualitative data aligns with the quantitative data that indicated Supportive Conditions and Structures to be the lowest ranked subscale. The project was derived from the data to continue math PLCs within the schools as the teachers perceived them positively. However, the project will fortify math PLCs within the district and address the problems of inconsistent math PLC meetings, including few math critical

thinking strategies within the math PLCs, and inconsistent administrative support for math PLCs within the schools and district.

The project (see Appendix A) is a three-day professional development session designed to guide school leaders through the implementation and monitoring process of executing a rigorous math critical thinking PLC within the study site schools. The professional development session will help schools sustain math PLCs, creating consistency and continual administrative support within the schools and district. When quality math PLCs are maintained, math professional development will be continuous and relevant as professional development that the PLC will provide will change as situations change within the school. PLCs are important to school life and allow teachers to collaborate and learn from each other in a way that is relevant to them and leads to continual professional development (Hord, 2014).

The three days are divided throughout the year for school leaders to learn how to monitor, schedule, and facilitate their math critical thinking PLCs. The project includes an agenda for the three days of professional development, a PowerPoint presentation for each of the three days, Math PLC guidelines, and a math critical thinking PLC schedule for the year (see Appendix A). The project leaders will guide school leaders through the planning, scheduling, facilitating, and monitoring math PLCs for an entire school year.

Rationale

The qualitative data indicated that teachers viewed PLCs positively, but also indicated problems with the existing math PLCs. Teachers' feedback regarding the

qualitative data strongly indicated that consistent principal support of the math critical thinking PLCs was lacking and a threat to the sustainability of the PLC leader's role within the math PLCs. The PLC leaders in the two schools under study were assistant principals. Lucy Calkins Units of Study was a new writing initiative that the district under study rolled out the year of the study. Teacher CC stated, "when Lucy Calkins was introduced, all the trainings in the district and at school were about writing and we didn't meet as math PLCs that year."

Hord and Hall (2014) suggested that administrators within the district and schools need to have a consistent message of support for PLCs. They went on further to suggest that if either one, the district or school, is weak in supporting the PLC, then it will fail. The project brings together PLC leaders in the schools and within the district to give the math PLC consistent administrative support. Furthermore, the PLC professional development team meets three different times to support school PLC leaders throughout the year and emphasize their importance to the math PLC's success. Other problems teachers mentioned were that math PLCs were held inconsistently, math critical thinking strategies were integrated in the math PLC meetings sporadically, there was not enough time for collaboration, and the administration did not maintain a constant focus on the math PLCs.

The math critical thinking component of the project will be rolled out to the schools by the district math department. These critical thinking math strategies will be given to the school leaders during the math critical thinking PLC professional

development. Leaders learning math critical thinking strategies and having a math PLC throughout the year to will ensure math critical thinking strategies are given to teachers in the school PLCs on a regular basis. Teachers' feedback suggested that math critical thinking strategies were not given to teachers regularly. Teacher AA stated, "I have gone out for math professional learning, but that was over the summer. It was good, but I haven't gotten critical thinking strategies and I need them." Another teacher stated: "The math PLCs are good, and I learn a lot like number talks, but they don't happen that often." The project will address in-depth PLC structure, time for teacher PLC collaboration, and PLC administrative support. The PLC is designed to specifically address the distinct characteristics of adult learners in the study site district.

The project addresses most problems derived from the study as well as supporting PLCs as the teachers viewed them favorably. The professional development sessions are designed to educate school leaders on how to effectively conduct math PLCs throughout the year. Assistant principals and principals will be responsible for attending the professional development sessions. The sessions with be spaced three times throughout the year. The project holds school administration accountable for following through with the math PLCs and their components. Schools will be responsible for sharing math PLC minutes at the sessions, holding schools accountable for conducting rigorous math PLCs within their schools. The PLC guidelines will be communicated to the schools so that there is consistency regarding the components of math PLCs within the schools. These components will be monitored and supported as the school leaders come to the math PLC

professional development three times within the year. District support in the district math department will be involved in the Math PLC professional development sessions and will be there for support and collaboration with the schools. The project addresses adding consistency and administrative support from the school and district administration.

Student CRCT scores in the study site district had fallen below the states' average scores for the past 6 years (GaDOE, 2017). Improving teachers' instructional skills is the first step toward improving student achievement (DuFour, 2014). Therefore, to improve students' math critical thinking, teachers' math critical thinking instructional strategies needed to be analyzed and improved. Teachers' survey data from the study indicated that math PLCs were in place, but lacked key components such as shared and supportive school and district leadership, and supported PLC structures such and consistent PLC meetings, and time for teachers' math collaboration. PLC conditions and structures teachers felt were missing included regular math PLC meetings, time for collaboration, and regular critical thinking strategies embedded within math PLCs. The qualitative data revealed that the teachers expressed frustration with the inconsistencies in the math PLCs and felt math PLCs could be more effective if the above structures were strengthened.

The data from the teacher surveys also indicated that the time provided for the math PLCs was inconsistent. DuFour (2014), Hord, (2012), and Olivier et al., (2016) concurred that PLCs are an effective way to increase teachers' instructional strategies. The qualitative feedback from the current study revealed that teachers wanted more time to develop critical thinking strategies, plan critical thinking math activities, and meet

more often vertically with math teachers and math PLCs. The quantitative data indicated that teachers needed more shared and supportive leadership and shared and supportive structures for PLCs. The lack of adequate time to collaborate, and lack of consistent PLC meetings were two areas of PLC structure that were deficient in the schools of study. For example, teacher B stated, "from year to year the emphasis changes in the school and whether we meet as math PLCs." The project addresses consistent structure in PLCs by teaching the PLC school leaders how to maintain monthly math PLCs, and defining the PLC. The professional development for math critical thinking PLCs is designed to address the lack of structure and leadership support of current math PLCs at the study site district. The structure of the new math critical thinking PLCs would add support for the schools and accountability for the school and district stakeholders.

Teacher surveys revealed that teachers needed more professional development for critical thinking, and more time to plan critical thinking math activities for the students. Merriam (2014) stated that adults need designated time to learn, process, and implement new ideas and skills. Stylianides and Ball (2008) stressed that math teachers' learning should always include problem-solving strategies that lead students to achieve higher levels of learning. The project may improve critical thinking among teachers at the study site district in two ways. First, the schools will add one critical thinking strategy to math PLCs each month. Teachers will need to attend math professional development workshops, conferences, or meetings and bring back critical thinking math strategies to share with the other math teachers in the school. Secondly, the district math director will

supplement the schools' math PLCs with a different critical thinking math strategy each month to share with the math teachers participating in the math PLCs. Learning new approaches from peers and PLC leaders might ensure that teachers acquire more critical thinking strategies on a consistent basis.

The professional development for math critical thinking PLCs may address the low math achievement in the district by increasing the level and consistency of math critical thinking strategies, collaboration, and math PLC structure. If teachers collaborate and focus on critical thinking, math critical thinking may be improved among the district's students. Research indicates that improved math instructional strategies for critical thinking can lead to increased math achievement (Ball & Cohen, 1996; Newman, 2014). Therefore, it is my belief that the project of math critical thinking PLC professional development will lead to increased math achievement in the study site district.

Literature Review

I conducted a literature review on professional development and Knowles's (2015) theory of adult learning, which corresponded to the project genre. The literature review also includes a discussion of themes related to the findings of the study which includes increased math PLC structure, and math critical thinking professional development. An analysis will be presented that discusses how the findings of the study and review of literature guided the development of the project of math critical thinking PLC professional development. I conducted the literature review using the following

databases: Education Source and ERIC. In addition, I employed the following search terms: *professional development, adult learning, critical thinking professional learning, professional learning community structure, planning time, collaboration, collaborative planning, math professional development, math professional learning communities, math critical learning professional development, and professional learning leadership.*

There is a broad spectrum of professional development presentations and styles when educating adults. Adults learn differently than children (Knowles, 2015; Merriam, 2014; Wang, 2015). It can be challenging to create an effective format that addresses all the participants' learning styles and needs. Merriam (2014) stated that professional development for adults should be developed to address the unique qualities of the adult learner. Building educator capacity requires precisely planned professional learning (Lieberman, Miller, & Roy, 2014). PLCs are comprised of many people within the school meeting consistently to collaborate and make school improvements for student achievement (Hord & Hall, 2014). Professional development for PLCs is complex, adding the component of math critical thinking makes professional development even more complex. Therefore, the district under study will benefit from a math critical thinking PLC leader professional development program on how to conduct and structure a math critical thinking PLCs.

The literature review will be broken up in to two themes of PLC structure and support, and Knowles's theory of adult learning. First, will be a review of PLC literature.

Kalkan (2016) stated that the informal and formal structure and support for PLCs is often ignored. Kalkan (2016) further explained that literature often talks about the success of schools who have PLCs, but not the in-depth structure needed to obtain success. Gray and Sommers (2015) also identified the importance of defining and monitoring structure within a PLC. Gray and Sommers (2015) indicated that principals must monitor the formal and informal structure of a PLC to ensure obstructions to PLCs are addressed and people resistant to school improvement accept the change. Other researchers (DuFour, 2014; Hord, 2012; Olivier et al., 2016) agree with the importance of consistent PLC structure and administrative support leading to effective PLCs.

Andragogy

Knowles' (2015) theory of adult learning theory, called andragogy, encompasses six assumptions that motivate adults to learn. The six principles of andragogy are: need to know, self-concept, prior experience, readiness to learn, orientation to learning, and motivation to learn. Knowles's principles of adult learning create a framework that enable adult professional development designers to create effective learning processes for adults (Knowles, 2015). Andragogy was created to be used in any adult learning environment (Knowles, 2015). According to the theory, adult learners tend to be self-directed and take ownership for their actions (Malcolm, 2015). Merriam (2014) stated that there are many theories and models on adult learning, however andragogy is the best choice because of the six principles within andragogy. The following provides details on the principles of andragogy and how it relates to findings of the current investigation.

One of the andragogical principles is orientation to learning, which implies that adults learn through life-centered, or problem-centered tasks (Knowles, 2015). Levi-Keren and Patki (2016) found that teachers who attended "one size fits all" (p.5) offsite sessions felt that the information they obtained did not help their professional growth. The authors further stated that professional development should have a needs assessment to make sure learning is satisfying to participants. Merriam (2014) stated that participating in complex conversations and thinking involved in problem-solving within andragogy leads to highly developed metacognitive skills of critical self-reflection. Complex conversations are an integral part of the project and will lead the teachers to highly developed reflection of their critical thinking math strategies and student activities. Hagen and Park (2016) found through the application of cognitive neuroscience, discussions involving problem-solving led to deeper learning. The problem-centered task of facilitating and sustaining a math critical thinking PLC is both problem-centered and applies to the PLC participants and leaders work life. Researchers (Hagen & Park, 2016; Keren & Patkin, 2016; Knowles, 2015; Merriam, 2014) agreed that adults are motivated by problem-based professional development that relates to their everyday lives.

Andragogy's principle of orientation is consistent with the findings of the current study. Teachers' survey responses indicated they were motivated to learn, collaborate, and problem-solve within the math PLCs. Teachers mentioned in the surveys that there were math PLCs in the past that improved their math instruction; however, those results

were not currently happening and teachers wished math PLCs were scheduled regularly throughout the year.

The project's professional development approach relates to andragogy's principle of orientation to learn as school leaders will be challenged with creating effective math critical thinking PLCs for their schools. School leaders' task of creating their PLC plan for their school is both life related and task related. Leaders will take the PLC plan back to their school and implement it, which is life-related. During their experience with the project's professional learning, they will evaluate their current math critical thinking professional learning needs for the teachers in their schools and create a plan for PLCs that addresses these needs. The PLC leaders will also evaluate their own needs and expectations of the math PLC professional development. The evaluation will help identify what changes need to be made to the math critical thinking professional development for day two. The evaluation's information will ensure the professional development will meet the needs of the PLC leaders.

Another principle of andragogy is learner's need to know how, what, and why they are attending the professional development (Knowles, 2015). Researchers (Knowles, 2015; Olivier et al., 2016; Troll, 2017) agreed that adult learners need to know and be involved in their own professional development process. Troll (2017) stated that teachers will accept new information easily when they have control over what they learn and how they learn it. Teachers are more motivated to participate and collaborate with other teachers when they have shared interests and goals (Olivier et al., 2016). Educators

indicated in the focus groups that they liked having shared leadership and knowing the reasons decisions were made. For example, teacher A in the focus group stated, "I like when I am involved in math PLCs because we decide together as a group what strategies we all have to use. And the conversation makes me understand how it was decided, and why we need to do it." The principle of the need to know is interwoven through the project's purpose to address students' low math achievement and critical thinking skills in the study site district. Individual math scores will be broken down for each school for leaders to analyze math data and understand why they are creating and implementing their school's math PLC. Each school leader in the project's professional development will understand their specific school's needs and will be guided through how to schedule and plan their math critical thinking PLCs based on their needs throughout the year.

Several authors (Blackley & Sheffield, 2015; DuFour, 2014; Hord, 2012; Olivier et al., 2016) expressed the importance of adults learning through collaboration and modeled observations. The readiness to learn is a principle in andragogy acknowledges that adults are motivated in situations where learners listen, observe, and are motivated by examples of superior performance (Knowles, 2015). Beaton (2017) explained that teacher learning is richer when teachers collaborate on a common problem when compared to silently listening to a speaker in a hotel conference room. Other researchers (Blackley & Sheffield, 2015; DuFour, 2014; Hord, 2012; Olivier et al., 2016) indicated that new teachers benefit from shared conversations and experiences in PLCs with veteran teachers. Bayar (2014) stated that teachers need time with one another to share

ideas and discuss common instructional strategies which will inspire each other to try innovative initiatives with their students. Praise and acknowledgement from administrators and peers is inspiring not only for that teacher, but for the teachers observing the premier strategy (Brayer, 2014). Researchers (Blackley & Sheffield, 2015; Brayar, 2014; DuFour, 2014; Hord, 2016; Olivier et al., 2016) agreed with Knowles's (2015) principle of adult learning, that motivation in learning occurs when adults are given situations to collaborate and learn from one another.

The readiness to learn principle of andragogy relates to the data from the study. The qualitative and quantitative information from the study produced a common theme of shared learning. The teacher interviews revealed that teachers valued observing each other and learning from other teachers used as models for teaching. Teacher D in the focus group shared, "I get so much out of observing another classroom, I always learn so much." Teacher B in the focus group added, "I have gotten so many ideas from going in to teacher A's classroom. I use the exact strategy or change it to fit the needs in my classroom, but I always learn a lot when I go in there." The readiness to learn principle led to the development of the project's critical thinking math PLCs, in which school leaders create environments for teachers to learn from one another.

Knowles (2015) stated that professional learning should have a personal payoff, which aligns with andragogy's principle of motivation to learn. Bayar (2014) conducted a qualitative study consisting of 16 teachers who were interviewed regarding their experiences of professional development over a 12-month timeframe. Bayar's research

revealed professional development that motivated teachers to learn should have the following components, a match to existing teach and school needs, teacher involvement in planning professional development, and high-quality instructors (Brayar, 2014). (Olivier et al., 2016; Troll, 2017) concurred that adults are motivated to learn when there is a personal payoff, they are actively involved in long-term engagement, and there is shared learning with superior performers.

The current project's professional development strategy aligns with the research associated with the andragogical principle of motivation and PLCs. The project involves the creation of a critical thinking math PLC to improve teachers' critical thinking math strategies. Schools creating their own math critical thinking PLC should have enough intrinsic value to motivate a school leader and a teacher. Principals will address math critical thinking within their schools so the principals will be more motivated to follow through with the math critical thinking PLCs.

Andragogical research on motivation and research on PLCs align with results from teacher interviews. A common theme that evolved from the data was shared practice. Teachers revealed that they were motivated and learned the most during conversations about common content with peers. Teacher C in the focus group explained, "I am always talking and working with the other math teachers to get new ideas or to help plan student activities. It is where I get most of my information so if I am stuck on what to do, or where to get things I need, I go to them." A new teacher in the focus group stated, "Teacher A has been teaching math for 12 years and can steer me in

the right direction, or share ideas or activities with me when I need when I get stuck, she keeps me going when I get frustrated." Teacher BB in the interview stated that the math PLCs last year were beneficial in helping him understand the higher-level math strategies and he missed not having the math PLCs this year.

I designed the project to have schools focus on creating their own math critical thinking PLC plan. According to Muneia (2015), adult learners are motivated by being responsible for their own learning. Dever and Lash (2013) emphasized the same concept, indicating that teachers were more motivated to learn when they worked together as active participants in the learning process. Devlin-Schere and Sardone (2013) found that teachers actively working through problems with common interests achieve the highest level of learning. Learning is not represented when the instructor tells participants information and are passive during the learning (Beaton, 2017; Devlin-Schere & Sardone, 2013; Dever & Lash, 2013; Merriam, 2014; Muneia, 2015; Nurhayati, 2015; Wang, 2015). Johnson et al. (2014) emphasized that effective adult learning must be engaging.

Johnson et al. (2014) conducted a case study at a university where an instructor used public deliberation in the classroom as a means of teaching andragogy as content. Upon course completion, students completed surveys on the principles of andragogy. The surveys indicated that the participants gained an understanding of multiple perspectives, an ability to weigh tradeoffs, and an increase in student critical thinking. Johnson et al.'s learner-center activity was an effective method for teaching critical thinking to adults.

Another study in universities in China indicated the effectiveness of andragogy compared to the insufficient method used in China of being teacher centered (Wang, 2015). Wang (2015) compared the Western use of andragogy in adult teaching to the Chinese method of rote memorization. According to Wang, China does not believe in the Western use of andragogy and teaches adults using teacher-focused methods and rote memorization. The study surveyed 160 teachers in China that taught English in eight Chinese universities. Results indicated that the rote method of teaching in China led to lower levels of learning within the structure of Bloom's Taxonomy (1956). Teaching through rote memorization can negatively affect the depth of learning in children and adults (Bloom, 1956; Knowles, 2015; Merriam, 2014; Wang, 2015).

The research regarding learner-centered professional development directly relates to the data derived from the current study. A common theme from the qualitative and quantitative data from the study was collaborative learning. Teachers in the focus groups and interviews indicated that they gained the most from PLCs when collaboration occurred, as opposed to attending conferences or other off-site professional development. Teacher A in the interview explained, "Sometimes outside conferences don't apply to your situation, or you get information and don't really come back and use it in your classroom." Teacher BB in the focus group explained, "Our principal lets us decide what to talk about in our PLCs so we get what we need out of them, and I like that." The research and the data both relate to Knowles' principle of self-concept.

The role of the learners' experience is the last principle of andragogy (Knowles, 2015). Researchers (Beaton, 2017; DuFour, 2014; Fairman, 2017; Hord, 2014; Merriam, 2014; Olivier et al., 2016; Wang, 2015) agree with Knowles' principle of the role of the learner's experience, which states that adults enter learning situations with a wider range of experience than youth do (Knowles, 2015). Knowles (2014) stated that the richest adult learning experiences occur during group discussions, problem-solving activities, peer-helping activities, and case methods. Fairman (2017) explained,

> If we want to harness the expertise of our staff members and deepen their engagement in school improvement, we have to deliberately build their capacity to lead. To do this, we need to provide explicit supports for teachers in leading their peers. We also need to share responsibility for important work and communicate expectations clearly. (p. 25).

The current project incorporated the principle of learner experience within the PLC format. The math critical thinking PLC professional development will present a format for school PLC leaders to create an environment that encourages teachers with a wide range of experiences to collaborate with each other.

The research aligns with the data from the study. Another common theme that evolved from the interviews with the teachers was collaboration. Teachers' responses aligned with the importance and effectiveness of working together to problem solve, share best practices, and expand critical thinking math strategies.

I used Knowles's (2015) six principles of adult learning, coupled with data from the study, to create professional development for math critical thinking PLCs that will effectively address low math achievement in the study site district. In the following section, I address study results and explain how research and data support the need for the district to strengthen the structure of current PLCs and add more math critical thinking professional development.

Increased Math PLC Structure

The genre of professional development and the project of math critical thinking PLCs is appropriate to address low math achievement in the district for several reasons. First, research indicates that teachers improve their instructional strategies through collaboration (Blackley & Sheffield, 2015; Brayar, 2014; DuFour, 2014; Hord, 2016; Knowles, 2015; Olivier et al., 2016). The critical thinking math PLCs are designed to increase math PLC structure for the schools so that regular math critical thinking conversations become part of the schools' culture, thus increasing students' critical thinking skills and potentially leading to increased math achievement.

Another reason the professional development for math critical thinking PLCs will affect the district's low math achievement is because the professional development and PLCs will be ongoing. The added structure of math critical thinking PLCs will allow new critical thinking math strategies to be shared on a continuous basis. Researchers (Beswick, 2014; Porumb, 2014) have found that professional development must be continuous so teachers can follow up with problems and bring new issues back for

discussion. Matherson and Windle (2014) also found that teachers wanted professional development learning opportunities that were not quick fixes and are sustained over time. I designed the current project to bring together PLC leaders three times a year. Beyond the PLC leaders meeting throughout the year, the schools' math critical thinking PLCs are to meet monthly. The math critical thinking professional development for the teachers will be continuous throughout the year. PLC leaders will have opportunities to bring issues they are having back at their schools to the group to problem solve.

Findings form the current study reflect teachers' desires for ongoing professional development. Survey data indicated that math PLCs had been in place during the previous year, and teachers found them to be beneficial. However, teachers noted that the math PLCs were not currently in place, and they wanted them to continue because they received "a lot of math instructional strategies from them"

Students' math achievement in the study site district may be positively influenced by the project because there is accountability, follow-up, and structure within the math critical thinking PLC professional development. The school PLC leaders will bring PLC minutes and math critical thinking issues from the schools' math critical thinking PLCs. The minutes will provide proof that the schools' PLCs are in place. The project defines three days throughout the year that the schools will follow-up with the strengths and weaknesses of their school's math critical thinking PLC. Stachler, Young, and Borr, (2013) found that student achievement improved when collaboration and extended professional development were integrated with teachers. Two groups of teachers were

given professional development. The group that was given professional development with collaboration and follow-up used the strategies significantly more than the teachers who were not given the collaborative professional development.

Finally, the project has the potential to increase students' math achievement because the PLCs are accessible to teachers. PLCs offer a way for schools to sustain professional development because they can occur within the schools' means of operation of time and expense (DuFour, 2016; Hirsch, 2016; Hord, 2012; Olivier et al., 2016). Too often, professional development is limited to only one or two teachers because of expenses related to travel or attending off-site conferences. Therefore, the added structure of the math PLC project will be accessible and realistic for teachers to build into their busy schedules and schools' limited budgets. More teachers can participate in the math critical thinking PLCs because they occur on-site. The quality of instruction the teachers receive will be reflected in students' increases in math achievement (Khoule, Pacht, Schwartz, & Van Slyck, 2015). The students will benefit with better critical thinking math strategies if the teachers have more access to collaboration and professional development. The previous section explained how the added structure of the math PLCs was appropriate for addressing low math achievement among students in the study site district. The section also showed how the criteria from research and the findings from the study guided the project. The following section addresses how findings and research led to adding more PLC structure, and math critical thinking professional development within the project.

Math Critical Thinking Professional Development

Math critical thinking professional development should be relevant and employed continuously to transform teachers' math critical thinking math instructional strategies to a higher level. Brendefur's (2013) research showed that teachers who had continuous math critical thinking professional development had higher level math instructional skills. Brendefur (2013) conducted a study using four preschool Head Start programs and 24 teachers. One group of teachers was given professional development throughout the year for math, the other group was not given any professional development. The teachers were given 16 hours of math professional development with follow-up sessions after they began to support them after using the higher-level math strategies. The students with the teachers who received math professional development developed better problem-solving and spatial abilities than children whose teachers did not have math professional development (Brendefur, 2013). The continuous math professional development helped the math teachers improve their critical thinking math instructional skills, helping students perform at higher levels.

A study in Iran also indicated that teachers felt the need for continuous critical thinking professional development. Asgharheidari and Tahriri (2015) used qualitative questionnaires to analyze attitudes among 39 teachers regarding the importance of critical thinking. The teachers indicated that critical thinking was an important part of their careers. However, most of the teachers expressed a strong desire for professional development to be scheduled more often related to teaching critical thinking skills.

Asgharheidari and Tahriri concluded that special professional development courses must be included in teacher training courses to increase teachers' ability to teach critical thinking.

Asgharheidari and Tahriri's (2015) study aligned with findings from Gumus and Belibas (2016) on critical thinking professional development. Gumus and Belibas analyzed data from the 2011 cycle of Turkey's Trends in International Mathematics and Science Study. The researchers conducted a multilevel regression analyses using student, school, and teacher level. Results indicated that critical thinking professional development activities were positively associated with student achievement.

Another study by Taton (2015) emphasized the importance of continuous professional development for critical thinking. Taton conducted a study in which Math Teachers' Circles (MTCs) met regularly throughout the school year. The MTCs allowed a regular time for teachers to collaborate about math pedagogy. Taton's research revealed that after one year of participation in MTCs, teachers felt more confident in their abilities to teach inquiry-based, problem-solving activities. Teachers reported that the MTCs built collegiality, which helped them discover new higher-level math instructional strategies. Taton indicated that during participation in the MTCs, teachers' scores have significantly increased on a standard test for measuring mathematical knowledge for teaching. Taton stated that professional development cannot replicate outdated pedagogy, but transformative professional learning must be ongoing (Taton, 2015).

Many researchers (Asgharheidari & Tahriri, 2015; Brendefur, 2013; Gumus & Belibas, 2016; Taton, 2015) agree that math critical thinking professional development needs to be continuous, which aligns with data from the current study. A common theme that evolved from data from the study indicated that math PLCs were beneficial to teachers' critical thinking teaching practices. Teachers indicated in interviews that they needed math PLCs to be ongoing to further develop their critical thinking math instruction. Teacher AA stated, "The math PLCs last gave us a lot of good ideas for number talks, but we need more of them. They only happened last year and then stopped." The project's math PLCs will integrate new critical thinking strategies monthly throughout the year. Moreover, math PLCs will be monitored by area superintendents and principals to ensure they occur monthly, and with integrity.

Piasta, Logan, Yeager-Pelatti, Capps, and Petrill's (2015) study emphasized the importance that math critical thinking professional development be meaningful to participants. The study included 65 teachers who participated in 10 days (64 hours) of math professional development. The professional learning occurred outside of the school in a lecture format. Piasta et al. concluded that math achievement did not improve students' math learning, even though teachers had received numerous, continuous hours of math professional development. The teachers indicated that the professional development did not fit their needs. Therefore, math professional development needs to be relevant to the teachers within the schools they are teaching.

The current project is designed to foster collaboration during math PLCs. Teachers will collaborate about current math strategies and best practices relevant to the issues the math teachers have with their own students. During PLCs, teachers will meet regularly to collaborate, review student data, and share best practices that are meaningful to their professional learning needs (DuFour, 2016; Hord, 2012; Olivier et al., 2016). The meaningfulness of professional development aligns with results from the current study. A common category of "deliberate focus" on specific subject matter from the qualitative data indicated that collaboration was regularly sought out by teachers as a means of increasing their math critical thinking instructional strategies. Teacher BB stated in an interview that the outside professional development sessions he was sent to over the summer did not always apply to what he needs, or what his students need.

Researchers (Asgharheidari & Tahriri, 2015; Brendefur, 2013; Gumus and Belibas, 2016; Piasta, Logan, Yeager-Pelatti, Capps, and Petrill's, 2015; Taton, 2015) agree that math critical thinking professional development needs to be meaningful and continuous. The current project is designed for schools to conduct math critical thinking PLCs monthly. The nature of PLCs will create collaboration and communication that is meaningful to the participants of the PLCs. The research and the findings from the study led to the project's development to address low math achievement in the district under study.

In summary, school districts are faced with many problems with professional development in today's environment. High turnover rates among district teachers and administrators creates a monumental task for professional development in the districts. Knowles (2015) theory of andragogy is appropriate to address the low math achievement in the district under study and guide the project's math critical thinking PLC professional development. Knowles' key principles for professional development are embedded in the project's professional development. The project was created based on findings from the study and themes from research, which include increasing the math PLC structure and adding continuous and meaningful math critical thinking professional development. School leaders are given the task of improving math critical thinking, and students' math achievement will benefit from the rigorous professional development that andragogy and the math critical thinking PLC professional development will produce.

Project Description

The first day of the math PLC will be held in August to introduce the critical thinking math PLC outline for the year. The first half of the day will be designated to inform the school leaders of the data and research that led to the need for the math critical thinking PLCS. The second half of the first day is allotted for schools to work with other math PLC leaders to plan their math PLCs for the year. During the dedicated time, district leaders will deliver critical thinking math ideas and strategies for the schools to use, as well as support and resources, such as a list of local math professional development sessions, math conferences, and sources for math manipulatives.

Day 2 of the professional development for the district is scheduled for January and will consist of a work session to analyze the work of the math PLC from the fall, report and collaborate on the status of the math PLC, and obtain math critical thinking resources from the district for the next semester.

Day 3 of the math critical thinking PLC professional development will take place in May. During day 3, school leaders will evaluate the year of math PLCs and analyze changes to the PLCs that should be made for the following year. The first part of the day will be scheduled for the district to review math strategies and math resources for next year. During the allotted time, school leaders will collaborate with one another to determine which strategies worked to improve math critical thinking and math achievement during the year, and which did not work. The schedule for the three-day math critical thinking professional learning community professional development is included in Appendix A.

The components of the math critical thinking PLC are a PowerPoint for the three days of professional development, a math PLC scheduling template, math critical thinking PLC guidelines, and a math PLC minutes' template. The implementation of the school's math critical thinking PLCs will start in August. The school math critical thinking PLCs will meet monthly.

Resources and Existing Supports

An existing support in the district is math professional learning liaisons (PLLs). PLLs are people who travel around to do math professional development in the schools.

PLLs could attend the math PLCs, or provide critical thinking instructional strategies for the schools' PLC meetings. There was a district math director who will play a part in the project's three-day math critical thinking PLC professional development sessions. The math director will also provide a monthly, districtwide math critical thinking instructional strategy or student activity to be shared at the schools' monthly math PLCs. Another existing support in the district are professional development workshops for math. Teachers can sign up for professional learning for the district workshops at no cost to the school. The school must pay for substitute teachers so the math teachers can attend the professional learning. Other existing supports in the schools include instructional coaches who can help coach teachers with the math critical thinking strategies and student activities.

Teachers and administrators play an important role in the project's success. PLC leaders will attend a three-day Math Critical Thinking Professional Development that is staggered throughout the year for ongoing support. PLC guidelines will be given to PLC leaders with expectations of how critical thinking math PLCs will be facilitated. Guidelines for the meetings, minutes, monthly schedules, and district meetings will be explained at the first math critical thinking PLC professional development meeting. The schools will be directed to send the math PLC minutes to the area-superintendents for accountability. School leaders will also receive critical thinking resources during the first meeting, and they will be responsible for planning in to their meetings. The first meeting will include templates for scheduling monthly math PLC meetings and minutes.

District support from the area superintendents, superintendent, district math directors, district curriculum directors, and math PLLs are all existing supports who will be active participants in the project either through leading math critical thinking professional development sessions, supporting the schools' math PLCs, or supporting the project's three-day math critical thinking professional development for the district.

Time is already in the schedule for the math critical thinking PLCs to meet. However, they need to meet monthly instead of four times per year, and there needs to be consistency and accountability with the math PLCs, which was addressed with the project. The project (see Appendix A) includes an outline for the Math Critical Thinking PLCs with signature lines for people who were required to attend the meetings. Accountability is integrated by requiring each school to create and send math PLC minutes each month to the area superintendents. Area superintendents will follow up each month with principals who are not in compliance with their Math Critical Thinking PLCs. The compliance of the minutes will be reviewed during the project's January and May meetings.

Potential resources for the project include capital allocated for math conferences, workshops, and math critical thinking sessions for teachers outside of the district. Some of the resources may already be planned within the schools' budgets but may need to be increased. Teachers will attend the math professional learning and bring back to the school critical thinking math strategies to share with the school's math PLCs. Additional capital could also be used to bring professional learning in to the school.

Potential Barriers and Solutions

One potential barrier is the support needed from district stakeholders, on multiple levels. The project requires coordination from stakeholders throughout all levels of the district, from the superintendent to the math teachers. Clear support and communication needs to be conveyed by key people within the district. If the support for the math critical thinking PLCs is not uniform throughout the district, then the fidelity of the project will be compromised.

A solution to the problem is ensuring the superintendent and area superintendents supported the project. Support from superintendents is needed to help the principals understand the importance of math critical thinking PLCs, so that support and willingness on the part of the principals was gained to carry PLCs out in the schools. School leaders have many responsibilities and are pulled in any array of directions on any given day (Hord, 2014; Knowles, 2015; Olivier et al., 2016). Therefore, it is important for principals' superiors to support math PLCs and the project for them achieve an increase in math achievement throughout the district. I presented the idea of the project to the district math director, who expressed interest in following through with the project. The math director's support will help ensure there is commitment and follow through for the different phases of the project.

Another potential barrier is ensuring the schools are scheduled throughout the district for the project's three-day math critical thinking professional development. For the project to affect math achievement in the district, school personnel will need support

to attend the project's three days of professional development, and then carry out the responsibilities between the project's sessions. The school PLC leaders' time for the professional development will require superintendent, or area superintendent, approval to allow key school personnel to attend the project's three-day math critical thinking PLC professional development. The math director expressed her commitment to the project and felt the superintendents will give their full support. The authorization for school personnel to attend the professional development will be proposed by the district math director, who will then obtain authorization from the area superintendents. After approval, the district math director will send out communication to the principals to bring key math PLC personnel from the schools to attend the three-day professional development. Clear direction from administrators will be required to enable the project to increase math achievement in the district.

Proposal for Implementation and Timetable

Implementation of the project required coordination from multiple district departments and school personnel. The math director will work with math professional development liaisons to prepare for the math critical thinking professional development. Next, communication will be sent to the schools from the district math director informing principals to become the Math Critical Thinking PLC leaders for their building, or designate the assistant principal. The requirement of school PLC leaders' attendance at the Math Critical Thinking PLC will be detailed in the communication. The location,

time, and dates for the Math Critical Thinking PLC professional development will be detailed in the communication, as well.

The timetable for the project is one academic school year. The first day of the project's professional development will take place in August 2018, during the district's preplanning. During that first day, school PLC leaders will create a plan and schedule for the first semester's math critical thinking PLCs, shared best practices and strategies for PLCs with other schools, learned about math critical thinking guidelines, and learned how to integrate critical thinking instructional strategies into their math PLCs. School leaders will implement the information and components from the math PLC professional development into their schools' math PLCs. Each school will institute the critical thinking math PLCs in August. School leaders will conduct math PLC meetings in their schools each month. During January, day two of the project's math critical thinking PLC professional development will be presented. During day two, school leaders will analyze math data, shared best practices with other schools, and create their schedules for math PLCs set to occur over the course of the second semester. The schools will continue their critical thinking math PLCs each month.

School leaders will attend day three of the math critical thinking PLC in May. School leaders will analyze the math MAP data, which will allow rich conversations regarding strategies for facilitating math PLCs, math critical thinking strategies, and other best practices. During the second half of the third day of the professional development,

school leaders will fine-tune their math critical thinking PLCs for next year and create next year's PLC schedule.

Table 6

Time Table for Math Critical Thinking Professional Learning Community Professional Development Implementation

Monthly Schedule	Activities
July - Week 5	District math director will work with researcher and district math professional development liaisons to discuss and plan the math critical thinking PLC professional development.
Week 6	Math director sends communication out to the principals scheduling the math critical thinking PLC professional development.
August - Week 7	Conducted day one of the district professional development for math critical thinking PLCs for school PLC leaders. Send out evaluation to participants Review evaluations and adjust professional development for Day 2.
Weeks 8-10	School leaders formalize their math critical thinking PLCs within their schools. Introduce fall math PLC schedule. Create PLC norms and goals.
September - Weeks 11-14	Schools conduct math critical thinking PLCs with critical thinking professional development from the district embedded.
October – Weeks 15- 18	Schools conduct math critical thinking PLCs with critical thinking professional development from the district embedded.
Nov. / Dec. – Weeks 19 - 26	Schools conduct math critical thinking PLCs with critical thinking professional development from the district embedded.

(*table continued*)

Monthly Schedule	Activities
January- Weeks 27 – 30	Conduct day two of the district professional development for math critical thinking PLCs for school PLC leaders. Send out evaluations to participants of the professional development. Reviewed evaluations and adjust professional development for Day 3 based on feedback.
February – Weeks 31 – 34	Schools discuss adjustments needed to math PLCs based on the January professional development. Schools conduct math critical thinking PLCs with critical thinking professional development from the district embedded.
March – Weeks 35 – 38	Schools conduct math critical thinking PLCs with critical thinking professional development from the district embedded.
April – Weeks 39 – 42	Schools conduct math critical thinking PLCs with critical thinking professional development from the district embedded.
May – Weeks – 43 – 46	Conduct day two of the district professional development for math critical thinking PLCs for school PLC leaders.

Roles and Responsibilities of Researcher and Others

The first responsibility I have is to meet with the math director and refine plans for the study site district's Math Critical Thinking PLC professional development. The math director's continued support and involvement is critical to the success of the project. Because she has given support for the project and its implementation, I will meet with her to plan the communication to key district personnel. The Math Critical Thinking PLC Professional Development will be rolled out by the district math director. I will work with the math director of the study site districts to support the project's facilitation throughout the year. The math director will have the responsibility of introducing the

math critical thinking PLC professional development. The district math director will also need to supply the schools with monthly critical thinking instructional strategies that will be shared in the schools' math PLCs.

The math district professional learning liaisons will also have a role in the project. The project is designed so that schools collaborate with one another and shared best practices. The professional learning liaisons (PLLs) for the specific regions will help their schools with the collaboration process, condense the information, and share it with all the schools in the district. The PLLs will also work with the math director to plan and communicate the monthly critical thinking math strategy to the schools.

The district math director also has the role of explaining the importance and structure of the math critical thinking PLCs to the schools during the first day of the project's professional development. The math director will also discuss the artifacts needed for the second and third professional development days, such as math PLC minutes, MAP math data, and math PLC schedules.

The principals also have a responsibility to follow through with the math critical thinking PLCs within their schools. The principals will need to follow the Math Critical Thinking PLC Guidelines that PLC leaders will receive on day one of the project. Their responsibility will be to choose math PLC leaders who will attend the professional development, choose teachers who will participate in math professional development outside of the school, create a schedule for the year for monthly math PLCs, ensure

minutes are completed from each PLC meeting and sent to their area superintendents, and respond to issues communicated in the school's math PLC.

The math teachers have a responsibility within the project. Designated math teachers have the responsibility of attending math critical thinking PLCs and being active members who share best practices and obstacles in teaching math critical thinking within the school. All math teachers need to take ownership for learning the new critical thinking instructional strategies and applying them within classroom with fidelity.

Project Evaluation Plan

PLC leaders will be given a survey after each of the three days during the Math Critical Thinking Professional Development. The project's participants will be evaluating, so it is called a participant-based evaluation (Lodico et al, 2010). Lodico et al. (2010) stated that participant-based evaluations focus on feedback from people involved in the professional development. The stakeholders include PLC leaders, principals, math teachers, math district coordinators, and district math professional learning facilitators.

The evaluation will be conducted in two phases. There will be a formative assessment and a summative assessment. Formative assessments will be conducted while the project is taking place so that the feedback given may help improve or adjust the program (Lodico et al, 2010). There will be two formative assessments conducted. The first will be administered after day one to receive feedback and make changes to the professional learning before the second day of the project. The second formative assessment will be given after day two of the project. The information gathered from that

assessment will be used to adjust the project's content for the third day. The evaluation will be a qualitative survey with opened-ended questions at the end. The schools will also conduct the PLCA survey in May to the math teachers through Survey Monkey. The evaluation will give schools and district leaders feedback regarding teachers' perceptions of their Math Critical Thinking PLCs. The information will be used by school math critical thinking PLC leaders to make enhancements to their math PLCs for next year.

The goals of the formative evaluations will be to determine if the goals of the project were reached and determine required changes and teachers' professional development needs for the next meeting. The goals of the Math Critical Thinking PLC Professional Development session are to have school PLC leaders learn best practices for facilitating a rigorous math critical thinking PLC, develop a schedule for their math PLC for the upcoming year, supplement critical math professional development within the PLC framework, and learn how to effectively monitor, sustain, and evaluate their math critical thinking PLC. The formative evaluations will be analyzed by the PLFs and the math director. If the goals are not achieved, the math director will adjust the professional development the following day to meet those goals. The evaluators will determine if school leaders understand how to implement math critical thinking professional development with their math PLCs. The evaluators will also identify how collaboration with other school leaders transfers best practices for math PLCs. The evaluation will be conducted to determine if school leaders changed their strategies for monitoring and

evaluating PLCs. There are questions on the evaluation survey that relate to each of the evaluation goals.

Project Implications

The project should affect people favorably within the local community. The project may increase teachers' math critical thinking pedagogy. The expanded critical thinking skills that students will gain from their teachers should increase math achievement within the district. The improved math scores may help the local community by preparing elementary students for a higher level of math critical thinking.

Prior to the project, the district had been struggling financially for several years. The district has also struggled to improve district math scores. The district is likely to implement the math critical thinking PLCs professional development in to place because it is cost effective.

Improved math skills for a demographically diverse district will create social change by improving the critical thinking math skills for all students. The improved higher order strategies will help students achieve higher levels of math thinking that might not have been presented to them, had the math critical thinking PLCs not been implemented. Therefore, math students within the school district will benefit from the elementary math critical thinking PLC professional development because it will apply to all students within the district. Moreover, as students advance to middle and high school, they will have a higher level of critical thinking skills to build on for their future math

achievement. The whole community will benefit from the project as it has the potential to improve math achievement which will benefit all stakeholders in the community.

There are many far-reaching implications for the project. For one, the math critical thinking PLC professional development could help other districts in search of cost-efficient ways to increase teachers' math critical thinking pedagogy. The project may also all districts, regardless of budget sizes. Any district could implement the method of improving teachers' math pedagogy because most of the resources are within the district and schools. Secondly, the project could help other schools in Georgia, where teachers are struggling to prepare students for the more rigorous test in the state. Finally, the project could benefit middle schools and high schools as the critical thinking math PLC professional development could be implemented in the upper grades, as well.

The critical thinking PLC professional development format could be used for other content areas. For example, critical thinking was not only important for math, but it was important for reading, social studies, and science. The project could be extended to improve teachers' critical thinking pedagogy in other content areas. Teachers' improved math pedagogy will benefit the district because it will create higher levels of student thinking in all content areas, which may have a positive effect on students' learning by layering higher levels of thinking and expectations for students' early education. The increased learning base may benefit the students, families, schools, and districts as students' progress to the upper grades.

Another far-reaching implication for the project is that the math critical thinking PLC professional development could increase teachers' desires to teach math. The district is experiencing a shortage of math teachers. The project will support math teachers and make them feel more effective in their teaching. The collaboration that the PLCs facilitates may help teachers build supportive relationships. The collaboration and relationships could give teachers a higher level of job satisfaction, resulting in better teacher retention.

In conclusion, the project I developed was a three-day Math Critical Thinking Professional Development session for the district under study. The project was designed using research and data from the study that will address the problem of low math achievement in the study site district and math critical thinking instructional skills of the teachers. The project will guide PLC leaders in the implementation and monitoring process of planning a rigorous continuous math critical thinking professional learning community within their school.

Section 4: Reflections and Conclusions

In the study, I analyzed teachers' perceptions of the effect of PLCs on their math critical thinking pedagogy. Two schools were chosen from a diversified school district in a metropolitan area in the southern United States. Analysis of data from the PLCA, focus groups, and interviews indicated teachers believed PLCs helped them improve their math critical thinking pedagogy. However, the qualitative results indicated that there were components of the PLC structure that need to change to support teachers' math critical thinking with rigor and consistency. I developed math critical thinking PLC professional development for the district to address the responses from teachers that arose from the data in the study. The next section is a reflective analysis of my experience as a researcher working on the project. Section 4 also describes limitations and strengths of the project, recommendations for alternative approaches to the problem, and directions for future research.

Project Strengths and Limitations

There are several strengths of the project. One of the most important strengths is the project targeted math critical thinking pedagogy which the district will likely benefit from because it is finely tuned to the needs of the district teachers' math critical thinking pedagogy. The data that drove the project are specific to the district and teachers' math critical thinking learning. Math achievement in the study site district was 10% below the state average in 2016 (Georgia Department of Education, 2016). The district should

benefit from the study's project, which was designed to increase teachers' math critical thinking pedagogy with a goal of increasing student math achievement.

The second strength of the project is its cost-effectiveness. Most resources needed for the project exist within the district and its schools. Teacher collaboration is one of the strengths of PLCs, and the math critical thinking PLC professional development was centered on the concept of collaboration. The cost of collaboration is minimal in that leaders can often create collaboration within teachers' daily schedules, minimizing offsite professional development and the need for substitute teachers. The district will need to support the schools with critical thinking math strategies. Some of these strategies may be expensive because the math department will have to develop the math critical thinking strategies to integrate into the schools' math PLCs. However, the expense will probably be absorbed by the district's math professional development budget, as the administration regularly plans for professional learning each year.

The project will also create accountability with district and school level support. The project will guide the PLC leaders throughout the year with math PLC guidelines and templates to monitor and support the schools. The added structure of creating a district math PLC support for leaders, guidelines for math PLCs in the schools, and critical thinking instructional strategies integrated in to the school math PLCs throughout the year will ensure that schools maintain rigor and continuity in their math PLCs.

Another strength is that the project will create leaders within the district and its schools. One of the key concepts of PLCs is shared leadership, as administration and

teachers share the responsibility for leadership and decision-making (DuFour, 2016; Hord, 2012; Olivier et al., 2016). Leaders from schools who attend math critical thinking professional development will gain knowledge and guidance needed to implement math critical thinking PLCs in their own schools. Leadership will also be created within each schools' math critical thinking PLC, as PLCs will be designed to foster collaboration among teachers and initiate positive changes. Teachers will be empowered to share effective critical thinking strategies while learning leadership skills in the process.

Another strength of the project is that it will create an example of how PLCs might promote reform within schools and serve as a model for other reforms in the district. Olivier et al. (2016) stated that PLCs can promote school reform by building structure that tackles school reform initiatives. The structure is schools creating math PLCs that are supported by the school district in which school staff collaborate, share math best practices, and discuss student math growth and achievement. The project will give schools guidance regarding how to address and implement necessary reform.

There are limitations to the project to consider. First, the project relies upon strong leadership within each school. School leaders will need to follow through from the math critical thinking PLC professional development and implement math PLCs within their schools. Even though the project's plan is for the leaders of the PLCs to meet every few months, if a school does not implement or enhance the math PLC with standards from the math critical thinking PLC professional development, then the

teachers within the schools may not experience full potential benefits of improved math critical thinking pedagogy.

Another limitation of the project was that study results may not apply to middle and high schools. Elementary, middle, and high schools have unique schedules and idiosyncrasies. Therefore, the project may not transfer to middle and high schools. A third limitation was that PLCs are complex and can be intimidating for some schools to manage. School leaders must believe in the importance of the project to dedicate the time and energy needed to make it work effectively. As results from the study indicated, poorly run math PLCs might not be effective in improving teachers' critical thinking math pedagogy. School leaders play an important role and need to understand the complexity of PLCs and the importance of integrating math critical thinking instructional strategies in to PLCs successfully. Therefore, schools struggling with leadership challenges may find the project hard to implement.

Recommendations for Alternative Approaches

An alternative approach in the study could be an experimental quantitative study conducted over an entire school year. Student math scores before and after the implementation of a critical thinking math PLC could be compiled and analyzed. Such a study will be based on state math scores or district assessment which is Measures of Academic Progress math scores and may produce data that are generalizable to larger populations.

Another approach could be a qualitative case study in one school that involves an evaluation of the effect of math PLCs on teachers' critical thinking pedagogy. The case study could document math teachers' experiences with the math PLCs within one school, which could be used to create a detailed account of how the PLCs affect teachers' math pedagogy within that specific school. Such a study could provide rich details of teachers' experiences with PLCs, as well as their math critical thinking pedagogy.

Another approach to the problem is a longitudinal explanatory mixed methods study conducted over a period of a few years which utilizes quantitative data from state math scores, as well as qualitative data from teacher interviews and observations of math critical thinking lessons. The quantitative data could be analyzed before and after math critical thinking PLCs are implemented. The study could reveal if the math critical thinking PLCs affect student math achievement. Observations of math critical thinking lessons could reveal if teachers understand critical thinking math strategies and whether they use higher level strategies in the classroom.

A different approach to the problem of math achievement in the district could be a qualitative study that focused on observations of math lessons, lesson plans, and teacher interviews. The qualitative approach could uncover detailed information about teachers' understanding and execution of math critical thinking strategies. Multicase studies could be designed to compare districts or schools. A final research design could be a quantitative causal-comparative study that compared one district that uses math PLCs to a

district that does not use PLCs. State scores could be compared to see if the math PLCs affect the scores.

Scholarship, Project Development, Leadership Change and Change

As a scholar completing the process of the study, I found qualitative and quantitative approaches were both useful. Familiarity with these different methods may also help me in my future professional career. The process of using the mixed method approach for the study enabled me to understand the importance and rigor involved in a mixed methods design. The two types of research utilized different types of data that were important and influenced the analysis and results of a study. The process of comparing the interview and focus group data to the teacher survey data was an exercise that created an appreciation in me for the importance of the rigor involved in a mixed methods study. The interviews and focus groups lead to a deeper understanding of the teachers' development of their math critical thinking pedagogy in the past few years. The information provided by the qualitative data could not have been gathered from the Likert surveys, alone. The quantitative survey was an easy and quick way to attain a broad perspective of the problem, defining the problem and delineating areas needed for further research. The quantitative data created information that I used to fine-tune questions for the teacher interviews. The information produced specific, rich detail relative to the problem. Therefore, in the future research I conduct, I will be inclined to use the mixed method approach due to its rigorous and comprehensive approach to data and analysis.

The process also enlightened me to the value of using the sequential approach to develop a research process that accentuates both qualitative and quantitative methods of study. Analyzing teachers' surveys quantitative surveys enlightened me to the ease of gaining information quickly. However, using the quantitative data to inform more detailed questions for the teachers showed me that rich information can be gained from asking questions built upon quantitative data. Understanding the importance of these informed questions will help me address future problems within the district and its schools.

The process of developing a project based on research humbled me to the responsibilities of a scholar. I will be less apprehensive in tackling a problem through research, having gained an understanding that a thorough definition of a problem can lead to more focused research and more effective solutions. The project development process helped me realize the importance of letting and research data mold the project. The project developed for the school is specific to the needs of the study site district. The study site district will be more effective because of a strict adherence to aligning the findings from the data with the project.

As a practitioner, the study also helped me realize how effective research can be for creating expedient change within school districts. District leaders often have limited budgets for professional development (Blackley & Sheffield, 2015). Therefore, research is needed to help district leaders make informed decisions about how to use limited assets. During the process of conducting my research, I discovered inefficiencies in the

study site district's professional development practices. The process made me realize the affect I can have as a leader in the district to make efficient use of professional development resources.

While working with school principals, it was interesting to see how the research was valuable to them and how they reacted to the study results. Both principals were anxious to hear about the findings and will be making changes in their approaches to math professional development next year, based on study findings. I also learned through the process how district leaders were quick to listen and react to valid research when it addressed their areas of influence in the district. For example, the math director was very anxious to hear the results of the study and the project and was willing to make quick adjustments to put the project in place for next year. The process taught me the power of research to enact rapid change.

The project was developed by addressing problem areas indicated by results. Detailed feedback from teachers' interviews led me to add the math critical thinking PLC structure within the district. The quantitative data revealed structure to be an issue in the efficiency of the PLCs. The data from the focus groups and interviews defined exactly what was specifically wrong with the structure of the PLCs. The details from the qualitative data led to an understanding of what was missing with the schools' current PLCs. The district needs to be more involved in supporting the schools and their PLCs. Also, administrators and leaders in the schools need direction and structure to help them support teachers' math critical thinking pedagogy. The project design spans an entire

year so that schools will support their teachers' math pedagogy throughout the year. The process of completing the project study taught me the importance of careful critical thinking and analysis when addressing a problem methodically to develop the most efficient way to solve a problem.

Reflection on the Importance of the Work

The importance of work pertaining to PLCs and math critical thinking pedagogy is the ways in which the work can respond to districts faced with limited budgets for professional development, and teachers looking for guidance in improving students' math achievement and critical thinking skills. Math achievements in the district involved in the study, as well as districts across the U.S., has decreased over recent years. Districts need to find financially efficient ways to give teachers math professional development for critical thinking. PLCs are important because they present a cost-effective way for districts to support teachers' learning.

Through the study, I have learned that PLCs are complex and hard for some schools to manage. Poorly run PLCs do not provide teachers with efficient support and often waste teachers' and administrators' time. Time is not a commodity that school districts can afford to waste. Research suggests that teachers believe PLCs are one of the most effective strategies for learning best practices (DuFour, 2016; Hord, 2012; Olivier et al., 2016). Because PLCs are cost-effective and effective for imparting best practices onto teachers, the importance of this study increased as it evolved. Increasingly, teachers are challenged to find time to learn and implement new instructional strategies.

The importance of the work was also identified throughout the study by observing the pressures experienced by the school district to find better professional development for math critical thinking, at the lowest costs. Finally, large-scale, ongoing effective critical thinking math professional development for school districts is important to ensure that students can compete in a global economy, over time.

Implications, Applications, and Directions for Future Research

The project has the potential to effect social change in several different ways. First, the project demonstrates a fiscally responsible way to increase teachers' math critical thinking pedagogy. School districts are always trying to find ways to stretch their budgets farther. The project provides an example of how schools may better manage the complexities of math PLCs and run them more efficiently. Almost all the resources needed by districts to implement the project exist within the district, cutting costs associated with sending teachers to conferences, workshops, and meetings. Social change will occur because PLCs provide a way for districts to combat the constant change and challenges of their budgets, thus alleviating some of the pressures that prevent districts from addressing other educational concerns.

Secondly, the research indicated that teachers receive best practices through PLCs. The project may help schools improve the efficiency of their PLCs. The critical thinking math PLCs have the potential to improve teachers' math critical thinking pedagogy, which should help increase student math achievement. The potential for social

change could increase along with rising math achievements in the district. This will benefit the school district and the families within the school district.

Another potential effect the project has on social change is the retention of teachers. Teachers in the U.S. are leaving the profession at a higher rate than that of other nations (Martin & Mulvihill, 2017). Darling-Hammond stated that teachers who are well-prepared leave the profession at a rate of two times less than teachers who are not prepared (Martin & Mulvihill, 2017). Giving teachers consistent critical thinking math professional development through PLCs may keep teachers more satisfied in their jobs and reduce their likelihood of leaving the profession. The project will also create more leaders in the schools, increasing the potential for promotions and other benefits that positively influence teacher satisfaction and retention.

Last, the project has potential for increasing teachers' math critical thinking pedagogy within the district. When teachers' math critical thinking pedagogy improves, students gain the potential to have more involved critical thinking skills. The increase in students' critical thinking skills might lead to future innovations and improve students' abilities to compete in a global economy. The project has the potential to effect social change in many different ways.

The application of the math critical thinking PLC professional development within the district should affect the teachers' math critical thinking pedagogy. The implication of teachers broadened critical thinking pedagogy over time is that it should have a positive effect on students' math critical thinking skills. Each year, as the math

critical thinking PLCs progress, the capacity of teachers' and students' math critical thinking skills may improve. The ongoing process of continued development of teachers' math critical thinking skills might lead to progressively higher levels of math skills among teachers, as well as students' math skills, by extension. Increased critical thinking instructional strategies will lead to implementation of a higher level of math thinking for students as years progressed. In turn, the project could lead to higher math test scores which have a positive effect on stakeholders within the community.

Future research could include a longitudinal study that follows teachers' job satisfaction in a school or district that uses math critical thinking PLCs. Such a study could analyze the question of whether math PLCs add to job satisfaction. Another direction for future research could include a study analyzing math critical thinking pedagogy and PLCs within middle and high schools. The current study included elementary schools only, and it will be beneficial to replicate the study in grades six through twelve. Another direction for future research is a study using state math test results before and after a math critical thinking PLC is put in place. A study with state math results will help determine how effective critical thinking math PLCs are toward improving students' math achievement.

Conclusion

In conclusion, I have learned through the process of the study that schools continue to be challenged to increase achievement without the resources they need. When I began the research for the study several years ago, PLCs were a trend related to

school reform. The large amount of pressures that schools are under have emphasized the importance of school stakeholders helping one another. Districts' increased financial and academic performance pressures have created a need for cost-effective support and efficient performance. Therefore, PLCs are just as important now, if not more, as they were several years ago, given that schools are continually faced with the pressure to do more with less.

The project supports the study site district by efficiently implementing professional development for schools to follow to facilitate critical thinking math PLCs. The project has the potential to promote social change by increasing math achievement for all students, increasing the economic health of the district, and creating an environment where teachers are given the support they need, are happier, and more likely to stay in their jobs.

Limitations of the study were listed. Future research and alternative approaches were discussed. Further research is needed to determine if PLCs add to teachers' job satisfaction and reduce turnover. It may also be beneficial to conduct a quantitative study using math test scores to deepen the understanding of the effect of math PLCs' on student achievement.

I have grown as a researcher in the process of completing my study. The importance of taking time to align a problem with the questions became clear when analyzing the magnitude of data in a mixed methods study. In future studies, the skill of aligning research for a mixed methods study will help me execute rigorous and

meaningful research. The research process also allowed me to work with district leaders and understand the importance of research in district decision-making. Clear, well-developed research can lead to quick, rational decision-making. The skills I have learned through the process will help me in my career when challenged to solve school and district problems.

References

Abdullah, N., Halim, L., & Zakaria, E. (2014). VStops: A thinking strategy and visual representation approach in mathematical word problem solving toward enhancing STEM literacy. *Eurasia Journal of Mathematics, Science & Technology Education*, *10*(3), 165-174. doi:10.12973/eurasia.2014.1073a

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research*, *85*(2), 275–314. doi:10.3102/0034654314 551063

Ahram, R., Stembridge, A., Fergus, E., & Noguera, P. (2016). Framing urban school challenges. *RTI Action Network.* Retrieved from http://www.rtinetwork. org/learn/diversity/ urban-school-challenges

Armstrong, P. (2015). Bloom's taxonomy. Retrieved from https://cft.vanderbiltedu/ guides-sub-pages/blooms-taxonomy/

Asgharheidari, F., & Tahriri, A. (2015). A survey of EFL teachers' attitudes towards critical thinking instruction. *Journal of Language Teaching & Research*, *6*(2), 388-396. doi:10.17507/jltr.0602.20

Bayar, A. (2014). The components of effective professional development activities in terms of teachers' perspective. *International Online Journal of Educational Sciences, 6*(2), 319–327. doi:10.15345/iojes.2014.02.006

Beswick, K. (2014). What teachers' want: Identifying mathematics teachers'

professional learning needs. *The Mathematics Enthusiast, 11*(1), 83-108. Retrieved from http://scholarworks.umt.edu/tme/vol11/iss1/6

Blackley, S., & Sheffield, R. (2015). Digital andragogy: A richer blend of initial teacher education in the 21st century. *Issues in Educational Research, 25*(4), 3 97-414. Retrieved from www.iier.org.au/

Bloom, B.S. (1956). *Taxonomy of educational objectives: The classification of educational* goals. New York, NY: Longmans, Green and Company.

Brendefur, J. J., Strother, S., Thiede, K., Lane, C., & Surges-Prokop, M. (2013). A professional development program to improve math skills among preschool children in Head Start. *Early Childhood Education Journal*, *41*(3), 187-195. doi:10.1007/s10643-012-0543-8

Brewer, E. W., Torrisi-Steele, G., & Wang, V. C. X. (2015). Survey research: Methods, issues and the future. In V. C. X. Wang (Ed.), *Scholarly publishing and research methods* (pp. 396–414). doi: 10.4018/978-1-4666-7409-7

Brodie, K. (2013). The power of professional learning communities. *Education as Change*, *17*(1), 5-18. doi:10.1080/16823206.2013.773929

Brodie, K. (2014). Learning about learner errors in professional learning communities. *Educational Studies in Mathematics*, *85*(2), 221-239. doi:10.1007/s10649-013-9507-1

Bruce, C. D., & Flynn, T. (2013). Assessing the effects of collaborative professional learning: Efficacy shifts in a three-year mathematics study. *Alberta Journal of*

Educational Research, 58(4), 691-709.

Butera, G., Friesen, A., Palmer, S. B., Lieber, J., Horn, E. M., Hanson, M. J., & Czaja, C. (2014). Integrating mathematics problem solving and critical thinking into the curriculum. *Young Children, 69*(1), 70-77. Retrieved from https://www.jstor.org/journal/youngchildren

Center for Teacher Quality. (2014). Steps in creating teacher powered schools. *The Center for Teacher Quality.* Retrieved from http://www.teachingquality. org/steps-creating-teacher-powered-school

Cherrstrom, C. C., Robbins, S. E., & Bixby, J. (2017). 10 years of adult learning. *Adult Learning, 28*(1), 3-11. doi:10.1177/1045159516664320

Chia-Yi, L., & Seokhee, C. (2011). Predicting creative problem-solving in math from a dynamic system model of creative problem-solving ability. *Creativity Research Journal, 23*(3), 255-261. doi:10.1080/10400419 .2011.595986

Choy, S., & Pou San, O. (2012). Reflective thinking and teaching practices: A precursor for incorporating critical thinking in the classroom? *International Journal of Instruction, 5*(1), 167-182. Retrieved from www.e-iji.net/

Churchin, S. M. (2013). *Effect of professional learning communities intervention on teacher and student learning.* Unpublished doctoral dissertation, Walden University, Minnesota, MN.

Clarke, D., Roche, A., Cheeseman, J., & van der Schans, S. (2014). Teaching strategies

for building student persistence on challenging tasks: Insights emerging from two approaches to teacher professional learning. *Mathematics Teacher Education & Development, 16*(2), 46-70. Retrieved from https://www.merga.net.au/ojs/index.php/mted/index

Courey, S., Balogh, E., Siker, J., & Paik, J. (2012). Academic music: Music instruction to engage third-grade students in learning basic fraction concepts. *Educational Studies in Mathematics*, *81*(2), 251-278. doi:10.1007/s10649-012-9395-9

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: Sage Publications.

Creswell, J. W. (2012). *Planning, conducting and evaluating quantitative research* (Laureate custom ed.). Boston, MA: Pearson Education.

Crosswell, L., & Beutel, D. (2012). Investigating pre-service teachers' perceptions of their preparedness to teach. *International Journal of Learning, 18*(4), 203-211. Retrieved from http://www.learning-journal.com/

Dever, R. R., & Lash, M. M. (2013). Using common planning time to foster professional learning. *Middle School Journal, 45*(1), 12-17. doi: 10.1080/00940771.2013.11461877

Devlin-Scherer, R. I., & Saradone, M. B. (2013). Collaboration as a form of professional development: Improving learning for faculty and students. *College Teaching, 61*(1), 30-37. doi:10.1080/87567555.2012.714815

Dewey, J. (1938). *Experience and education*. New York, NY: Kappa Delta Pi.

Doabler, C. T., Fien, H, Nelson-Walker, N., & Baker, S.K. (2012). Evaluating three elementary mathematics programs for presence of eight research-based instructional design principles. *Learning Disability Quarterly*, *35*(4), 200-211. doi:10.1177/0731948712438557

DuFour, R. (2016). *Learning by doing: A handbook for professional learning communities at work*. Bloomington, IN: Solution Tree.

Dyment, J. E., Davis, J. M., Nailon, D., Emery, S., Getenet, S., McCrea, N., & Hill, A. (2014). The impact of professional development on early childhood educators' confidence, understanding and knowledge of education for sustainability. *Environmental Education Research*, *20*(5), 660-679. doi:101080/13504622. 2013.833591

Fairman, S. (2017). Building a schoolwide leadership mindset. *Educational Leadership*, *74*(8), 22-27. doi:10.1298/110022450.795730.

Feldman, J., & Fataar, A. (2014). Conceptualizing the setting up of a professional learning community for teachers' pedagogical learning. *South African Journal of Higher Education*, *28*(5), 1525-1540.

Flores, K. L., Matkin, G. S., Burbach, M. E., Quinn, C. E., & Harding, H. (2012). Deficient critical thinking skills among college graduates: Implications for leadership. *Educational Philosophy & Theory, 44*(2), 212-230. doi:10.1111/j.1469-5812.2010.00672.x

Fusch, P. I., & Ness, L. R. (2015). Are we there yet? Data saturation in qualitative

research. *The Qualitative Report, 20*(9), 1408-1416. Retrieved from: http://www.nova.edu/ssss/QR/QR20/9/fusch1.pdf

Georgia Department of Education. (2015). *Understanding the College Career Readiness Performance Index.* Retrieved from: http://www.gadoe.org/CCRPI /Pages/default.aspx

Georgia Department of Education. (2015). *College and career ready performance index.* Retrieved from: http://www.gadoe.org/External-Affairs-and-Policy/communications/Documents/CCRPI%202013-2014%20Overview.pdf

Georgia Office of Student Achievement. (2015). *Georgia Milestone: Georgia's new standardized test.* Retrieved from: http://gosa.georgia.gov/georgia-milestones-Georgia's-new-standardized-test

Georgia Department of Education. (2016). Retrieved from: http://www.gadoe.org/ Curriculum-Instruction-and-Assessment/Assessment /Documents

Giannoukos, G., Besas, G., Galiropoulos, C., & Hioctour, V. (2015). The andragogy, the social change and the transformative learning educational approaches in adult education. *Journal of Education and Practice, 6*(10), 46-50. Retrieved from iiste.org/Journals/index.php/JEP

Gray, J. A., & Summers, R. (2015). International professional learning communities: The role of enabling school structures, trust, and collective efficacy. *International Educational Journal: Comparative Perspectives, 14*(3),61-75.

Gray, J., Mitchell, R., & Tarter, C. J. (2014). Organizational and relational factors in

professional learning communities. *Planning & Changing*, *45*(1/2), 83-98. Retrieved from https://education.illinoisstate.edu/planning

Gumus, E. G., & Bellibas, M. M. (2016). Teacher professional development and student achievement in Turkey: Evidence from TIMSS 2011. *BCES Conference Proceedings*, *14*(1), 325-326.

Hagen, M., & Park, S. (2016). We knew it all along! Using cognitive science to explain how andragogy works. *European Journal of Training & Development, 40*(3), 171-190. doi:10.1108/EJTD-10-2015-0081

Hairon, S., & Dimmock, C. (2012). Singapore schools and professional learning communities: Teacher professional development and school leadership in an Asian hierarchical system. *Educational Review, 64*(4), 405-424. doi:10.1080/00131911.2011.625111.

Heitin, L. (2017). U.S. Achievement stalls as other nations make gains. *Education Week. 3*(5), 15-22. Retrieved from http://www.edweek.org

Herman, J., & Linn, R. (2014). New assessments, new rigor. *Educational Leadership, 71*(6), 34-37. Retrieved from www.ascd.org/publications/educational-leadership.aspx

Herman, J., Linn, R., & National Center for Research on Evaluation, S. T. (2013). *On the road to assessing deeper learning: the status of smarter balanced and PARCC assessment consortia*: CRESST report 823. *National Center For Research On Evaluation, Standards, And Student Testing (CRESST)*. Retrieved

From http://www.hewlett.org/uploads/documents/On_the_Road_to_Assessing DLThe_Status_of_SBAC_and_PARCC_Assessment_Consortia_CRESST_ Jan_2013.pdf

Herrington, R. (2011). *Professional learning communities: Perceptions of teacher quality and sustainability.* Unpublished doctoral dissertation. Walden University, Minneapolis, MN.

Hill, L. H. (2014). Graduate students' perspectives on effective teaching. *Adult Learning*, *25*(2), 57-65. doi:10.1177/1045159514522433

Hill, T. L. (2012). *Implementing constructivist mathematics methods in the elementary classroom.* Unpublished doctoral dissertation. Walden University, Minneapolis, MN.

Holmes, V. (2012). Depth of teachers' knowledge: Frameworks for teachers' knowledge of mathematics. *Journal of STEM Education: Innovations & Research, 13*(1), 55-71. Retrieved from www.jstem.org/

Hord S., Hall E. (2014). *Implementing change: Patterns, principles, and potholes.* Thousand Oaks, CA: Corwin Press.

Hord, S. M., & Sommers, G. F. (2010). *Guiding professional learning communities.* Thousand Oaks, CA: Corwin Press.

Huffman, J. B., Olivier, D. F., Wang, T., Chen, P., Hairon, S., & Pang, N. (2016). Global conceptualization of the professional learning community process: Transitioning from country perspectives to international commonalities. *International Journal of*

Leadership in Education, 19(3), 327–351. doi:10.1080/13603124.2015.1020343

Johnson, M. J., Partlo, M., Hullender, T., Akanwa, E., Burke, H., Todd, J., & Alwood, C. (2014). Public deliberation as a teaching andragogy: Implications for adult student learning from a doctoral higher education policy course. *Journal of the Scholarship of Teaching & Learning*, *14*(1), 95-108. doi:10.14434/josotl.v 14i1.3943

Kalkan, F. f. (2016). Relationship between professional learning community, structure, and organisational trust in primary educational schools. *Educational Sciences: Theory and practices, 16*(5), 1619-1637. doi 10.12738/estp.2016.5.0022

Khoule, A., Pacht, M., Schwartz, J. W., & van Slyck, P. (2015). Enhancing faculty pedagogy and student outcomes in developmental math and English through an online community of practice. *Research & Teaching in Developmental Education, 32*(1), 35-45. Retrieved from https://www.jstor.org/journal/reseteacdeveeduc

Killion, J. (2015). Professional learning for math teachers is a plus for students. *Journal of Staff Development, 36*(3), 58-60.

Killion, J. (2016). How the world's best schools stay on top. *Journal of Staff Development, 37*(1), 62-69.

Kim, M. K., & Noh, S. (2010). Alternative mathematics assessment: A case study of the development of descriptive problems for elementary school in Korea. *Eurasia Journal of Mathematics, Science & Technology Education, 6*(3), 173-186. Retrieved from www.ejmste.com/

Krainer, K. (2014). Teachers as stakeholders in mathematics education research. *Mathematics Enthusiast, 11*(1), 49-59. Retrieved from scholarworks.umt.edu/tme/

Kyounghye, S., & You-Kyung, H. (2012). The vision and the reality of professional learning communities in Korean schools. *KEDI Journal of Educational policy. 9*(2), 281-298.

Leclerc, M., Moreau, A. C., Dumouchel, C., & Sallafranque-St.-Louis, F. (2012). Factors that promote progression in schools functioning as professional learning community. *International Journal of Education Policy & Leadership, 7*(7), 1-14. Retrieved from journals.sfu.ca/ijepl/

Leung, S. (2013). Teachers implementing mathematical problem posing in the classroom: Challenges and strategies. *Educational Studies in Mathematics*, *83*(1), 103-116. doi:10.1007/s10649-012-9436-4.

Levi-Keren, M. K, & Patkin, D. P. (2016). Mathematics teachers' professional development program needs and expectations. *International Journal for Mathematics Teaching and Learning,* 1-33. Retrieved from http://www.cimt.org.uk/

Lieberman, A., Miller, L., & Roy, R. (2014) *Reach the highest standard in professional learning*. Thousand Oaks, CA: Sage.

Lodico, M., Spaulding D., & Voegtle, K. (2010). *Methods in educational research.* (Laureate custom ed.). Hoken, NJ: Jossey-Bass.

Loeng, S. S. (2013). Eugen Rosenstock-Huessy – An andragogical pioneer. *Studies in Continuing Education, 35*(2), 241-253. doi:10.1080/0158037X.2012.749850

Magee, P. A., & Flessner, R. (2012). Collaborating to improve inquiry-based teaching in elementary science and mathematics methods courses. *Science Education International, 23*(4), 353-365. Retrieved from www.icaseonline.net/sei/issues.html

Martin, L. E., & Mulvihill, T. M. (2017). Current issues in teacher education: An interview with Dr. Linda Darling-Hammond. *Teacher Educator, 52*(2), 75-83. doi:10.1080/08878730.2017.1294921

McKim, K. (2015). The value of mixed methods research. *The Journal of Mixed Methods Research, 42*(1), 1-20. doi:10.1177/1558689815607096.

Merriam, S., (2009) *Qualitative research.* San Francisco, CA: Jossey-Bass.

Merriam, S. B., & Bierema, L. L., (2014). *Adult learning: Linking theory and practice*. San Francisco, CA: Jossey-Bass.

Mulnix, J. (2012). Thinking critically about critical thinking. *Educational Philosophy & Theory*, *44*(5), 464-479. doi:10.1111/j.1469-5812.2010.00673.x

Muneia, M. S. (2015). A theoretical basis for adult learning facilitation: Review of selected articles. *Journal of Education and Practice, 6*(31). 54-61. Retrieved from iiste.org/Journals/index.php/JEP

Nargundkar, S., Samaddar, S., & Mukhopadhyay, S. (2014). A guided problem-based learning (PBL) approach: Impact on critical thinking. *Decision Sciences*

Journal of Innovative Education, 12(2), 91-108. doi:10.1111/dsji.12030

National Center for Educational Statistics (2014). *Program for International Student Assessment.* Retrieved from http://nces.ed.gov/surveys/pisa/pisa 2012/pisa2012highlights_3.asp

National Public Radio (2015). *U.S. students slide in global ranking on math, reading science.* Retrieved from http://www.npr.org/blogs/thetwo-http://h way/2013/12/03/248329823/u-s-high-school-students-slide-in-math-reading-science.

National Commission on Teaching and America's Future (2014). *Teachers having their Say: Collaboration is the Key.* Retrieved from https://nctaf.org/featured-home/teachers-having-their-say-collaboration-is-the-key/

National Council of Teachers Quality (2014). *Teacher Prep Review 2014.* Retrieved from https://www.nctq.org/dmsView/Chapter2_OverallFindings

Neumann, M. D. (2014). Mathematics teaching, listening, probing, interpreting, and responding to children's thinking. *Investigations in Mathematics Learning, 6*(3), 1-28. Retrieved from www.tandfonline.com/loi/uiml20

New York Department of Education (2015). Depth of knowledge*. New York Department of Education.* Retrieved from http://schools.nyc.gov/Academics/CommonCore Library/Professionallearning/DOK/default.htm

Nurhayati, S. (2015). Andragogical content knowledge as a key component in the training of the instructors of nonformal education. *International Education*

Studies, *8*(2), 219-230. doi:10.5539/ies.v8n2p219

Olivier, D. F., & Hipp, K. K. (2013). Assessing and analyzing schools as professional learning communities. In K. K. Hipp & J. B. Huffman (Eds.). *Demystifying professional learning communities: School leadership at its best.* Lanham, MD: Rowman & Littlefield Education.

Olivier, D. F., Hipp, K. K., & Huffman, J. B. (2013). Professional learning community assessment. In J. B. Huffman & K. K. Hipp (Eds.). *Reculturing schools as professional learning communities.* Lanham, MD: The Scarecrow Press.

Olivier, D. F., & Huffman, J. B. (2016). Professional learning community process in the United States: Conceptualization of the process and district support for schools. *Asia Pacific Journal of Education, 36*(2), 301-317. doi:10.1080/02188791.2016.1148856

Organisation for Economic Cooperation and Development (2015). *Asian Countries top OECD's latest PISA survey on state of global education.* Retrieved from http://www.oecd.org/newsroom/asian-countries-top-oecd -s-latest-pisa-survey-on-state-of-global-education.htm

Organisation for Economic Cooperation and Development (2016). *Program for International Assessment Results.* Retrieved from https://www.oecd.org/pisa/keyfindings/PISA-2012-results-US.pdf

Owen, S. (2014). Teacher professional learning communities: Going beyond contrived collegiality toward challenging debate and collegial learning and

professional growth. *Australian Journal of Adult Learning*, *54*(2), 54-77. Retrieved from https://www.ajal.net.au/

Parish, S. (2015). *Number talks: Helping children build mental math and computation strategies, grades k-5.* San Francisco, CA: Jossey-Bass.

Piaget (2015). *Piaget.* Retrieved from: http://gsi.berkeley.edu/gsi-guide-contents/learning-theory-research/cognitive-constructivism/#piaget

Piaget, J. (1968). *Six psychological studies*. Anita Tenzer (Trans.), New York, NY: Vintage Books.

Piasta, S. P., Logan, J. R., Yeager Pelatti, C., Capps, J. L., & Petrill, S. A. (2015). Professional development for early childhood educators: Efforts to improve math and science learning opportunities in early childhood classrooms. *Journal of Educational Psychology*, *107*(2), 407-422. doi:10.1037/a0037621

Porumblu, D. (2014). Self-knowledge, personal and professional development as a unit in logical continuity. *Journal Plus Education, 10*(2), 330-336. Retrieved from www.uav.ro/jour/index.php/jpe

Salkind, N. J. (2017). *Statistics for people who hate statistics*. Thousand Oaks, CA: Sage Publishing.

Salleh, H., & Tan, C. (2013). Novice teachers learning from others: Mentoring in Shanghai schools. *Australian Journal of Teacher Education*, *38*(3). doi:10.14221/ajte.2013v38n3.1

Sanchez, C., & Summers, J. (2014). *Study delivers failing grades for many programs*

training teachers. Retrieved from http://www.npr.org/blogs/ed/2014/06/17/ 323032745/study-delivers-failing-grades-for-many-programs-training-teachers.

Scher, L., & O'Reily, F. F. (2013). Professional development for K-12 math and science teachers: What do we really know? *Journal of Research on Educational Effectiveness 2*(3), 209-249. doi:10.1080/1924574080264152.

Scriven, R., & Paul, R. (2015). Defining critical thinking. *The Critical Thinking Community.* Retrieved from http://www.criticalthinking.org/pages/ defining-critical-thinking/766

SEDL. (2016). *Dr. Shirley M. Hord.* Retrieved from http://www.sedl.org/ pubs/catalog/featured_authors/shirley_hord.html

SEDL. (2016). *The professional learning community assessment.* Retrieved from http://www.sedl.org/pubs/catalog/items/plc01.html.

Selling, S. K., Garcia, N., & Loewenberg Ball, D. (2016). What does it take to develop assessments of mathematical knowledge for teaching? Unpacking the mathematical work of teaching. *Mathematics Enthusiast*, *13*(1/2), 35-51. Retrieved from scholarworks.umt.edu/time/

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 4-14. Retrieved from journals.sagepub.com/home/edr

Senge, P. M. (1990). *The fifth discipline: The art and practice of learning community.* New York, NY: Doubleday.

Sergiovanni, T. (2005). *Strengthening the heartbeat: Leading and learning together in schools.* San Francisco, CA: Jossey-Bass.

Stachler, W. W., Young, R. B., & Borr, M. M. (2013). Sustainability of professional development to enhance student achievement: A shift in the professional development paradigm. *Journal of Agricultural Education, 54*(4), 13-30. doi:10.5032/jae.2013.04013

Steele, A., Brew, C., Rees, C., & Ibrahim-Khan, S. (2013). Our practice, their readiness: Teacher educators collaborate to explore and improve preservice teacher readiness for science and math instruction. *Journal of Science Teacher Education*, *24*(1), 111-131. doi:10.1007/s10972-012-9311-2

Stewart, C. (2014). Transforming professional development to professional learning. *MPAEA Journal of Adult Education*, *43*(1), 28-33. Retrieved from https://www.mpaea.org

Stylianides, A J., & Ball, D. L. (2008). Understanding and describing mathematical knowledge for teaching: Knowledge about proof for engaging students in the activity of proving. *Journal of Mathematics Teacher Education, 11*(4), 307-332. doi:10.1007/s10857-008-9077-9

Taylor, R., Watson, R., & Nutta, J. (2014). *Leading, teaching learning the Common Core Standards for all students.* New York, NY: Rowman and Littlefield.

Tests.com. (2015). *ITBS practice tests*. Retrieved from http://www.tests.com/practice/ITBS-Practice-Test.

Thessin, R. A. (2015). Learning from one urban school district: Planning to provide essential supports for teachers' work in professional learning communities. *Educational Planning*, *22*(1), 15-27. Retrieved from isep.info/educational-planning-journal.

Toll, C. (2017). 5 Perspectives for leadership success. *Educational Leadership, 74*(8), 28-31. Retrieved from http://www.ascd.org

United States Department of Education. (2013). College and career success for every student. Retrieved from http://www.ed.gov/news/speeched/education-http://www.ed.gov/news/speeches/educating-every- college- and-career-success

United States Department of Education. (2014). *Department of education speeches*. Retrieved from http://www.ed.gov

University of Wisconsin (2015). *Norman Webb's Depth of Knowledge.* Retrieved from http://facstaff.wcer.wisc.edu/normw/MIAMI%20FLORIDA%20 FINAL%20slides%2011-15-05.pdf

Vanderbilt University (2016). *Metacognition.* Retrieved from https://cft.vanderbilt. edu/guides-sub-pages/metacognition

Van de Walle, J. A., & Lovin, L. H. (2006). *Teaching student-centered mathematics: Grades 3-5* (Volume 2). Boston, MA: Pearson Education, Inc.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological process.* Cambridge, MA: Harvard University Press.

Wadsworth, B. (1996). *Piaget's theory of cognitive and affective development:*

Foundations of constructivism. White Plains, NY: Longman Publishing.

Wagner, T. (2010) *The global achievement gap.* New York, NY: Basic Books.

Wang, V. X., & Storey, V. A. (2015). Andragogy and teaching English as a foreign language in China. *Reference Librarian, 56*(4), 295-314. doi:10.1080/02763877.2015.1057680

Watson, C. (2014). Effective professional learning communities? The possibilities for teachers as agents of change in schools. *British Educational Research Journal*, *40*(1), 18-29. doi:10.1002/berj.3025

Webb, N. L. (1997). *Research monograph number 6: Criteria for alignment of expectations and assessments on mathematics and science education.* Washington, D.C.: CCSSO.

Wells, C., & Feun, L. (2013). Educational change and professional learning communities: A study of two districts. *Journal of Educational Change*, *14*(2), 233-257. doi:10.1007/s10833-012-9202-5

Appendix A: The Project: Math Critical Thinking Professional Learning Community

Professional Development

The goals of the Math Critical Thinking PLC Professional Development session are to have school PLC leaders learn best practices for facilitating a rigorous math critical thinking PLC, develop a schedule for their math PLC for the upcoming year, supplement critical math professional development within the PLC framework, and learn how to effectively monitor, sustain, and evaluate their math critical thinking PLC. The three days of the professional development will be spread throughout the school year to provide support to schools over the course of the year, as they develop their PLCs. The district administration can monitor and support the progress of schools' math critical thinking PLCs continuously throughout the year.

Another goal of the critical thinking math PLC professional development is to introduce ways to convey math critical thinking strategies to teachers to improve their critical thinking instructional strategies in the district. The regular monthly addition of math critical thinking instructional methods will increase the students' critical thinking strategies, and lead to increased math achievement. A third goal is for the school leaders to become educated on the best practices for implementing and monitoring an effective math critical thinking PLC so they effectively support the process and the teachers. The ongoing collaboration that will happen during the school PLCs, the project professional development sessions, and the district PLC will create best practices and learning for math critical thinking among math teachers, school leaders, and district administrators.

Empowering teachers and administrators with critical thinking math knowledge will increase instructional strategies and improve math achievement.

Another goal is to develop district support and consistency for the schools' math PLCs. Key district math personnel will be involved in the project's sessions. District math professional learning facilitators will share critical thinking strategies and resources the schools can take back to their math PLCs. The new information will create communication, professional development, and support to school leaders and their math PLCs.

The last goal is to improve student math achievement in the study site district in a way that can be sustained through personnel turnover, district reorganization, budget cuts, and other challenges that effect teacher and administrator's knowledge of math critical thinking math PLCs.

Learning outcomes for the project were that school leaders will understand and develop the structure and schedule to conduct math critical thinking professional learning communities. These math PLCs within the schools will facilitate ongoing math critical thinking learning for the teachers within the schools. The math PLCs will need to embed math critical thinking professional development into the structure of the school PLCs. The learning for the math critical thinking professional development will be ongoing.

The target audience for the project was principals and assistant principals of schools with math PLCs. The principals were included in the process based on data from the study that indicated principals play an important role in the success of the

professional learning community within their school. The assistant principals and principals are responsible for implementing, monitoring and following up with the math PLCs.

Supporting Materials for the Math Critical Thinking Professional Learning Community Professional Development

Below are the supporting documents and PowerPoint needed to conduct each phase of the Math Critical Thinking Professional Learning Community Professional Development.

Math critical thinking professional learning community guidelines. The guidelines are designed for PLC leaders to follow when implementing their critical thinking PLCs. Math Critical Thinking Community members should include: principal, assistant principal, math coach, one math teacher from each grade level. Math PLCs should set norms to be followed at each meeting. Minutes will be taken at each math PLC meeting following agenda in meeting minutes template. Minutes are to be sent monthly to the district area-superintendent. Schools must conduct Math Critical Thinking PLCs each month August through May. A new critical thinking strategy should be discussed at each math PLC meeting. Each schools' PLC leaders are to attend district math critical thinking PLC professional development in August, January, and May. Math teachers are to conduct math critical thinking PLCs that are scheduled regularly and are not considered grade level planning.

Math critical thinking professional learning community minutes template.

School leaders will use this template to document math critical thinking professional learning meetings.

School _____

Date _____

Norms: _____

_____

_____

PLC Members Signatures:

Principal_____

Assistant Principal _____

Coach _____

5th Grade Math _____

4th Grade Math _____

3rd Grade Math _____

2nd Grade Math _____

1st Grade Math _____

K Math _____

Gifted _____

ESOL _____

Others _____

Team members absent: _____

_____

_____

This Month's Math Critical Thinking Strategy:

_____

_____

_____

_____

Agendas for professional development sessions in August, January, and May.

Day One - August

8:30 – 9:30 Introduce Math Critical Thinking Professional Learning Community Implementation. Outline dimensions of a successful math PLC. Norms, collaboration, trust, student data review, shared best practices.

9:30-10:30 Imbedding math critical thinking professional development with in your school's PLC – District Director of Math

District Support for Math Professional Learning Communities. District monthly math critical thinking meetings.

10:30-12:00 Review of Math Critical Thinking Professional Learning Community scheduling template and Fall math professional development opportunities. Introduction of District Math PLC and attendees

12:00-1:00 Lunch on your own

1:00-2:30 School leaders collaboratively work on their Math Critical Thinking PLC schedule for the first semester with designated math professional development infusion. All schools turn in math PLC implementation schedule.

2:30-3:00 District Math Director reviews math support for the first semester and fields questions school leaders may have regarding their math PLC plan.

Discuss artifacts schools will need to bring to the math critical thinking professional development days in January and May.

Math PLC minutes and action plans, math data, math successes to share, math obstacles to receive guidance.

3:00-3:30 School Superintendent speaks about importance of math critical thinking PLCs being implemented with fidelity.

<u>Day Two – January</u>

8:30 – 9:30 Review of first semester MAP math data - Math Director

Shared best practices for critical thinking from schools – from district PLC

9:30-10:30 Update from the District Math PLC Committee – Math Director

Shared best practices for math critical thinking

10:30-12:00 Review of second semester math conventions, professional development, resources. – Math professional learning liaisons.

12:00-1:00 Lunch on your own

1:00-2:30 School leaders collaboratively work on their Math Critical Thinking PLC

schedule for the second semester with designated math professional development infusion. All schools turn in math PLC implementation schedule for spring.

2:30-3:00 District Math Director reviews math support for the second semester and fields questions school leaders may have regarding their math PLC plan.

Discusses artifacts schools will need to bring to the math critical thinking professional development days in and May.

Math PLC minutes and action plans, math data, math successes to share, math obstacles to receive guidance.

3:00-3:30 School Superintendent speaks about importance of math critical thinking PLCs being implemented with fidelity.

Day Three – May

8:30 – 9:30 Discuss Math MAP results from second semester

9:30-10:30 Review of math critical direction for thinking professional development for PLCs for next year.

10:30-12:00 Review of Math Critical Thinking Professional Learning Community scheduling template for upcoming school year. Math professional development opportunities for the upcoming year. School leaders will be put in to groups other than their school to share and discuss best practices of their math critical thinking PLCs.

12:00-1:00 Lunch on your own

1:00-2:30 School leaders collaboratively work with their own school on their Math Critical Thinking PLC schedule for the upcoming year with designated math professional

development infusion. All schools turn in math PLC implementation schedule. Schools turn in math critical thinking PLC schedule for next year.

2:30-3:00 District Math Director reviews directions for Math Critical Thinking Professional Learning Communities for next year.

3:00-3:30 School Superintendent speaks about progress and developments of the math critical thinking professional learning communities.

Math critical thinking professional learning community professional development evaluation.

1. How did the professional development training help you understand how to effectively embed critical thinking in to your math PLC?
2. How would you describe the task of completing the math PLC schedule for the year during the professional development?
3. What were some best practices for running a math PLC that you learned from another school?
4. What are some ways you learn how to monitor and evaluate your math PLC?
5. How would you describe the time spent sharing PLC obstacles and best practices with other schools?
6. What would have helped make the training more effective for you?
7. What some ideas you may have for the next math critical thinking professional development?

Yearly schedule of math PLCs and professional development. This schedule will be given to school math PLC leaders during the professional development to guide their math PLCs throughout the year.

August - Conduct day one district professional development for math critical thinking PLC for school PLC leaders. School leaders formalize their math critical thinking PLC within their school. Introduce fall math PLC schedule. Create PLC norms and goals.

September - Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

October - Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

November / December - Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

January - Attend day two district professional development for math critical thinking PLC for school PLC leaders.

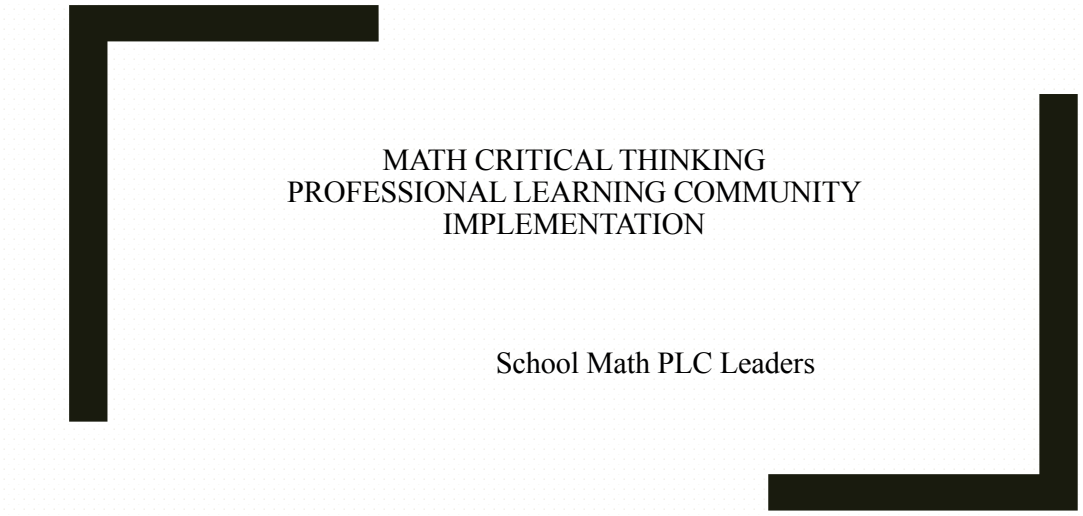
February - Schools discuss adjustments needed to math PLC based on January professional development. Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

March - Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

April - Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

May - Attend day three district professional development for math critical thinking PLC for school PLC leaders.

PowerPoint for professional development. The following PowerPoint will be used by the presenter to guide the participants through the Math Critical Thinking Professional Learning Community Professional Development. The PowerPoint guides participants through an overview and the three days of professional development in August, January, and May.



Overview and Time Table for Math Critical Thinking Professional Learning Community Implementation

August

School PLC leaders attend day one district professional development for math critical thinking.

School PLC leaders formalize their math critical thinking PLC within their school. Conduct first Math Critical Thinking PLC with appropriate participants. Introduce fall math PLC schedule to Critical Thinking Math PLC. Create PLC norms and goals.

September

Schools conduct Math Critical Thinking PLC with critical thinking professional development from the district embedded.

Time Table and Overview for Math Critical Thinking Professional Learning Community Implementation (cont.)

October

Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

November / December

Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

Time Table for Math Critical Thinking Professional Learning Community Implementation

January

School PLC leaders attend day two district professional development for math critical thinking PLC for school PLC leaders.

Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

February

Schools PLC leaders discuss adjustments needed to math PLC based on January professional development. Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded, and discuss any adjustments needed to the PLC.

Time Table and Overview for Math Critical Thinking Professional Learning Community Implementation (cont.)

March

Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

April

Schools conduct math critical thinking PLC with critical thinking professional development from the district embedded.

May

Attend day two district professional development for math critical thinking PLC for school PLC leaders. Reflect on math PLC and plan for next year.

Math Critical Thinking Professional Learning Communities

Day One - August

Math Critical Thinking
Professional Learning Community
Implementation

Dimensions of a Successful Critical Thinking Math PLC:

1. **Monthly Meeting Agenda**
2. **Meeting Guidelines**
3. **Meeting Minutes**
4. **Monthly Critical Thinking Instructional Strategies From the District**

School Responsibilities

Steps for Scheduling Critical Thinking Math PLC Meetings

1. **Create agendas, meeting minutes monthly**
2. **Follow Math PLC Critical Thinking Guidelines**
3. **Send meeting minutes to area superintendents**
4. **Implement Math Critical Thinking Instructional Strategies each month:**

   Schools will receive monthly critical thinking instructional strategies from math department that must be communicated to the teachers.

School Responsibilities (cont.)

1. **PLC Leaders Attend Math Critical Thinking Three Professional Development Days which are in the Months of August, January, and May**
2. **School Leaders are to bring PLC artifacts needed for each meeting:**

   a. Math PLC minutes

   b. Current math MAP data

   c. Math successes

   d. Math obstacles

Collaborative Work PLC Leaders

Group Activity:

1. **Share school math strategies**
2. **Share math best practices**
3. **Brainstorm ideas for effectively facilitating Math PLCs**
4. **Each PLC Leader completes math PLC schedule for the fall**

Professional development evaluation

Math Critical Thinking
Professional Learning Communities

Day Two – January

Math Critical Thinking Professional Learning Communities
Day Two - January

Update of first semester district MAP math data - math director. School data activity

Shared best practices for math critical thinking from schools - small group activity

Share math critical thinking PLC successes, and discuss obstacles – whole group

Math Critical Thinking Professional Learning Communities
Day Two - January

Math professional learning liaisons review math support for the second semester and field questions school leaders may have regarding their math PLC plan

School leaders collaboratively work on their Math Critical Thinking PLC schedule for the second semester with designated math professional development infusion, and have math data discussions. All schools turn in math PLC implementation schedule for spring.

Math Critical Thinking Professional Learning Communities
Day Two - January

1. **Discuss artifacts schools will need to bring to the math critical thinking professional development day in and May.**
2. **Math PLC minutes and action plans, math MAP data, math successes to share, math obstacles to receive guidance.**

Turn in: Evaluation form, spring math PLC schedule, fall math PLC minutes, groups best practices anchor chart

Math Critical Thinking Professional Learning Communities

Day Three - May

Math Critical Thinking Professional Learning Communities
Day Three - May

Discuss District Math MAP results for the year

Schools review math MAP data. Data talk group discussion

Review direction of math critical thinking professional development for PLCs for next year.

Math Critical Thinking Professional Learning Communities
Day Three - May

Math professional learning liaisons share math professional development opportunities for the upcoming year.

School leaders will share and discuss best practices from their math critical thinking PLCs. Group discussion.

Math Critical Thinking Professional Learning Communities
Day Three - May

Group discussion regarding successes and obstacles - Math PLC reflection activity.

Review of directions for Math Critical Thinking Professional Learning Communities for next year.

Turn in: evaluation, meeting minutes, next year's math PLC schedule.

Appendix B: Professional Learning Community Assessment

Professional Learning Communities Assessment – Online Revised

Directions:
This questionnaire assesses your perceptions about your principal, staff, and stakeholders based on the dimensions of a professional learning community (PLC) and related attributes. This questionnaire contains a number of statements about practices which occur in some schools. Read each statement and then use the scale below to select the scale point that best reflects your personal degree of agreement with the statement. Shade the appropriate oval provided to the right of each statement. Be certain to select only one response for each statement. Comments after each dimension section are optional.

Key Terms:
Principal = Principal, not Associate or Assistant Principal
Staff/Staff Members = All adult staff directly associated with curriculum, instruction, and assessment of students
Stakeholders = Parents and community members

Scale: 1 = Strongly Disagree (SD)
2 = Disagree (D)
3 = Agree (A)
4 = Strongly Agree (SA)

	STATEMENTS	SCALE			
	Shared and Supportive Leadership	SD	D	A	SA
1.	Staff members are consistently involved in discussing and making decisions about most school issues.	0	0	0	0
2.	The principal incorporates advice from staff members to make decisions.	0	0	0	0
3.	Staff members have accessibility to key information.	0	0	0	0
4.	The principal is proactive and addresses areas where support is needed.	0	0	0	0
5.	Opportunities are provided for staff members to initiate change.	0	0	0	0
6.		0	0	0	0

	The principal shares responsibility and rewards for innovative actions.				
7.	The principal participates democratically with staff sharing power and authority.	0	0	0	0
8.	Leadership is promoted and nurtured among staff members.	0	0	0	0
9.	Decision-making takes place through committees and communication across grade and subject areas.	0	0	0	0
10.	Stakeholders assume shared responsibility and accountability for student learning without evidence of imposed power and authority.	0	0	0	0
11.	Staff members use multiple sources of data to make decisions about teaching and learning.	0	0	0	0

COMMENTS:

STATEMENTS	SCALE			
Shared Values and Vision	SD	D	A	SA
12. A collaborative process exists for developing a shared sense of values among staff.	0	0	0	0
13. Shared values support norms of behavior that guide decisions about teaching and learning.	0	0	0	0
14. Staff members share visions for school improvement that have an undeviating focus on student learning.	0	0	0	0
15. Decisions are made in alignment with the school's values and vision.	0	0	0	0
16. A collaborative process exists for developing a shared vision among staff.	0	0	0	0
17. School goals focus on student learning beyond test scores and grades.	0	0	0	0

18.	Policies and programs are aligned to the school's vision.	0	0	0	0
19.	Stakeholders are actively involved in creating high expectations that serve to increase student achievement.	0	0	0	0
20.	Data are used to prioritize actions to reach a shared vision.	0	0	0	0

COMMENTS:

	Collective Learning and Application	SD	D	A	SA
21.	Staff members work together to seek knowledge, skills and strategies and apply this new learning to their work.	0	0	0	0
22.	Collegial relationships exist among staff members that reflect commitment to school improvement efforts.	0	0	0	0
23.	Staff members plan and work together to search for solutions to address diverse student needs.	0	0	0	0
24.	A variety of opportunities and structures exist for collective learning through open dialogue.	0	0	0	0
25.	Staff members engage in dialogue that reflects a respect for diverse ideas that lead to continued inquiry.	0	0	0	0
26.	Professional development focuses on teaching and learning.	0	0	0	0
27.	School staff members and stakeholders learn together and apply new knowledge to solve problems.	0	0	0	0
28.	School staff members are committed to programs that enhance learning.	0	0	0	0
29.	Staff members collaboratively analyze multiple sources of data to assess the effectiveness of instructional practices.	0	0	0	0
30.	Staff members collaboratively analyze student work to improve teaching and learning.	0	0	0	0

COMMENTS:

	STATEMENTS	SCALE			
	Shared Personal Practice	SD	D	A	SA
31.	Opportunities exist for staff members to observe peers and offer encouragement.	0	0	0	0
32.	Staff members provide feedback to peers related to instructional practices.	0	0	0	0
33.	Staff members informally share ideas and suggestions for improving student learning.	0	0	0	0
34.	Staff members collaboratively review student work to share and improve instructional practices.	0	0	0	0
35.	Opportunities exist for coaching and mentoring.	0	0	0	0
36.	Individuals and teams have the opportunity to apply learning and share the results of their practices.	0	0	0	0
37.	Staff members regularly share student work to guide overall school improvement.	0	0	0	0

COMMENTS:

	Supportive Conditions - Relationships	SD	D	A	SA
38.	Caring relationships exist among staff and students that are built on trust and respect.	0	0	0	0
39.	A culture of trust and respect exists for taking risks.	0	0	0	0
40.	Outstanding achievement is recognized and celebrated regularly in our school.	0	0	0	0
41.	School staff and stakeholders exhibit a sustained and unified effort to embed change into the culture of the school.	0	0	0	0
42.		0	0	0	0

Relationships among staff members support honest and respectful examination of data to enhance teaching and learning.

COMMENTS:

	Supportive Conditions - Structures	SD	D	A	SA
43.	Time is provided to facilitate collaborative work.	0	0	0	0
44.	The school schedule promotes collective learning and shared practice.	0	0	0	0
45.	Fiscal resources are available for professional development.	0	0	0	0
46.	Appropriate technology and instructional materials are available to staff.	0	0	0	0

	STATEMENTS	SCALE			
		SD	D	A	SA
47.	Resource people provide expertise and support for continuous learning.	0	0	0	0
48.	The school facility is clean, attractive and inviting.	0	0	0	0
49.	The proximity of grade level and department personnel allows for ease in collaborating with colleagues.	0	0	0	0
50.	Communication systems promote a flow of information among staff members.	0	0	0	0
51.	Communication systems promote a flow of information across the entire school community including: central office personnel, parents, and community members.	0	0	0	0
52.	Data are organized and made available to provide easy access to staff members.	0	0	0	0

COMMENTS:

Source: Olivier, D. F., Hipp, K. K., & Huffman, J. B. (2013). Assessing and analyzing schools. In K. K. Hipp & J. B. Huffman (Eds.). *Demystifying professional learning communities: School leadership at its Best.* Lanham, MD: Rowman & Littlefield.

Appendix C: Professional Learning Community Assessment Authorization

Department of Educational Foundations and Leadership
P.O. Box 43091
Lafayette, LA 70504-3091

July 27, 2015

Elizabeth Daly
4425 Wellington Place
Cummings, GA 30040

Dear Ms. Daly:

This correspondence is to grant permission to utilize the *Professional Learning Community Assessment-Revised* (PLCA-R) as your instrument for data collection for your doctoral study through Walden University. I believe your research examining *the effectiveness of professional learning communities in improving math critical thinking pedagogy* will contribute to both PLC and math pedagogy literature. I am pleased that you are interested in using the PLCA-R measure in your research.

This permission letter allows use of the PLCA-R through paper/pencil administration, as well as permission for the PLCA-R online version. For administration of the PLCA-R online version, services **must** be secured through our online host, SEDL in Austin, TX. Additional information for online administration can be found at www.sedl.org. While this letter provides permission to use the measure in your study, authorship of the measure will remain as Olivier, Hipp, and Huffman (exact citation on the following page). This permission does not allow renaming the measure or claiming authorship.

Upon completion of your study, I would be interested in learning about your entire study and would welcome the opportunity to receive an electronic version of your completed dissertation research.

Thank you for your interest in our research and measure for assessing professional learning community attributes within schools. Should you require any additional information, please feel free to contact me.

Sincerely,

Dianne F. Olivier

Dianne F. Olivier, Ph. D.
Associate Professor/Interim Department Chair
Joan D. and Alexander S. Haig/BORSF Professor
Department of Educational Foundations and Leadership
College of Education
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Reference Citation for Professional Learning Community Assessment-Revised measure:

Source: Olivier, D. F., Hipp, K. K., & Huffman, J. B. (2013). Assessing and analyzing schools. In K. K. Hipp & J. B. Huffman (Eds.). *Demystifying professional learning communities: School leadership at its Best.* Lanham, MD: Rowman & Littlefield.

Appendix D: Professional Learning Community Assessment Online Authorization

On Jun 28, 2015, at 9:32 AM, Professional Learning Communities Assessment-Revised wrote:

Dear Elizabeth Daly,

Thank you for contacting SEDL regarding the Professional Learning Communities Assessment-Revised Online. Your administrator account for the PLCA-R online has been created.

A quantity of "10" survey completions have been added to your account so you can test the PLCA-R site to see how it works before using it with live survey participants.

You can log on to the PLCA-R Administrative interface at:
http://www.sedl.org/plc/survey/adminhttp://www.sedl.org/plc/survey/admin
http://www.sedl.org/plc/survey/admin
You will log on to the admin site using
- Your e-mail address "elizabethdaly@att.net"
- Your password "PLCmY08a9h5t" (After you log on to the site, you can change this password to something memorable to you.)

NEXT STEPS:
Once you set up a survey "cohort" on the Admin site, you will have a password for that cohort which the participants will use to take the survey. You will also be able to send a link to participants that has the password embedded into the link, so they do not have to type in the password separately.

Survey participants will access the PLCA-R online at:
http://www.sedl.org/plc/surveyhttp://www.sedl.org/plc/survey
http://www.sedl.org/plc/survey
Let me know if you have any difficulty accessing the site or have other questions about customizing the PLCA-R Online.

WATCH A DEMO:
You can watch a walkthrough video and view some screenshots of the different parts of the PLCA-R admin site at:
http://www.sedl.org/pubs/catalog/items/plc01.htmlhttp://www.sedl.org/pubs/catalog/items/plc01.html
http://www.sedl.org/pubs/catalog/items/plc01.html
http://www.sedl.org/pubs/catalog/items/plc01.html
Contact Brian Litke at blitke@air.org for assistance or additional information about the PLCA-R Online.

Appendix E: Focus Group Questions

RQ: What are teachers' perceptions of the effectiveness of PLCs for learning better math critical thinking pedagogy?

1) How would you compare your math PLC to traditional meetings of teachers at your school?
2) How would you describe your PLC experiences at your school?
   How does leadership support math PLCs and shared learning?
   Describe shared visions for critical thinking for math?
3) In what way does your school support collective learning of math critical thinking?
   How do teachers in your school work collectively to learn from one another?
4) What evidence is there that your school has supportive conditions?
   How would you describe the level of trust among staff members at your school?
   What are structured staff math critical thinking discussions like?
5) How would you describe math shared teaching practices at your school?
   Shared practices for math critical thinking?
   How do teachers learn math from one another at your school? How do teachers learn critical thinking?
6) How would you describe the relationship between participation in your PLC and math pedagogy?
   How has your participation in PLCs affected your math pedagogy? What measurements do you have to indicate this? Your critical thinking math pedagogy?
7) What specific attributes of your math PLC makes it sustainable?
   What threatens the sustainability of a math PLC?

Appendix F: Interview Questions Authorization

From: Rita Herrington <Rita.Herrington@clover.k12.sc.us>
Subject: Interview
Date: October 13, 2015 9:01:53 PM EDT
To: Elizabeth Daly <elizabethdaly@att.net>

Hi Mrs. Daly,
Yes, you may use my PLC interview questions. I look forward to reading your dissertation. Best wishes.

Rita Herrington

Sent from my iPad

Appendix G: Letter of Cooperation from a Research Partner

Dekalb Community School District

Mr. Knox Phillips
Executive Director

January 31, 2017
Ms. E. Daly 4425 Wellington Place
Cumming, GA 30040

Reference: Improved Math Critical Thinking Pedagogy through Professional Learning Communities (File # 2016-032)
Dear Ms. E. Daly:
This letter is to inform you that your research proposal has been approved by the Department of Research, Assessments, and Grants for implementation in the DeKalb County School District (DCSD). The teacher surveys and focus group must take place outside of work hours.
When you begin your research you must secure the approval of the principal/chief site administrator(s) for all schools named in the proposal. You should provide the application with all required attachments and this district approval letter to the principal(s) in order to inform their decision. **Please remember the principal/chief site administrator has the final right of approval or denial of the research proposal at that site. In addition, note that teachers and others may elect not to participate in your research study, even though the district has granted permission.**
The last day to collect data in schools in DCSD for the 2016-2017 school year is Friday, March 31, 2017. The deadline is to protect instructional time during the assessment season and end of the year activities scheduled at individual schools. This approval is valid for one year from the date on this approval letter. Should there be any changes, addenda, design changes, or adverse events to the approved protocol, a request for these changes must also be submitted in writing/email to the DCSD Department of Research, Assessments, and Grants during this one year approval period. Changes should not be initiated until written approval is received. Further, should there be a need to extend the time requested for the project; the researcher must submit a written request for approval at least one month prior to the anniversary date of the most recent approval. If the time for which approval is given expires, it will be necessary to resubmit the proposal for another review by the DCSD Research Review Board.
Completed results are required to be submitted to the Department of Research, Assessments, and Grants.
Best wishes for a successful research project. Feel free to call 678.676.0325 if you have any questions.
Sincerely,

Knox Phillips
Knox Phillips Executive Director
Joy Mordica, Ph.D.
Joy Mordica, Ph.D. Coordinator III
Michael J. Shaw
Michael J. Shaw Coordinator II

Appendix H: Interview Questions

1). Describe opportunities you have had to improve your math critical thinking pedagogy?

How has the math PLC affected your math critical thinking pedagogy?

2). How does leadership support your math critical thinking pedagogy?

3). How would you describe your collaborative math critical thinking learning?

4). What evidence is there that you have shared math values?

5). Describe what gets in the way the most of improving your math critical thinking learning.

6). Describe the structure of the math PLC and its effectiveness?

7). Describe the level of shared math values and vision in the school?

8). Are structures in place for supportive learning conditions for math critical thinking? Relationships?