ABSTRACT

GRAHAM, BRUCE MICHAEL. A Theoretical Framework for Professional Development Program Evaluation and the Creation of an Associated Evaluation Tool. (Under the direction of Dr. Erin Krupa).

Research has shown that access to high-quality professional development leads to improvement in teachers' practice and improvements in student learning outcomes. However, teachers continue to experience ineffective professional development on a regular basis and often have no say in the types of professional development in which they participate. This paper reviews the literature on effective professional development, with a particular focus on mathematics professional development, and merges the findings into a theoretical framework for professional development program evaluation. The framework is built around six different aspects of professional development: (1) Alignment to professional goals, (2) Focus on content and pedagogical knowledge, (3) Promotion of active learning and collaboration, (4) Duration and type, (5) Support from experts and opportunities for teacher leadership, and (6) A plan for professional development program evaluation. The paper also creates a professional development program evaluation tool that teachers can use to evaluate the quality of their professional development. The paper then provides an example of using the evaluation tool with an analysis of the results. Several next steps for future research are also discussed. After reading this paper, math teachers, and teachers in general, should be able to use the evaluation tool as a way to determine the quality of the professional development in which they participate.

A Theoretical Framework for Professional Development Program Evaluation and the Creation of an Associated Evaluation Tool.

by
Bruce Michael Graham

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master's of Science

Mathematics Education

Raleigh, North Carolina
2023

APPROVED BY:

_____	_____
Dr. Erin Krupa Committee Chair	Dr. Gemma Mojica
_____	
Dr. Ruby Ellis	

DEDICATION

This paper is dedicated to Joey LeBeau who unwittingly planted the seed for my desire to pursue a grander role in mathematics teacher education when we were both just first year teachers in the Grandview School District.

BIOGRAPHY

Bruce Michael Graham was born and raised in Spokane, Washington. He attended Eastern Washington University in Cheney, Washington where he earned his Bachelor of Arts degree in Mathematics Education, with a minor in Spanish Education, in 2013. During his time at EWU, he had the opportunity to work with excellent mathematics teacher educators, gain knowledge of different teaching modalities, and was exposed to his first teaching professional development as a pre-service math teacher. He did his student teaching under Tammy Anderberg and Dawn Bushyeager at University High School in Spokane Valley, Washington where he gained valuable experience in mathematics and Spanish teaching. He was allowed to experiment with his teaching style in a very supportive environment.

After graduation, Bruce started his teaching career at Grandview High School (GHS) in Grandview, Washington. The Grandview School District placed a very strong emphasis on professional development and support for beginning teachers. Bruce had the opportunity to engage in quality professional development well beyond what is normally experienced by beginning math teachers and he took full advantage of every opportunity. He had tremendous support as he worked to implement all of the ideas and concepts he learned in his classroom and in 2017 was the Secondary Teacher of the Year for the Grandview School District. Throughout his tenure at GHS, he held many different leadership positions and was involved in a variety of activities. He was the math department head and professional learning community (PLC) leader for three years, the advisor for several clubs for four years, the head Junior Varsity (JV) Softball Coach for four years, and thoroughly enjoyed attending countless sporting events and school plays. He was passionate about supporting his students both in and out of the classroom.

In 2018 Bruce decided it was time for a change and accepted a teaching position at Northern High School in Durham, North Carolina. Here he immediately got involved as a JV softball coach and would become the math department head for two of the three years he spent at the school. At Northern he was again given the freedom to mold his classroom in whatever way he saw fit but experienced much less support than at GHS. It was this juxtaposition of teaching experiences that would eventually lead him to pursue his master's degree at North Carolina State University.

In the midst of the global COVID-19 Pandemic he applied to and was accepted at NC State. He was also given the amazing opportunity to work as a graduate research assistant under Dr. Hollylynne Lee and her team on the Invigorating Statistics & Data Science Teaching through Professional Learning (InSTEP) project where he has learned valuable knowledge related to the world of research. He was able to help contribute to bringing an online professional development platform to math teachers and has learned so much from Dr. Lee and her team. Bruce is very excited to be continuing his journey at NC State and is looking forward to further exploring his own recommendations for future research during his doctoral pursuits.

ACKNOWLEDGMENTS

I must first acknowledge my advisor, Dr. Erin Krupa, who was patient with me and trusted me throughout this whole process. Her constant encouragement and feedback around my ideas helped me make this thesis better and I am incredibly grateful to have had her as an advisor. I look forward to continuing to learn from her as I continue with my doctoral studies at NC State.

I would also like to acknowledge the other two members of my committee: Dr. Ruby Ellis and Dr. Gemma Mojica. I have learned so much from both of them in both an education and research setting. I know I can always reach out to them for support or if I just need someone to run ideas by. I look forward to continuing my learning with them as a doctoral student.

Additionally, I would like to acknowledge Dr. Hollylynne Lee, Dr. Gemma Mojica, and Dr. Emily Thrasher for giving me the opportunity to be part of a research team as a master's student. I have learned so much from all three of them and feel incredibly blessed to be a part of their team. I look forward to continuing to work with them while I pursue my doctorate.

Finally, I would like to acknowledge all my family and friends who supported me throughout this thesis process. Thank you for checking in on me, feeding me, supporting me, reminding me to sleep, and cheering me on. This thesis would not have been possible without your love and support.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 - Introduction

The United States is currently struggling to keep teachers in the classroom. According to a recent survey of their membership, the National Educators Association (NEA) stated that 55% of their members are thinking of leaving the classroom sooner than originally planned (Jotkoff, 2022). Another survey from Merrimack College reported that 44% of teacher respondents indicated that they were likely to leave the profession in the next two years, which is up from a survey by MetLife in 2011 which reported that percentage to only be 25% (Kurtz, 2022). Many schools face staff shortages and often teachers are called on to take on extra responsibilities. In the same NEA survey 80% of members reported an increased workload due to staff shortages (Jotkoff, 2022). There is no single solution to the issue of teacher retention but providing quality professional development (PD) for teachers can help equip them with tools they need to help improve one's teaching and lead to better experiences in the classroom (McChesney & Aldridge, 2018).

The Trends in International Mathematics and Science Study (TIMSS) assesses student performance in Math and Science for grades 4 and 8 in countries around the world every four years since 1995. In 2019 the United States had a score gap of 256 points between the 10^{th} and 90^{th} percentiles in 8^{th} grade math (TIMSS, 2019). This is the difference in score between students scoring in the high end (90^{th} percentile), 642 points in the US, and low end (10^{th} percentile), 385 points in the US, of the TIMSS mathematics scale (0-1000). The gap in the US was larger than most of the other education systems that participated in the study (31 of the 45 countries). Looking across administrations of the TIMSS, the gap in 2019 was larger than all prior administrations of the study. This means that students in the US have simultaneously been scoring higher and lower on the assessment. This gap in scores is often used as one indicator of

equity within a school system and the US results indicate that there is an inequity. It is important that the US school system works to combat the falling scores and continues pushing students on the upper end to continue their improvement. While there is no one proven strategy that will help increase student learning outcome, quality PD for teachers can be one such avenue that can be used in pursuing this goal (Darling-Hammond et al., 2017, Fishman et al., 2003)

In the era of high-stakes standardized testing, teacher evaluations have increased in importance and as part of evaluations, teachers are often asked to have Profession Growth Plans that allow them to lay out their professional goals for a school year. Since these goals are included in their teachers' evaluations, school districts need to have a plan in place to help assist their teachers in meeting these goals. Districts have the autonomy to create and implement this plan themselves, but providing high quality PD to their teachers can often be challenging considering all the other needs districts must also meet (Breslow & Bock, 2020).

The Need for Professional Development

Teachers in the United States have a variety of past experiences and preparation with both pedagogy and content that they bring with them to the profession (Box, 2019). In addition to this much consideration has been given to teacher self-efficacy (TSE), or a teacher's beliefs in their abilities to teach successfully, and the impact this has on the classroom environment (Zee & Koomen, 2016). This diversity of experience and TSE, along with the constantly changing environment of the modern classroom, means that teachers need access to quality PD. Many definitions of PD exist throughout the literature, but this paper will use a definition that was created based on the work of Darling-Hammond et al. (2017). This paper will define PD as structured professional learning for teachers that strives to bring about changes to teacher knowledge and practices, and potentially improvements in student learning outcomes. Improving

the knowledge and instructional practice of teachers through PD has become increasingly important for many stakeholders within the education system (Sztajn et al., 2017). This is not necessarily an easy process. “Research has demonstrated considerable differences among teachers in the knowledge, beliefs, and skills they bring to professional development programs and their personal characteristics, such as states of growth and flexibility” (Clarke, 2007, p. 28). Accounting for these differences and how they may clash with the goals of professional development is something that designers of these programs need to consider as they work to provide training to teachers (Fishman et al., 2003). Teachers know best what their needs are, however, the National Center for Education Statistics (NCES) in 2015-16 reported that only about 11% of teachers reported having influence on the types of PD they could receive (García & Weiss, 2019). While it is impossible to gear PD to each individual teacher, given the complex system that teachers work in and the needs that they have, it is important for PD to be sure that it meets teachers where they are at.

Over the last several decades, as the focus has shifted to higher standards for student learning outcomes, the demand for quality PD for teachers has grown (Borko, 2004; Box, 2019; Clarke, 2007; Darling-Hammond et al., 2017; Desimone, 2009; Garet et al., 2001; Guskey, 2003; Loucks-Horsley, 1996; Sztajn et al., 2017). This has naturally led researchers to learn about what constitutes good PD practices and what kinds of PD have the biggest impact on a teacher. As the field of research around mathematics education has grown, patterns have emerged in what constitutes good PD and what teachers should be looking for as they pursue their own professional growth (Clarke, 2007; Darling-Hammod et al., 2017; Guskey, 2003; Loucks-Horsley et al., 1996). For example, PD features such as active learning and alignment with teacher’s growth goals lead to better outcomes for teachers (Clarke, 2007; Darling-Hammond et

al., 2017; Desimone, 2009; Garet et al., 2001; Sztajn et al., 2017). When teacher outcomes are better, this translates to better outcomes for students which allows schools to meet the desired higher standards (Darling-Hammond et al., 2017). Since the goal is meeting those high standards, schools and districts should be working to ensure that their PD offerings to teachers include as many of these best practices as possible.

Traditionally PD has been provided as a one-off training that teachers attend outside of their classroom setting (Langreo, 2022). There is not always a connection back to their practice and teachers may see it as taking time away from other demands of their job (McChesney & Aldridge, 2018). It has become increasingly common to diversify the methods with which PD is delivered to teachers ranging from video clubs to multi-year programs that allow teachers to implement their learning in real time in their classroom (Garet et al., 2001; McChesney & Aldridge, 2018; Sztajn et al., 2017). Many of these PD sessions (both traditional and reform based) have been shown to lead to greater outcomes for students (Darling-Hammond et al., 2017; Garet et al., 2001). It can be challenging to know what types of PD delivery will work best for teachers and districts as well as how to evaluate their effectiveness because teacher learning and changes in practice are difficult to measure (Desimone, 2009).

Statement of Problem

Research has demonstrated the importance of teachers' content and pedagogical content knowledge (Hill et al., 2005) and how it contributes to student learning outcomes (Darling-Hammond et al., 2017). The wide variety of experiences among teachers means that teachers need some way to evaluate how well PD aligns with best research practices, how well it aligns with school and district goals, and how well it aligns with their own professional goals. The goal of this paper is to synthesize the research literature on best practices for PD and use these

practices to create a theoretical framework that allows mathematics teachers and coaches to reflect on the potential effectiveness (or preview the potential effectiveness) of particular PD programs that are available to them.

CHAPTER 2 – Review of Literature

In this chapter literature around professional development (PD) and mathematics professional development (MPD) will be reviewed in order to establish the motivation for this theoretical framework. It should be noted that educational reform movements necessitate the improvement of PD as they seek to achieve the goals that they have set for improving student learning. This is because "changes of this magnitude will require a great deal of learning on the part of teachers and will be difficult to make without support and guidance (Ball & Cohen, 1999; Putnam & Borko, 1997; Wilson & Berne, 1999)" (Borko, 2004, p. 3). This means that improving student learning is closely connected to improving their teachers skills in the classroom, and thus teachers need access to quality PD (Darling-Hammond et al., 2017). The chapter will start by exploring why quality PD is necessary to achieve the vision of mathematics education reform and bring about improvement in student achievement. The next two sections will discuss what the research indicates as characteristics of quality PD for teachers from several stakeholders' points of view and will exam different foci of MPD. This will be followed by a section that will discuss methods of delivery for PD and MPD for teachers including technology considerations. The next section of this chapter will discuss the challenges of PD implementation to ensure that the limitations of incorporating quality PD are also being considered in the construction of the framework. Finally, current tools for evaluating PD will be discussed in order to better elaborate on the need for the framework and evaluation tool discussed in this paper. It is important to have a holistic view regarding the most effective ways of improving teachers' practice and student learning outcomes. The likely effectiveness of a MPD has many factors to take into account and a thorough review of the literature is necessary to be able to capture that holistic view.

The Need for Professional Development

According to Box (2019), as education in the United States has grown from focusing on religion, reading, writing, and mathematics to the modern system of elementary and secondary systems, the training of teachers has also evolved. The launch of Sputnik led to the realization that secondary mathematics and science teachers needed training to keep up with other countries which in turn led to the first broad in-service teacher training (Box, 2019). The in-service training continued to evolve as different education reform movements gained traction.

Much of the current MPD has roots that begin in the early 2000s due to standards that were created in an effort to allow the US to keep up with the rest of the world. In 2000 the National Council of Teachers of Mathematics (NCTM) published *Principles and Standards for School Mathematics* in which they laid out the first set of rigorous college and career readiness standards for the 21st century. NCTM emphasized the need for well-prepared and well-supported teachers, and this implies that teachers should have access to quality PD. The No Child Left Behind Act (NCLB) of 2001 made it a requirement that states provide "high-quality" PD to all teachers but did not specify what that "high-quality" PD looked like or how teachers would have access to it (Borko, 2004). Thus, the need for education research became even more important since specifics of "high-quality" PD were needed to comply with NCLB (Darling-Hammond & Sykes, 2003).

Further efforts were made to clarify what it meant for students to be successful and in 2010 the Common Core State Standards for mathematics and English Language arts/literacy (ELA) were developed. As these standards began to be implemented in classrooms, Marrongelle et al. (2013) noted that without full buy-in from the teachers, the transition may not have all the intended changes. In fact, the authors argue that the implementation of these standards did lead

to many disappointments and challenges, specifically around how teachers would ensure that students met the standards. NCTM published *Principles to Actions: Ensuring Mathematical Success for All* in 2014 and in it they included descriptions of 8 mathematical teaching practices (Figure 2.1) teachers can use to improve the teaching and learning of mathematics. These teaching practices "represent a core set of high-leverage practices and essential teaching skills necessary to promote a deep learning of mathematics" (NCTM, 2014, p. 20).

Figure 2.1

The Eight Mathematics Teaching Practices

Mathematics Teaching Practices
1. **Establish mathematics goals to focus learning.** Effective teaching of mathematics establishes clear goals for the mathematics that students are learning, situates goals within learning progressions, and uses the goals to guide instructional decisions.
2. **Implement tasks that promote reasoning and problem solving.** Effective teaching of mathematics engages students in solving and discussing tasks that promote mathematical reasoning and problem solving and allow multiple entry points and varied solution strategies.
3. **Use and connect mathematical representations.** Effective teaching of mathematics engages students in making connections among mathematical representations to deepen understanding of mathematics concepts and procedures and as tools for problem solving.
4. **Facilitate meaningful mathematical discourse.** Effective teaching of mathematics facilitates discourse among students to build shared understanding of mathematical ideas by analyzing and comparing student approaches and arguments.
5. **Pose purposeful questions.** Effective teaching of mathematics uses purposeful questions to assess and advance students' reasoning and sense making about important mathematical ideas and relationships.
6. **Build procedural fluency from conceptual understanding.** Effective teaching of mathematics builds fluency with procedures on a foundation of conceptual understanding so that students, over time, become skillful in using procedures flexibly as they solve contextual and mathematical problems.
7. **Support productive struggle in learning mathematics.** Effective teaching of mathematics consistently provides students, individually and collectively, with opportunities and supports to engage in productive struggle as they grapple with mathematical ideas and relationships.
8. **Elicit and use evidence of student thinking.** Effective teaching of mathematics uses evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning.

Note. Figure comes from Principles to Actions (NCTM, 2014, p. 10)

While *Principles to Actions* does a good job of explaining these teaching practices and how they are rooted in research, what their implementation looks like in the classroom is less clear. As a result, MPD is needed for teachers to successfully implement these practices. Running parallel with this development of national standards for student learning was the idea of accountability. School districts are expected to improve student performance in mathematics and ELA every year in order to continue to receive funding (NCLB, 2002). The grades the districts receive are based on students' performance, students' improvement, or a combination of both. Poor grades often mean that districts need to satisfy additional requirements to receive all of the allocated funding for the school year (Every Student Succeeds Act, 2015). This accountability affects PD. Sztajn et al. (2017) argues that we know very little about PD because:

> As PD becomes a policy mechanism for accomplishing goals establish by larger initiatives such as the [NCLB] act of 2001 or Race to the Top, there is a greater emphasis on experimental designs as the premier approach for studying PD, preferably connecting teacher learning to student achievement. (p. 794)

The field of MPD research has begun to show what constitutes "high-quality" PD and has been able to give guidance for further research and this will be discussed in the coming sections.

Research Based Professional Development Practices

MPD often builds on or challenges teachers' existing knowledge and beliefs about teaching mathematics. Working from that as a base, PD design builds in a variety of features with the goal often being improved teacher practices or student learning outcomes. These PD activities can take many forms and have a variety of structures. Even though reporting on mathematics PD is not standardized (Sztajn, 2011), the body of research that exists on MPD, and PD in general, has led to the development of best practices for teacher learning. Loucks-Horsley

et al. (1996) explored whether there was agreement among different communities regarding effective PD and were able to articulate seven principles that PD should include:

(1) A clear, well-defined image of effective classroom learning and teaching.
(2) Opportunities to develop knowledge and skills and broaden teaching approaches in order to create better learning opportunities for students.
(3) Use instructional methods to promote learning for adults which mirror the methods to be used with students.
(4) Build or strengthen the learning community of science and mathematics teachers.
(5) Prepare and support teachers to serve in leadership roles.
(6) Provide links to other parts of the education system.
(7) Include continuous assessment of the PD program.

Loucks-Horsley et al. (1996) also suggested several policy changes that would support successful implementation of these principles.

Thompson & Zeuli (1999) stated that teachers needed a transformative experience in order to impact their existing beliefs and knowledge of teaching and learning. The authors argue that to do this the PD needs the following:

(1) Create a high level of cognitive dissonance.
(2) Provide sufficient time, structure, and support for teachers to think through the dissonance experienced.
(3) Embed the dissonance creating and resolving activities in teachers' situations and practices.
(4) Enable teachers to develop a new repertoire of practice that fits with their new understanding.
(5) Engage teachers in a continuous process of improvement.

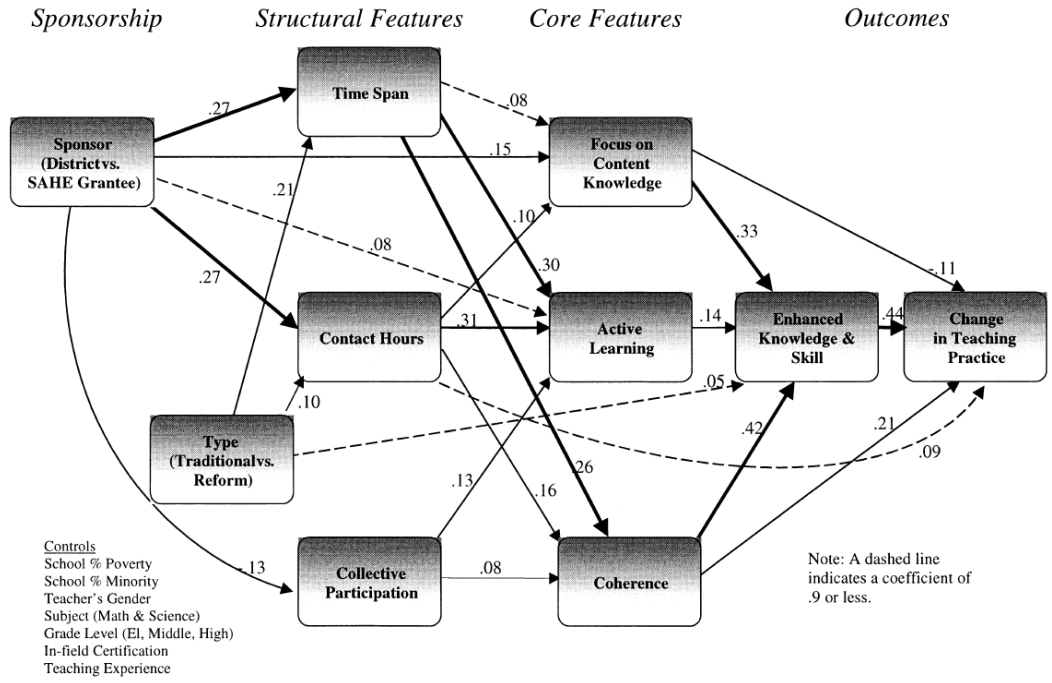
All these features work together to help teachers through the cognitive dissonance that can come with changes to their teaching (Thompson & Zeuli, 1999).

Garet et al. (2001) looked at several structural and core features of different PD funded by the Eisenhower program. The structural features included the form of a PD activity, the duration of the activity, and the degree of collective participation. The core features included the degree of content focus, opportunities for active learning, and the degree of coherence in a teacher's professional learning (Garet et al., 2001). Figure 2.2 shows the relationships between

the structures based on the results of their analysis. There are several key results that impact PD. The first is that duration has a considerable impact on both active learning and coherence (Garet et al., 2001). So longer PD activities are more likely to have components of active learning and to align with a teacher's professional learning goals. The second result that was noted by Garet and colleagues is that both a focus on content knowledge and the degree of coherence had a substantial positive impact on enhanced knowledge and skills of the participating teachers. The last key result from this study is that the best indicator of change in teaching practice is teachers reporting an enhancement of knowledge and skill.

Figure 2.2

The Relationship Features of Professional Development to Teacher outcomes.



Note. Garet et al., 2001, p. 933

In a review of 13 lists of characteristics of effective PD, Guskey (2003) noted that while the criteria to determine "effectiveness" of PD was not always agreed upon there were five characteristics that were frequently mentioned:

(1) Enhancing teachers' content and pedagogical knowledge.
(2) Providing sufficient time and other resources.
(3) Promoting collegial and collaborative exchange.
(4) Establish procedures for evaluating the PD experience.
(5) Conducting school or site-based PD.

Much of the research Guskey (2003) found was inconsistent and further investigation was necessary. He also noted that these characteristics were complex and that a single list for effective PD was potentially not possible.

Clarke (2007), through a synthesis of research studies, put together ten key principles from research that could be used to guide the planning of PD and are listed in figure 2.3. Clarke argues that without well planned PD programs, widespread implementation of reforms is less likely to occur.

Figure 2.3

Ten Important Principles of Professional Development

Ten Important Principles of Professional Development
1. Address issues of concern and interest, largely (but not exclusively) identified by the teachers themselves, and involve a degree of choice for participants.
2. Involve groups of teachers rather than individuals from a number of schools, and enlist the support of the school and district administration, students, parents, and the broader school community.
3. Recognize and address the many impediments to teachers' growth at the individual, school, and district level.
4. Using teachers as participants in classroom activities or students in real situations, model desired classroom approaches during in-service sessions to project a clearer vision of the proposed changes.
5. Solicit teachers' conscious commitment to participate actively in the professional development sessions and to undertake required readings and classroom tasks, appropriately adapted for their own classroom.
6. Recognize that changes in teachers' beliefs about teaching and learning are derived largely from classroom practice; as a result, such changes will follow the opportunity to validate, through observing positive student learning, information supplied by professional development programs.
7. Allow time and opportunities for planning, reflection, and feedback in order to report successes and failures to the group, to share "the wisdom of practice," and to discuss problems and solutions regarding individual students and new teaching approaches.
8. Enable participating teachers to gain a substantial degree of ownership by their involvement in decision making and by being regarded as true partners in the change process.
9. Recognize that change is a gradual, difficult, and often painful process, and afford opportunities for ongoing support from peers and critical friends.
10. Encourage participants to set further goals for their professional growth.

Note. Clarke, 2007, p. 3

Darling-Hammond et al. (2017) looked at 35 different studies that met set methodological criteria to determine features of effective PD. These criteria required any studies to have an experimental or comparison group design and an analysis of student outcomes. From these studies the authors were able to determine seven characteristics of effective PD:

(1) The PD is content focused.
(2) It incorporates active learning.
(3) It supports collaboration.
(4) It models effective practice.
(5) It provides expert support.
(6) It allows for feedback and reflection.
(7) It is of a sustained duration.

The studies examined did not necessarily contain all these characteristics, but they did contain some combination of them, and it should also be noted that any PD should be aligned with a teacher's goals and needs (Darling-Hammond et al., 2017).

Several commonalities of effective PD emerge as these six syntheses of PD research are analyzed. First, PD should focus on content and pedagogical content knowledge to help teachers feel more comfortable with the material that they teach. The PD should also be open to feedback from teachers so that the facilitators can improve the PD for future implementations. Second, it is important that PD has some sort of mechanism for supporting teachers as they work to implement the new learning in their classrooms. Third, quality time has an impact on the effectiveness of the PD, but non-quality time will make the PD less effective. Finally, having some method of evaluating the PD was important for both teachers and PD designers.

Much research has been done to validate, expand, and improve ideas around what effective PD looks like for teachers. Desimone (2009) noted the challenges that come with defining what exactly constitutes PD. There are an extensive number of ways in which teacher learning can occur and can be structured, semi-structured, or unstructured which means

measuring its growth can be complicated (Desimone, 2009). Borko (2004) alludes to the complex web in which teacher learning can happen.

> For teachers, learning occurs in many different aspects of practice, including their classrooms, their school communities, and professional development courses or workshops. It can occur in a brief hallway conversation with a colleague, or after school when counseling a troubled child. To understand teacher learning, we must study it within these multiple contexts, taking into account both the individual teacher-learners and the social systems in which they are participants (Borko, 2004, p. 4).

The implication is that there are a variety of ways PD can be used to make an impact on teaching and that sometimes effective PD is only effective in one context but not in another. For the purposes of this paper PD is defined as structured professional learning for teachers that strives to bring about changes to teacher knowledge and practices, and potentially improvements in student learning outcomes which is modified from the definition put forth by Darling-Hammond et al. (2017).

Rogers et al. (2007) completed a study comparing math and science teachers and PD facilitators views of effective PD. Working with a PD program on an Improving Teacher Quality Grant they found that teachers and facilitators agreed that PD should provide teachers with materials and strategies that apply directly to their curricular needs, provide opportunities for teachers to experience activities as a "student", and provide opportunities for teachers to build their own network of support. PD facilitators cited two additional views that teachers did not discuss and that involved the importance of developing content and pedagogical content knowledge and the importance of reflection as part of the PD process. Interestingly neither the teachers nor the facilitators discussed several of the factors that were identified earlier in this

section. This is potentially an indication that for PD to be effective it does not necessarily need to include all the features that were mentioned earlier.

In the midst of the implementation of the CCSS for mathematics Marrongelle et al. (2013) came up with recommendations for scaling up PD in order for the new standards to have a higher likelihood of being successfully implemented. They noted four different PD features and what they should look like in connection with the standards. The PD should allow teachers to be making connections between the new standards and their practice, ensure teachers understood what student learning looked like according to the new standards, be aligned with their schools' goals, and build support systems among teachers as they worked on implementation. These recommendations align with the effective features of PD while including the context of the CCSSM. Ideally this is what PD facilitates, connecting teacher learning and the practice of teaching.

Research on Mathematics Professional Development

All the practices mentioned in the previous section can be looked at through a lens of mathematics professional development (MPD). The content and pedagogical knowledge required for teaching mathematics is a particularly important focus. Mathematics is a complex and nuanced subject that sometimes requires following a set of procedures while at other times requires a deep understanding of a concept to move a problem forward. Balancing procedural and conceptual fluency is one of many challenges faced by the mathematics teacher. This challenge has been the focus of many reform efforts over the previous two decades with many different visions of school mathematics vying to win out. The most ambitious of these visions comes from NCTM's *Principles and Standards for School Mathematics* (NCTM, 2000):

> The curriculum is mathematically rich, offering students opportunities to learn important mathematical concepts and procedures with understanding…. Students confidently engage in complex tasks carefully chosen by teachers…. Teachers help students make, refine, and explore conjectures on the basis of evidence and use a variety of reasoning and proof techniques to confirm or disprove those conjectures…. Alone or in groups and with access to technology, [students] work productively and reflectively, with the skilled guidance of their teachers. Orally and in writing, students communicate their ideas and results effectively. (p.3)

This vision positions the teacher as a facilitator of learning rather than a deliverer of knowledge. Much of the teaching work force is still transitioning to this pseudo-constructivist view of teaching and hence training is needed to help teachers implement this vision of school mathematics in the classroom. This training can be built by looking at the knowledge that is necessary for teachers to implement this kind of vision. This knowledge is typically broken up into two subgroups: Content Knowledge (CK) and Pedagogical Content Knowledge (PCK). Often MPD can be grouped into one of these two subgroups or will have distinct elements of both included in the training. Ball et al. (2005) further breaks this knowledge into four different components:

(1) Common knowledge of mathematics content
(2) Specialized knowledge of mathematics content
(3) Knowledge of mathematics and students
(4) Knowledge of mathematics and teaching

The difference between common knowledge and specialized knowledge of mathematics content lies in being able to link concepts and see all the interconnectedness there is in mathematics. A typical well-educated adult does not need to be able to utilize all this interconnectedness and instead can stick with the mathematics that is typically required in their

fields, such as engineering or accounting. A teacher, however, is building the foundation for students to pursue any field of study they would like and thus working with not only the common knowledge of mathematics content but also the specialized knowledge is imperative for math teachers. Pedagogical content knowledge is further divided by Ball et al. (2005) into the third and fourth components listed above. Teachers need to have the necessary knowledge to be able to know the preconceptions, conceptions, and misconceptions that students bring into their classroom so that they can teach the subject matter in an appropriate manner. Being able to understand how their students will interact with mathematics will allow math teachers to be more effective in their delivery of the content.

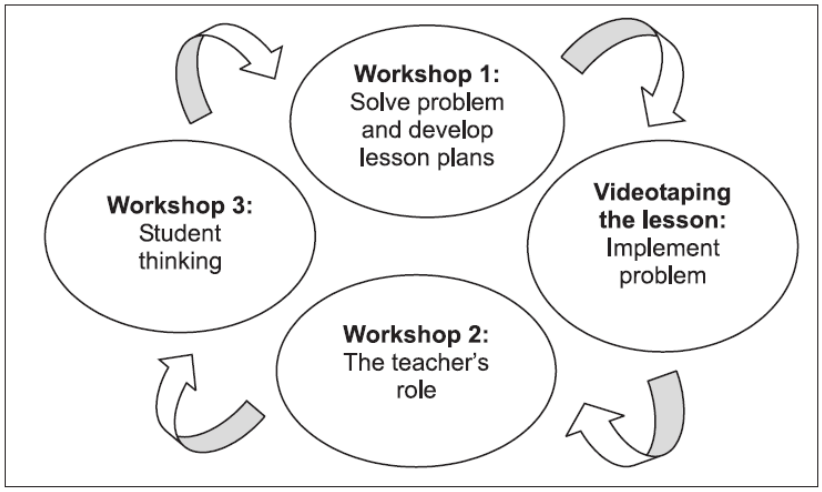
Researchers have the luxury of being able to focus on a few aspects of the knowledge for teaching mathematics, but teachers do not always separate their knowledge into different domains (Koellner et al., 2007). All this knowledge is intertwined, and the authors argue that teachers often draw on multiple components of their knowledge to make instructional decisions. These decisions include, but are not limited to, planning and scaffolding a classroom activity; establishing norms for classroom discourse that promote student thinking and problem solving; ensuring that all the goals for any students that having Individualized Education Plans (IEPs) are met; making a decision to pivot mid-lesson to address a classes' misconception about a topic; and selecting and sequencing mathematical representations to demonstrate connections between the topic and those representations.

As a result of this intertwining of mathematics knowledge, Koellner et al. (2007) created a Problem-Solving Cycle (PSC) to help teachers develop their knowledge base. Teachers participate in a series of three workshops that allow them to look at their teaching from three different angles: planning, teacher's role, and students' thinking. The authors also recommend

videoing the lessons in between the first and second workshops so that it can be referenced during the last two workshops (See figure 2.4). In the ever-changing landscape of the mathematics education reform movement, success is dependent on improving teachers' professional knowledge (Koellner et al., 2007).

Figure 2.4

The Problem Solving Cycle of Professional Development



Note. This figure comes from Koellner et al., 2007, p. 279.

The PSC model put forward by the authors allows teachers to build their professional knowledge by working with the intertwined strands of knowledge required to teach mathematics in several different settings, allowing teachers to plan, implement, and reflect. Koellner et al. (2007) does acknowledge that while not every teacher in their study engaged with all aspects of the professional knowledge described above, all teachers did have the opportunity to do so and that this model should be used complimentarily with other PD to meet districts goals for professional learning.

The flexibility of the PSC means that it is applicable in many different settings. For example, the cycle could be applied to help improve teachers' ability to facilitate mathematical discussions. Stein et al. (2008) put forward five practices for helping make mathematical

discourse productive: (1) anticipating student responses, (2) monitoring students while they work on a task, (3) selecting students work to be presented, (4) sequencing the presentations appropriately, and (5) connecting the presentations as a class. These five practices are one method for increasing math discourse in the classroom and when used together consistently "help make it more likely that teachers will be able to use students' responses to advance the mathematical understanding of the class as a whole" (Stein et al., 2008, p. 322). The PSC can be used to help teachers implement these practices in the classroom be allowing teachers to work together during the cycle. During the first workshop teachers would focus on the "anticipating" practice but also plan for the other four practices. Then after videoing their lesson, they could break down their own teaching with their peers and analyze their own pedagogical moves around the five practices. In this way the PSC can be used to help improve a teachers' pedagogical knowledge. Often researchers will focus on one particular type of content knowledge or pedagogical knowledge for their studies and hope to duplicate the results outside of their field study. These design studies are important for moving the research field of PD in mathematics forward to be able to provide teachers with quality MPD.

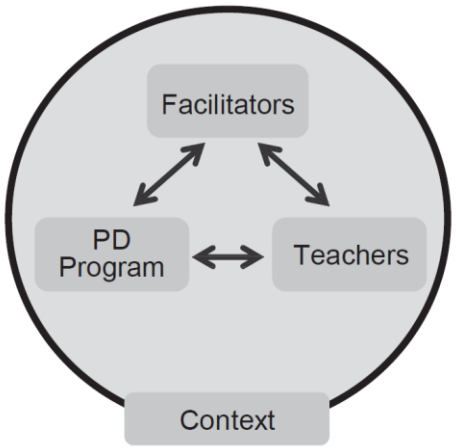
Focus of Research Studies

Researchers have spent a significant amount of time looking at different elements of teacher PD (See figure 2.5). In thinking about PD, there are four elements that must be considered: the professional development program (PDP), the facilitators of the PDP, the teachers involved in the PDP, and the context in which the PDP occurs (Borko, 2004). Focusing on these elements, Borko (2004) organized researchers work into three phases, where each phase builds on the previous phase, in order to elaborate how the studies can further the goal of providing high-quality PD to teachers. Phase one research, according to the author, revolves

around individual PD programs at a single site. Phase two research concerns itself with PD programs implemented at multiple sites, usually by different facilitators. Finally, phase three research looks at multiple PD programs at multiple sites.

Figure 2.5

Elements of a PDP



Note. This figure comes from Borko, 2004, p. 4.

Borko (2004) asserts that researchers can work within these three phases to improve PD for teachers. In 2017 Sztajn et al. did a review of research findings in MPD and updated Borko's phases to be looked at in a different lens: (1) individual PD programs, (2) the scalability of a PD program, (3) comparing different PD programs. During their review the authors looked at 113 different research studies and found that 73% were classified as phase one research, 24% were classified as phase two research, and 3% were classified as phase three research. These percentages indicate that a great deal of research has been done around individual PD programs, but very little research has been done around comparing different PD programs and their implementation.

Phase one research lays the groundwork for providing high-quality PD for teachers because it shows that individual PD programs have an impact on a teacher's professional

knowledge (Borko, 2004). In their review, Sztajn et al. (2017) noticed that of the phase one research that they examined, most programs agreed on the vison for the mathematics classroom as described by NCTM as well as features of effective PD, so they decided to look at phase one research based on the tools that designers chose to use in a PD program, i.e., video clips of mathematics instruction. Video clubs is one such type of PD program that uses video clips and Sztajn et al. (2017) discussed one such program that allowed both teachers and researchers to analyze their teaching. Teachers in the study were able to reflect on the videos and researchers were able to use the video clips to look for growth in teachers across the study. Borko (2004) asserts that having some sort of record of teaching to refer to can go a long way in facilitating teacher change.

Phase two research examines a PD program implemented in multiple places and by multiple people (Borko, 2004). Sztajn et al. (2017) looked at what issues surround implementing phase two research and determined that three main features effect bringing PD to scale: (1) how PD facilitators are prepared, (2) how scaling the PD is approached, and (3) how the context impacts the PD program. The authors found that the PD facilitator was instrumental in bringing effective PD to scale. Borko (2004) outlined the important job facilitators have for creating a community of learners and ensuring that the tasks are structured to meet that community's needs. There are relatively few research studies that look at how PD facilitators can be effectively trained (Sztajn et al., 2017) but one such program came out of work related to the PSC PD model. In this project researchers helped PD leaders prepare for sessions around the PSC by solving the problems, looking at facilitation practices, and analyzing video clips to show in sessions (Borko et al., 2014). In terms of scaling the PD program itself, Sztajn et al. (2017) found two approaches in their review. The first was to develop a PD curriculum to complement the

curriculum for students and the second was to work with different geographical areas to implement PD on a smaller scale. The last feature that effects bringing PD to scale has to do with the context of the location a PD is being implemented in. “Both PD designers and policymakers must understand, and plan for, how the social and policy contexts of schools influence PD implementation and impact” (Sztajn et al., 2017, p. 810). The authors go on to state, from review of the literature, that there needs to be a shared vision of what constitutes high-quality instruction for PD to be effective in bringing about changes in teaching. Phase two research still has a lot of room to grow to help bring the vision of the mathematics classroom put forward by NCTM into better focus.

Phase three research is meant to compare across different PD programs that have all engaged with mathematics education at scale (Borko, 2004). Sztajn et al. (2017) were only able to find three studies consisting of phase three research, which reflects the scarcity of research in phase three. Each of the three studies used different methods to compare different PD programs, suggesting there is some flexibility in conducting phase three research. All three phases have more room for research. Within phase one research there needs to be more consistency in how it is reported (Marra et al., 2011; Sztajn, 2011; Sztajn et al., 2017) and design experiments are something that would help build a bridge between phase one and phase two (Borko, 2004). Additionally, within phase two more work is needed to ensure that materials are well constructed enough to ensure that a PD program can be implemented at scale (Borko, 2004; Sztajn et al., 2017). This includes materials related to training PD facilitators. In general phase three highlights the issues with bringing PD to scale and making that sustainable. Factors such as resource requirements and teacher retention rate demonstrate how hard it can be to sustain PD (Borko, 2004; Sztajn et al., 2017).

These three phases of research provide a sort of road map for what types of collaboration can and should occur between researchers and teachers to provide high quality PD for teachers. This collaboration is imperative to helping sustain PD and allow teachers to improve their professional knowledge. Ultimately the goal is to help close the gap "between what is known about PD and what teachers actually experience in PD programs" (Sztajn et al., 2017, p. 793). The goal should be to get away from one-off workshops and move towards sustainable and scalable research.

Design Considerations of Professional Development

As previously mentioned, a teacher's professional knowledge is intertwined and interrelated. Their mathematics content knowledge impacts their pedagogical content knowledge and vice versa. This is an important consideration when designing PD because the focus of the PD may be content knowledge, but that does not mean that no improvement of the other strands of knowledge will occur. This knowledge is influenced by several factors, one of which being a teacher's beliefs, values, and practices. Changes in a teacher's knowledge does not happen through persuasion but rather through scenarios where their existing knowledge is challenged or broken down, reflection on the challenge, and rebuilding the knowledge with the new ideas interspersed in an environment where they feel safe to do so (Swan, 2011). This is an important idea to consider in PD development because without it, PD will be less effective.

It is impossible to focus a PD program on all the different aspects of professional knowledge at once so in designing PD there needs to be some sort of focus. This focus can be thought of as a PD orientation which includes the "project characteristics that drive the PD design and implementation" (Marra et al., 2011, p. 794). Park Rodgers et al. (2010) established five different orientations for PD: (1) activity-driven, (2) science/mathematics content-driven, (3)

pedagogy-driven, (4) curriculum materials-driven, and (5) needs-driven. There is significant overlap between these orientations and the professional teaching knowledge discussed earlier, as well as overlap with aspects of quality PD. The implication being that PD designers should have an orientation or knowledge focus In mind as they are creating their PD program. If the orientation is activity driven, teachers work with materials that are intended for use with their students, but it is not always clear whether this addresses content or pedagogical knowledge. If the orientation is science/mathematics content driven, teachers are gaining new content knowledge, but the pedagogical knowledge is not explicitly present. If the orientation is pedagogy driven, teachers are learning new instructional strategies, but content knowledge is not explicitly addressed. If the orientation is curriculum materials driven, teachers are learning new curricular materials, but the content knowledge and pedagogical knowledge may not be explicitly addressed. If the orientation is needs driven, teachers help PD facilitators design and implement instruction, but again content knowledge and pedagogical knowledge may not be explicitly addressed. Marra et al. (2011) found an additional orientation through their research being a balanced science/mathematics content and pedagogy orientation and represents PD programs that intentionally work to include both the content driven and pedagogy driven orientations. This finding shows the importance of establishing the orientation of a PD program from the beginning so that it can be implemented with the correct intentions. Once the orientation of a PD program is established, different methods of delivery can be considered.

Methods of Delivery for Professional Development

There are a variety of methods of delivery for PD and, as might be expected, some are viewed as more effective than others. Historically PD sessions were presented as a one-day training workshop where teachers came and learned about some topic related to their teaching

(Box, 2019). There was usually no follow-up and implementation of any of the topics was at the discretion of the teachers after the workshop. This is still a very common PD practice despite there being evidence that they are not as effective for teachers as other models of delivery (Darling-Hammond et al., 2017; Garet et al., 2001). In a recent survey conducted by the EdWeek Research Center, 57% of teachers reported that PD they have received in the past year was mostly a one-time workshop with some or no follow-up (Langreo, 2022). Many districts offer this type of training because it can save on costs, or it helps their teachers with licensure renewal requirements. However, many teachers object to this kind of professional development because they feel it is a waste of time or that it is not often applicable to their practices (Langreo, 2022). PD has evolved in the last several decades to now include more than just one-day workshops with research helping to drive the development of different delivery methods.

One type of delivery that has emerged from research on MPD has been summer institutes that often involve preparing teachers for the coming school year (Melhuish et al., 2022; Nadelson et al., 2012; Rogers et al., 2007). While these institutes can cover anything from curriculum to school initiatives and take place over several days they can be done with a focus on mathematics. The flexibility of this method of delivery means that it can be led by different people ranging from a specialist that is brought in to help teachers understand the initiative to an in-district coach that is helping teachers unpack the curriculum or content standards. This type of PD with a mathematics focus addresses teachers' concerns about applicability to their classroom and are often set up in a way that helps them feel more prepared rather than as a waste of time.

Video clubs, already mentioned earlier in this chapter, are another effective method for delivering PD with a mathematics focus (Coles, 2019; Koc et al., 2009; Sherin & van Es, 2009). Teachers can watch clips of their own teaching during the school year and reflect about what

they are seeing, or they can watch someone else's teaching and think about how they can take and implement those ideas in their own classroom. It also helps teachers see the topic implemented in a classroom rather than as something theoretical that they would have to think through. Video clubs can help teachers improve several strands of their professional knowledge at once and have a variety of ways that it can be focused. The PSC model mentioned earlier is one such example of a method for implementing a video club. Sherin & van Es (2009) designed video clubs to focus on mathematics teachers' professional vision, that is where teachers direct their attention during a lesson and how they process what they notice during a lesson. The video clubs these researchers utilized met several times across a school year which allowed them to look at growth over the school year (Sherin & van Es, 2009). The nice thing about video clubs is that the duration can be left up to the teachers, it could be one unit, one quarter, or even the whole year. Giving the teachers the ability to choose the length of the video club gives them some sense of ownership of the MPD which in turn leads to better buy-in from them.

Related to video clubs are lesson studies, which is a type of PD that allows teachers delivering the same lessons to evaluate the effectiveness of a lesson and discuss ideas for better future implementation. This form of PD has also been shown to be an effective type of PD to use with a mathematics lens (González & Vargas, 2020; Takahashi & McDougal, 2016; White & Southwell, 2003). In a lesson study, a group of teachers first engage in planning a lesson or task that will be taught, they discuss potential student misconceptions, scaffolding ideas, and timing, among other pedagogical and content related ideas ahead of the lesson and then the lesson is implemented in classrooms (Takahashi & McDougal, 2016). This can also occur in a variety of ways. Teachers could draw on a video club experience and have each teacher video the implementation or one teacher at a time could implement the lesson while the rest of the group

watches (González & Vargas, 2020). The implementation is followed by a reflection session where teachers reflect, both individually and as a group, on the lesson. This session can be imperative for teachers as it gives them time to solidify what they have seen and learned as they head back to their own classrooms. Lesson studies can take place in a single day or over several days and can be done multiple times throughout the school year.

A third type of PD that can be implemented with a mathematics focus and is in the same vein as video clubs and lesson studies are coaching cycles or embedded PD. This type of PD provides support to a teacher throughout the year and research has produced several approaches to this method of delivery (i.e., Jacobs et al., 2007 or Norton & McCloskey, 2008). When completed with a mathematics lens, these are usually done with a math coach and one or two other teachers in a school who are teaching the same subject. The math coach sits down with the teachers ahead of time to discuss the math focus of the coaching cycle sometimes as a one on one meeting or sometimes in a PD setting (Jacobs et al., 2007). This can be co-constructed with the teachers or something that the school or district is focusing on (Norton & McCloskey, 2008). Then the coach observes the teachers, looking for what was discussed during the pre-observation meeting and taking notes for later review (Jacobs et al., 2007). After the observation the coach and teachers debrief and work to come up with a new action plan for implementing the desired idea. This action plan may need further coaching cycles to complete and just like a lesson study or a video club, it can be done at any point throughout the school year. These coaching cycles as well as video clubs and lesson studies are good examples of how MPD can be embedded within a teacher's work and can often yield great results (Jacobs et al., 2007; Norton & McCloskey, 2008; Takahashi & McDougal, 2016). They can be more costly than the one-day workshops since some methods of implementation could require multiple substitute teachers to cover classes

or use of videography technology that a district might not have on hand but there are ways to reduce cost depending on the set up within each district.

The literature suggests that the duration of a PD is a strong factor in improving the impact of that PD (Darling-Hammond et al., 2017; Garet et al., 2001; Guskey, 2003). Sustained PD efforts with a mathematics focus can have a greater impact on a teacher's learning than a one-day workshop can, which is why it is important to not have just one video club meeting or one lesson study. As teachers get used to the flow of a PD that is being sustained over time, there is a greater impact on their teaching (Clarke, 2007; Darling-Hammond et al., 2017; Garet et al., 2001). This sustained PD can look like monthly check-in meetings to assess the implementation of a PD program around a mathematics initiative or as a mix of video clubs and in-person sessions that allow teachers to collectively build their knowledge around the math focus of a PD program. One example of this is the training work done with facilitators of the PSC model from Koellner et al. (2007) mentioned earlier where facilitators participated in a summer institute, watched video clips to prepare for PD sessions during the school year, and receive feedback on their work (Sztajn et al., 2017). Additionally, only implementing a single type of PD will not have the same impact as using combinations of PD deliveries. Using a summer institute to kick off the math focus of the video club for the school year or semester allows teachers to have more time with the ideas they are working on and can be solidified using quarterly check-in meetings around the PD program's focus. This in turn will lead to more sustained impacts on their teaching.

Another form of PD that has gained some traction has been Online Professional Development (OPD) where teachers are able to engage in activities through an online portal. The growth of OPD programs has stemmed from the need to provide quality PD to teachers that also

fits with their schedule and can be embedded within the school year (Dede et al., 2008). OPD programs can be synchronous where everyone learns online together, asynchronous where the program is often self-paced so that teachers can move along at their leisure, or a mixture of both (Elliot, 2017). The programs can be very regimented or more open. Parsons et al. (2019) completed a survey of 258 teachers and found that the majority of the teachers surveyed found OPD to be moderately or largely beneficial. The same study also found that teachers were likely to participate in OPD that showed exemplary teaching or teachers implementing PD ideas in their classrooms (Parsons et al., 2019). Other studies have similarly found that teachers prefer content that ties directly back to their classroom (Duncan-Howell, 2010; Lee et al., 2020; Rienties et al., 2013). Sites such as Coursera allow teachers to work through courses focused on improving their content knowledge. Other sites such as Invigorating Statistics and Data Science Teaching through Professional Learning (InSTEP) house a whole PD program that focuses on one content strand. InSTEP, in particular, allows teachers to work on improving both their content and pedagogical knowledge specifically around Statistics and Data Science (Lee et al., 2023). Massive Open Online Courses (MOOCs) operate in a similar vein to InSTEP but have a less narrow focus and could be on a topic that is not just content related but related to technology tools. One particular study involving MOOCs found success in reaching and engaging teachers with their materials as evidenced by discussion forums, follow-up surveys, and other click log data (Lee et al., 2020). So, while one of the possible drawbacks to OPD programs is that teachers must build their own communities of learning, either through online discussion boards or by having other teachers in their building join them in the online space there has been success around engaging teachers in an online space (Duncan-Howell, 2010; Lee et al., 2020; Parsons et al., 2019; Rodesiler, 2017). It is possible for the online discussion boards to be a valuable

resource for teachers (Hollebrands & Lee, 2020; Matrenga & Silverman, 2020) but that feature must be intentionally implemented for there to be any benefit. Due to the COVID-19 pandemic, there was a sharp increase in the number of OPD offerings for teachers (Flores & Swennen, 2020) which means that it will become important for teachers to be able to determine the likely effectiveness of OPD programs (Meyer et al., 2023). There is also the potential for OPD programs to allow for scaling up of quality PD and provide a greater reach for quality resources to teachers (Dede et al., 2008; Meyer et al., 2023).

One final type of PD program that will be mentioned in this section is PD around learning trajectories (LTs). This type of PD focuses on helping teachers learn more about anticipated paths of learning for students and what stumbling blocks might occur along the trajectory. PD around LTs can help improve not only a teacher's knowledge of how students learn mathematics but their own content knowledge as well (Mojica, 2010; Wilson et al., 2014). Teachers engaged in this type of PD can also focus on how a particular LT aligns with their curriculum and how the curriculum might be scaffolded to help students through a particular trajectory. PD around LTs is another example of a program that shows how intertwined components of a teacher's professional knowledge is and how programs need to consider these connections as a program is being implemented.

Researchers can help drive this development of high-quality PD in a variety of ways. In thinking about the phases mentioned earlier, researchers should find ways to help scale up PD so that more teachers can have access to those programs (Borko, 2004; Sztajn et al., 2017). This could be in the form of replicability of PD programs that have shown promise in one site. Another way researchers can help provide quality PD to teachers is to ensure that their work is being presented at conferences teachers are able to attend. This includes everything from national

conferences, like the NCTM annual meeting, to more local state conferences, like the North Carolina Council of Teachers of Mathematics (NCCTM) annual conference. Stakeholders in education can further help by establishing grants to help fund teachers' attendance at such conferences so that they are exposed to research around quality PD. If the goal is a mathematics classroom like what is described by NCTM then working to help get teachers "high-quality" PD should be one of the priorities.

Challenges of Implementation

As mentioned throughout the review, implementation of high-quality PD can be a challenge. The cost of implementing a PD program can be a deciding factor for districts looking for ways to provide their teachers with options, and districts often find it cheaper to keep PD in-house rather than bring in an outside facilitator. One indicator of quality PD is that it is sustained over a period of time, but teacher retention rates make this challenging (Clarke, 2007; Garcia & Weiss, 2019; Garet et al., 2001; Sztajn et al., 2017). Darling-Hammond et al. (2017) also identified several systemic issues that contribute to challenges around quality PD implementation. They noted that PD agendas are often set without understanding what all the PD needs are, that not implementing PD programs as intended or cutting corners sets the programs up to fail, and that districts or schools often do not have a good strategy for assessing the effectiveness of a PD program.

In addition to these systemic challenges to PD implementation, there are challenges at the individual level as well. During implementation a teacher may experience an obstacle that is outside of their control and even if the obstacle is in their control, it is possible that they do not have the support to overcome that obstacle (Darling-Hammond et al., 2017). The stresses of teaching can also contribute to failed implementation of a PD program since teachers only have

so much time to cover everything that is asked of them (Darling-Hammond et al., 2017; Garcia & Weiss, 2019; Sztajn et al., 2017). All of these challenges need to be taken into account as stakeholders work towards creating and providing high-quality PD to teachers.

Review of Current Evaluation Tools

In reviewing the literature on quality MPD it became apparent that PD should have some sort of evaluation mechanism. Loucks-Horsley et al. (1996) noted the importance of this aspect of quality PD so the idea of evaluating the effectiveness of a PD program is not new. However, several authors have noted the challenges of PD evaluation and that many recommendations are unable to be implemented on a regular basis (Earley & Porritt, 2014; McChesney & Aldridge, 2018). Several evaluation tools have been used over the past few decades but much of it has focused on simple measures of effectiveness or anecdotal evidence (Earley & Porritt, 2014). This evaluation is also used to inform the administrators, PD facilitators, or policymakers about the effectiveness of the PD (McChesney & Aldridge, 2018). One of the more common evaluation methods used is the pretest-posttest method (Lynch, 2002; Martineau, 2004; Weiss, 1999). PD participants are given a pretest and posttest that was created to evaluate PD outcomes and the information gathered from those surveys are used to determine the effectiveness of the PD program (Allen & Nimon, 2007). Allen & Nimon (2007) proposed a similar evaluation tool in the retrospective pretest which asks teachers to post-PD reflect on their habits from before the PD. One of the drawbacks to this evaluation method is the validity of the results as it relies on the teacher's memory of their behaviors pre-PD (Allen & Nimon, 2007). Similar issues exist with the pretest posttest model in that teachers are only asked how immediately after the PD concludes about the PD rather than after implementation of learning from the PD (McChesney & Aldridge, 2018).

Checklist questionnaires used as evaluation tools is another type that has been used to measure the effectiveness of PD (Champion, 2006; McChesney & Aldridge, 2018). McChesney & Aldridge (2018) specifically sought to create a questionnaire that teachers could use that measured the impact of PD. The authors intended for the Impact of Teacher Professional Development (ITPD) Questionnaire to be used for a broad range of PDs and contexts but was limited by the fact that it did not measure change in teachers' beliefs which they hold as an important indicator of the impact of PD (McChesney & Aldridge, 2018). Another potential limitation of the ITPD questionnaire is that it is trying to serve too many purposes, which is a common pitfall of surveys and questionnaires (Champion, 2006). One final pitfall of the ITPD questionnaire is the reliance on teacher self-reporting which has been identified as a common issue with this type of evaluation tool (Champion, 2006; McChesney & Aldridge, 2018).

There is a gap between recommendations from research about evaluating PD and the practice of evaluating PD (Breslow & Bock, 2020; Earley & Porritt, 2014; McChesney & Aldridge, 2018). Some work has been done to close this gap by creating works that guide the design, implementation, and evaluation of PD Programs (Breslow & Bock, 2020; Darling-Hammond et al., 2018; Earley & Porritt, 2014). Figure 2.6 shows a tool from one such work that was created based on effective PD practices by Breslow & Bock (2020). This professional learning design checklist incorporates seven aspects of effective PD and asks for a rating and an explanation. Breslow & Bock (2020) intend for this tool to be used in the planning of PD activities with the goal of allowing designers to ensure that their program is strong in all seven areas before the designers go ahead with implementation. The authors did not intend for this to be the evaluation tool rather they lay out a method for the designers to create their own evaluation questions to determine effectiveness or impact (Breslow & Bock, 2020).

Figure 2.6

Professional Learning Design Checklist

PD Design Feature	1	2	3	4	Explanation for your Rating
Is Content Focused					
Incorporates Active Learning					
Supports Collaboration					
Uses Models of Effective Practice					
Provides Coaching and Expert Support					
Offers Feedback and Reflection					
Is of Sustained Duration					

Note. This figure comes from Breslow & Bock, 2020, p. 5.

So, while figure 2.6 displays a tool that evaluates the strength of a PD program, it does not consider the likelihood of the effectiveness of a PD program. Overall, the tools that are available for the evaluation of a PD program are primarily checklists or questionnaires that either measure too broadly or are not strongly tied to literature on effective PD (Earley & Porritt, 2014). In the next chapter, this paper takes all of the information gathered around quality professional development and distills it down into a theoretical framework that teachers can use to help them evaluate their own PD offerings and help them better advocate for the types of PD that they need to improve their teaching.

CHAPTER 3 – Discussion of Theoretical Framework

It is clear that there is a disconnect between the type of mathematics professional development (MPD) that teachers experience and the type of MPD that research says is high-quality. One-off workshops are still very common (Langreo, 2022), and not all teachers have the opportunity to engage in high-quality MPD due to the challenges of implementation. The first section of this chapter will present a *Theoretical Framework for Professional Development Program (PDP) Evaluation*. This section will also discuss each of the aspects of the framework and the interconnectedness of some of the components. The last section will introduce an evaluation tool that teachers can use to evaluate the professional development they are receiving and will describe how each part of the tool connects back to the framework.

Theoretical Framework for PDP evaluation

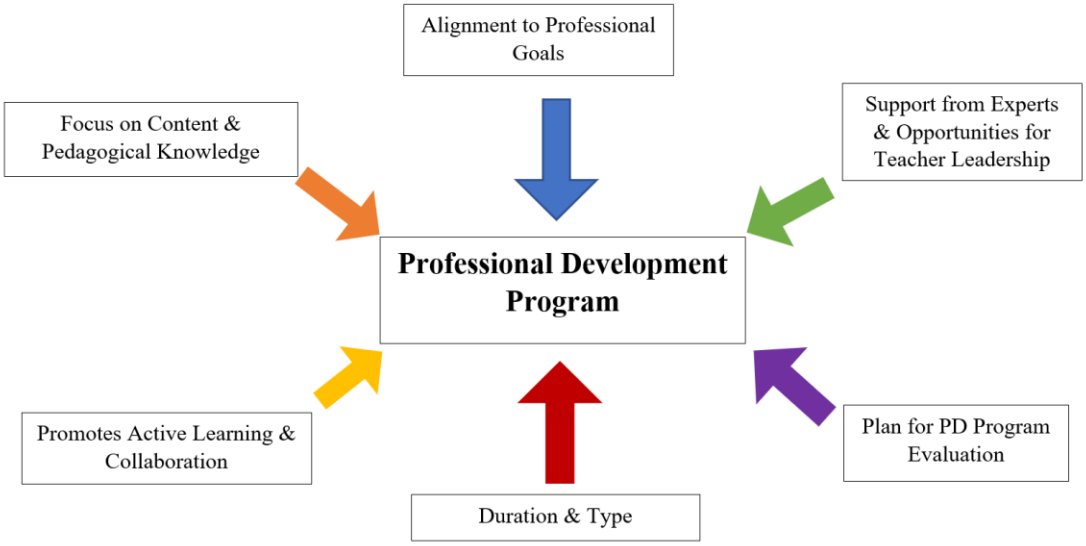
As noted in the previous chapter there has been a great deal of research done around what practices make up high-quality PD (Borko, 2004; Clarke, 2007; Darling-Hammond et al., 2017; Garet et al., 2001; Gusky, 2003; Loucks-Horsley et al., 1996; Sztajn et al., 2017; Thompson & Zeuli, 1999). All this research can be synthesized into six different aspects that will make up the framework for PDP evaluation: (1) Alignment to professional goals, (2) Focus on content and pedagogical knowledge, (3) Promotion of active learning and collaboration, (4) Duration and type, (5) Support from experts and opportunities for teacher leadership, and (6) A plan for PDP evaluation (See figure 3.1). Ultimately high-quality PDPs include ideas from all these aspects.

Alignment to Professional Goals

MPD should align to a teacher's professional goals. A teacher should constantly be working to improve their craft and one way to go about doing that is by setting goals (Clarke, 2007; Thompson & Zeuli, 1999).

Figure 3.1

A Theoretical Framework for PDP Evaluation



These professional learning goals could be related to improving their own teaching practice, their roles within the school, current school-based issues, or even simply improving at the administration side of their job (Louws et al., 2017). Since they are setting most of their own professional goals, teachers should have the ability to choose the MPD or PD that will help them achieve those goals (Clarke, 2007). In general PD should align with stated professional goals. This includes any school- or district-level professional goals. Teachers should be aware of their school- and district-level professional goals and these goals should be posted by the school and district so teachers can have access to them. When PD aligns with a teacher's professional learning goals, it is more likely that the teacher will buy-in to the PD which will in turn make the PD more effective for the teacher (Clarke, 2007; Garet et al., 2001). When considering or reflecting on a PDP, a teacher should determine how well the stated outcomes of the program align with the professional goals they are working on for that school year.

Focus on Content & Pedagogical Knowledge

MPD should have some focus on improving a teacher's content and/or pedagogical knowledge. The research indicates that improvement in content and pedagogical knowledge leads to an improvement in one's teaching practice and student achievement (Darling-Hammond et al., 2017). MPD should have this focus and model the desired approaches to teaching content with effective pedagogical moves (Clarke, 2007; Darling-Hammond et al., 2017). This modeling allows teachers to develop the skills necessary to implement their new knowledge and MPD can assist in this development by using instructional methods of learning for adults that would simply need to be adapted slightly for use with students (Loucks-Horsley et al., 1996). PD should also take into account the diverse learning experiences of the teachers, just like teachers need to take into account the diverse learning experiences and needs of their students. By working to improve pedagogical and content knowledge of teachers, PDPs are providing teachers with the ability to help increase student achievement. When considering or reflecting on a PDP, a teacher should ensure that the program has a focus on improving the teacher's content and/or pedagogical knowledge.

Promotes Active Learning & Collaboration

PD should engage teachers in active learning and promote collaboration among teachers. Bonwell & Eison (1991) define active learning as "anything that involves students in doing things and thinking about the things they are doing" (Bonwell & Eison, 1991, p. 2). This paper will define active learning as anything that involves teachers in doing activities and thinking about the activities that they are doing. Teachers should have the opportunities to engage in activities that create and resolve cognitive dissonance (Thompson & Zeuli, 1999). This means that teachers are not only doing the work but are also provided with time to discuss the activities

and reflect on their new learning that resulted from their participation (Garet et al., 2001). The active learning activities should allow teachers to make changes in their teaching rather than feel like they are simply learning another thing that they must incorporate into an already very full schedule (Darling-Hammond et al., 2017). Part of this active learning involves getting teachers to buy into what is being presented in a particular PDP. When teachers are more committed to what a PDP is offering, the program is more likely to be effective and successful (Clarke, 2007).

Active learning in a PDP should also incorporate some degree of collaboration. Teachers need the opportunities to discuss mathematics pedagogy and learning with their colleagues to help them improve their own practice (Loucks-Horsley et al., 1996). In fact, many teachers believe that interactions with their colleagues can be the best way to improve their practice (Clarke, 2007). PDPs should be working to involve groups of teachers from the same school in order to increase their effectiveness (Clarke, 2007; Darling-Hammond et al., 2017; Garet et al., 2001). PD should be intentional about the collaboration it provides though, in order to avoid having a negative impact rather than a positive one (Guskey, 2003). Teachers should have support from all levels of the school system in implementing new PD ideas and this support can be essential for successful implementation. When considering or reflecting on a PDP, a teacher should be sure that the PD or MPD contains active learning and opportunities to collaborate with fellow teachers, ideally teachers from the same school.

Duration & Type

PD can have a wide variety of duration and types. Research suggests that it is better for PD to occur over a sustained duration rather than in a one-off setting (Darling-Hammond et al., 2017; Garet et al., 2001). While this is not true for all PDPs, high-quality PD will have this characteristic of sustained over time. A multi-day summer institute that focuses on helping

teachers implement curriculum for the coming school year or video clubs that meet throughout the school year are examples of sustained duration PDPs. One-off PD days done throughout the year, however, would be a non-example of sustained duration since there is often not a common thread between these PD days. The goal of sustained duration is to promote learning over time since that will better translate to change in teaching practice (Darling-Hammond et al., 2017). Teachers need opportunities within PD to plan, discuss, and reflect and this takes time.

There are also a variety of forms a PDP can take and this can be classified by type. A more in-depth discussion of types of PD with a mathematics focus can be found in the previous chapter under delivery methods. What is important to consider about the type of MPD is how it relates to one's teaching and one's preferences. MPD is more likely to be effective when it aligns with a teacher's preferred method of learning. MPD can be embedded within the classroom as video clubs or coaching cycles. It can also occur outside the classroom with the intention of implementation within the classroom such as a curriculum summer institute or an online MPD program. The MPD can also be outside the classroom in an effort to present new strategies or provide teachers with new content knowledge. Often the duration of a PDP will influence the type of MPD so sustained duration programs are more likely to be a combination of in- and out of- classroom types. When considering or reflecting on a PDP, teachers should be aware of the planned duration and type of MPD that they are being asked to engage in.

Support from Experts & Opportunities for Teacher Leadership

To be able to provide high-quality MPD to a greater number of teachers, work needs to be done to help scale up PDPs. Both Borko (2004) and Sztajn et al. (2017) discuss the importance of having systems in place to train facilitators who can provide the PD to teachers. Throughout the learning process provided by a PDP, teachers need support from experts and

coaches to successfully implement the ideas they learn (Darling-Hammond et al., 2017; Loucks-Horsley et al., 1996). Quality facilitators can help ensure active learning, quality collaboration, and smooth implementation as they work to help teachers improve their practice. Teachers also need the support from administrators and district officials as they work to help achieve district and school related professional learning goals. Getting teacher input in terms of setting district and school professional learning goals is equally important. Teachers should have a say in the PDPs they engage in (Clarke, 2007).

PDPs should also have structures in place to help prepare and support teachers to serve in a leadership role for future MPD implementation (Loucks-Horsley et al., 1996). Having this type of structure in place will help contribute to the scalability of a PDP as well as build in the ability to help with the sustainability of the MPD. Teachers having a leadership role in a PDP will allow the MPD to continue to future iterations rather than just one. These structures are part of the larger goal of encouraging teachers to engage in a continual process of improving their teaching practice (Clarke, 2007; Darling-Hammond, 2017; Thompson & Zeuli, 1999). Change does not happen overnight and is an on-going process that teachers engage with so the PD or MPD they engage in should support this as well. When considering or reflecting on a PDP, a teacher should identify what expert and school-based supports are available to them as well as whether there is an opportunity for them to grow into a leadership role within the program.

Plan for PD Program Evaluation

PDPs should not always be the same session after session. PDPs should be able to change over time and that requires that there is some sort of mechanism that requires evaluation of the program (Darling-Hammond et al., 2017; Guskey, 2003; Loucks-Horsley et al., 1996). Since teaching is an ever-evolving process PD should be as well. PDPs that have been shown to be

effective are ones that utilize feedback and reflections from teachers to build better programs for improving teacher learning (Darling-Hammond, 2017). PDPs need to be working to improve in much the same way that teachers should be working to improve their own teaching. When considering or reflecting on a PDP, a teacher should check to see if the program has a mechanism for evaluating its own effectiveness.

Interconnectedness within the Framework

Within the Theoretical Framework for PDP Evaluation there exists underlying interconnectedness between the different aspects. This is due mostly to the interconnectedness of a teacher's professional knowledge and how often changes in one knowledge area can affect another knowledge area. The most interconnectedness lies between the content & pedagogical knowledge and the promotes active learning & collaboration aspects. NCTM's vision for a mathematics classroom mentioned paints a picture of learning and collaboration that requires teachers to have broad and deep content and pedagogical knowledge. This occurs through active learning and collaboration with peers and therefore a connection exists between these two aspects allowing for enaction of this vision. The active learning & collaboration aspect is also influenced by the duration and type aspect. If a PDP is of a sustained duration with in-classroom structures, then it is more likely to include active learning and collaboration. That does not mean that a one-day workshop PD will not have active learning and collaboration, it simply means that the depth to which this aspect is addressed will likely not be as good.

A teacher's professional learning goals influence the content & pedagogical knowledge aspect as well as the support from experts & opportunities for teacher leadership aspect. Teachers should actively be seeking out PDPs that fill gaps in their content or pedagogical knowledge. These gaps should be reflected in the goals they set for themselves as the result of

being a reflective practitioner. It is important that the content or pedagogical knowledge gained from a PDP assists a teacher in achieving their goals. Their goals also may revolve around getting more involved in leadership roles, especially as they move past their seventh year of teaching (Louws et al., 2017). It is important that these interconnections are considered when looking at the framework even though the framework does not explicitly show them. The interconnections are not displayed on the framework because there is no easy way to show them all at the same time and have the intended impact.

Applying the Framework

This framework can be applied in a variety of ways. Teachers can simply look to what extent a PDP satisfies each of the six aspects based on descriptions mentioned previously, but it would be better to take a more formal approach for evaluating a PDP. Several formal approaches exist in the literature such as checklists, surveys, and questionnaires that could be drawn on to apply this framework (Allen & Nimon, 2007; Breslow & Bock, 2020; Champion, 2006; Earley & Porritt, 2014; McChesney & Aldridge, 2018). This paper chose to create an open-ended survey as an evaluation tool that can be used to apply the framework. As a reminder, the six aspects of the framework are: (1) Alignment to professional goals, (2) Focus on content and pedagogical knowledge, (3) Promotion of active learning and collaboration, (4) Duration and type, (5) Support from experts and opportunities for teacher leadership, and (6) A plan for PDP evaluation. The *Professional Development Program (PDP) Evaluation* tool (See figure 3.2) is one way that this framework can be used by teachers to look at the likely effectiveness of their PD. This tool allows teachers to arrive at a score for the PDP that is being considered. It can be used to preview a PDP before participating to determine the appropriateness of the program.

Figure 3.2

Professional Development Program (PDP) Evaluation tool

Professional Development Program (PDP) Evaluation Tool					
Alignment to Professional Goals					
What are your Professional Learning Goals?					
Content or Pedagogical Knowledge					
The PDP focused on developing content or pedagogical knowledge					**Score**
Strongly Disagree (0)	Disagree (2)	Neutral (4)	Agree (6)	Strongly Agree (8)	
What knowledge did you gain from participating in the PDP?					
Active Learning & Collaboration					
The PDP engages participants in active learning*					**Score**
Strongly Disagree (0)	Disagree (1)	Neutral (2)	Agree (3)	Strongly Agree (4)	
How did you engage in active learning during the PDP?					
The PDP allowed for collaboration with other teachers (Co-workers, Same Content Teachers, etc.)					**Score**
Strongly Disagree (0)	Disagree (1)	Neutral (2)	Agree (3)	Strongly Agree (4)	
In what ways did you collaborate with your peers? Was this collaboration encouraged to continue after the PDP?					
Duration & Type					
The PDP had the following duration:					**Score**
Single Day (1)	Several days (2)	Several weeks (3)	Several months/semester (4)	School Year (5)	Several Years (6)
What was the type* of PDP? What is your preferred type of PDP?					
The PDP aligned with your preferred type of PDP					**Score**
No (0)	Somewhat (1)	Yes (2)			
Plan for PD Program Evaluation					
The PDP discussed a plan for its own evaluation or you filled out an evaluation form					**Score**
No (0)	Not clearly (1)	Yes (2)			
Support from Experts & Opportunities for Teacher Leadership					
The PDP provided support from experts on the program					**Score**
No (0)	Not clearly (1)	Yes (2)			
The PDP discussed opportunities for teacher leadership					**Score**
No (0)	Not clearly (1)	Yes (2)			
*See back for definitions				**Total Score**	

Active Learning
Active learning is defined as anything that involves teachers in doing activities and thinking about the activities that they are doing. This could be actively doing a math activity that will later be incorporated in the classroom or reflecting on how new pedagogical knowledge could be incorporated in the classroom. It is not passively sitting in a room while someone lectures for the entirely of the program.
Type of PDP
When considering the type of PDP the whole program should be considered. If the PDP is only one session then just that session should be considered when filling out the evaluation tool. If the PDP is several sessions, like a coaching cycle, then all of the sessions should be considered when filling out the evaluation tool. Additionally they type should be specified i.e. Video club, summer institute, lecutre along with your preferred type of PDP.
Additional Notes

It can also be used to reflect on the PDP that a teacher has recently participated in, and that reflection can then inform future participation in similar PDPs. Teachers rate the PDP based on either the advertisement of the program or on their own participation in the program. In this section, how the tool incorporates each of the six aspects of the framework will be discussed.

The evaluation tool begins with an open-ended section for the teacher to provide their learning goal for the PDP program they are evaluating. This goal could be very broad or more specific, but it should link to the PDP somehow since alignment to professional goals is an important aspect of the framework. The focus on content and pedagogical knowledge section has both a quantitative question and an open-ended question. The quantitative question is a Likert scale question that will give a numerical score for this aspect.The open-ended question is meant for teachers to articulate the learning goals of the PDP and that should be drawn from the program itself. They can also include new knowledge that has been gained as a result of participating in the PDP. The active learning & collaboration section of the tool is similar to the content or pedagogical knowledge section, but active learning and collaboration are considered separately. A definition of active learning and several examples and a non-example are included on the second page of the tool for teachers to reference in case they are unsure of what constitutes active learning. The Likert scale score is cut in half so that the overall score for this section has the same weight as the content or pedagogical knowledge section. The open-ended questions give teachers the chance to articulate how the PDP allowed for active learning and collaboration, if at all. The duration and type section also has quantitative and open-ended sections. For the first quantitative question, the scale is different because, while one-day workshops are not always effective, there is still the possibility for them to be useful to teachers. The second quantitative question allows teachers to give a score based on how well the PDP

aligns with their preferred type of PDP. In the open-ended section teachers should describe what the PDP is method of delivery is and the number of contact hours that they are spending on the PD. This also provides context for the evaluation of duration because it is possible that even though the PDP was several days, which is a score of 2, it covered the implementation of a curriculum for the coming school year and as a result was of great benefit to the teacher. The second page of the evaluation tool also provides some clarification on the type of PDP.

The last two sections of the evaluation tool, plan for PDP evaluation and support from experts & opportunities for teacher leadership, only contain quantitative questions. The Likert scale used reflects the more cut and dry nature of these aspects of the framework. Either the PDP has these aspects, or it does not have them. When the tool is used as a way to preview a PDP, these aspects might not be advertised but based on the information shared there is potential for them to be present. When the tool is used as a reflection on a PDP, it is more likely that the "Not Clearly" response will not be considered since the teacher will know at that point whether the aspects are present or not, but it is still an option as there may not have been enough clarification on these aspects during the PDP.

The evaluation tool has eight quantitative questions that can all be added up to give a PDP a score. PDPs will receive a score on a scale of 1 to 30 with higher scores corresponding to PDPs that are more likely to be effective and lower scores corresponding to PDPs that are more likely to be less effective. The numerical score, however, is not the only part of the evaluation. The open-ended questions provide context to that numerical value. If a PDP receives a low score, it is likely that the program does a poor job in the active learning & collaboration section or the content or pedagogical knowledge section, since those are the sections with the most weight in the tool. The teachers likely had little to include in those sections due to lack of information

provided by the PDP or the teacher felt it was missing during the actual PD. If a PDP receives a high score, then the opposite is probably true and that will appear in the answers to the open-ended questions. By combining both quantitative and open-ended questions the tool ensures that the evaluation is not determined by a single number and that it takes a more holistic view of a PDP. The tool also stays focused on the six aspects of effective PD from the literature and does not take too broad of an approach like other evaluation tools. There is still some work to be done around the validity and reliability of the tool, but two major pitfalls of current evaluation tools have been addressed.

This PDP evaluation framework and evaluation tool was developed by analyzing literature around best practices for PD for teachers and looking at the current state of the field of PD in mathematics. It consists of six categories: (1) Alignment to professional goals, (2) Focus on content and pedagogical knowledge, (3) Promotion of active learning and collaboration, (4) Duration and type, (5) Support from experts and opportunities for teacher leadership, and (6) A plan for PD program (PDP) evaluation. All these categories help make up high-quality PD for mathematics teachers and contain a degree of interconnectedness, especially between the focus on content & pedagogical knowledge and promotion of active learning & collaboration categories. This framework and evaluation tool was developed as a means for teachers to evaluate their own PD using research backed tools. In the next chapter an online professional development program will be assessed using the framework and evaluation tool and the strengths and weaknesses of the evaluation tool will be discussed.

CHAPTER 4 – Application of the Framework

The *Theoretical Framework for Professional Development Program (PDP) Evaluation* is based on a synthesis of the current literature around professional development (PD) and mathematics professional development (MPD) for teachers. In this chapter an online PDP will be described, and the evaluation tool will be applied to the program. A discussion of the strengths and weaknesses of the program will follow the evaluation based on the results and will tie back to the framework. The following section will look at the effectiveness of the evaluation tool and next steps for the tool will be proposed and justified. The chapter will conclude with suggestions for further applications of the evaluation tool and PDPs evaluation framework.

Invigorating Statistics and Data Science Teaching through Professional Learning: A PDP

The Invigorating Statistics and Data Science Teaching through Professional Learning (InSTEP) PDP was designed as a free online personalized professional learning platform for teachers and instructional coaches to help with their content and pedagogical knowledge of statistics and data sciences for grades 6-12+ (Lee & Mojica, 2023). This platform contains a plethora of materials related to the teaching of data science & statistics (DS&S). Using a recommendation engine, the platform creates a customized list of recommended modules and investigations for teachers to engage with to meet the goal of enhanced knowledge of teaching DS&S (Lee & Mojica, 2023). The recommendation engine uses the results of three different surveys that look at a teacher's learning goals, their confidence to teach statistics, and their level of conceptual understanding of statistical content. In other words, a teacher's professional goals, their pedagogical knowledge, and their content knowledge.

The platform was built on the seven dimensions of teaching DS&S which are: (1) Data and statistical practices, (2) Central statistical ideas, (3) Tasks, (4) Data, (5) Technology tools,

(6) Argumentation, and (7) Assessment of student thinking. The platform contains modules within each of these seven dimensions that teachers select from. The platform also has several data investigations that follow a six-phase data investigation process created by Lee et al. (2022). These are the two primary ways teachers can learn about DS&S. The data investigations allow teachers to experience working with large data sets from the point of view of the learner before providing teachers with a classroom lesson plan for implementation in their own classrooms. The data investigations are meant to demonstrate the interconnectedness of the seven dimensions with particular attention paid to the data & statistical practices and central statistical ideas dimensions (Lee & Mojica, 2023).

The modules located in the seven dimensions are meant to be self-directed and self-paced. The data and statistical ideas dimension presents practices and processes of DS&S and is where a teacher would be able to learn more about the data investigation process that they engage with in the data investigations. The central statistical ideas dimension focuses on content in the K-12 curriculum and the tasks dimension provides support in implementing DS&S tasks in the classroom. The data dimension assists teachers in developing better strategies for working with bigger and messier data and the technology tools dimension gives teachers a deeper knowledge of the tools they can use to work with this data. The argumentation dimension provides instruction on how to work discourse on DS&S into your classroom. Finally, the assessment of student thinking dimension looks at ways to assess students statistical thinking and use that assessment to inform their instruction. The dimensions work to strike a balance between focusing on content and pedagogical knowledge. The data & statistical practices and data dimensions focus on content knowledge, the central statistical ideas, tasks, argumentation, and

assessment of student thinking modules focus on pedagogical knowledge, and the technology tools dimension has a dual focus.

The InSTEP platform also has several other features that could be helpful for a teacher's professional learning. The platform offers the ability to earn microcredentials to demonstrate one's learning, as well as collaborative spaces to interact with other teachers who are working through the material on the platform. All the classroom resources on the platform are screened by experts in the DS&S education field to ensure that teachers are receiving quality materials (Lee & Mojica, 2023). This PDP has much to offer to teachers whose professional learning goals center on DS&S.

Applying the Evaluation Tool to the InSTEP PDP

The *Evaluating PDPs Evaluation Tool* was applied to the InSTEP PDP through a lens of a program that a North Carolina Math 1 teacher with 6 years of experience had completed and was reflecting on (see figure 4.1). Hence the learning goal is: My professional learning goal is to gain further confidence in teaching the statistics curriculum that is part of my high school's NC Math 1 curriculum. The InSTEP PDP shows a strong alignment to the teachers professional learning goal since the program's focus is DS&S. The knowledge that the teacher said they gained can all be found on the home page of the website: instepwithdata.org and the about page: instepwithdata.org/public/about/ but the description is based on what learning the teacher completed while they worked in the platform. The same webpages were used to identify the type of professional development. The teacher made a judgement call on the duration since the program is "self-paced" and spent two to three months working and learning on the platform. The InSTEP PDP received a score of 19 out of 30 from the evaluation tool.

Figure 4.1

InSTEP PD Evaluation

Professional Development Program (PDP) Evaluation Tool					
Alignment to Professional Goals					
What are your Professional Learning Goals? My professional learning goal is to gain further confidence in teaching the statistics curriculum that is part of my high schools NC Math 1 curriculum.					
Content or Pedagogical Knowledge					
The PDP focused on developing content or pedagogical knowledge					**Score**
Strongly Disagree (0)	Disagree (2)	Neutral (4)	Agree (6)	Strongly Agree (8)	8
What knowledge did you gain from participating in the PDP? Through engaging in this PDP I gained statistical content knowledge related to different processes in data science and statistics. I learned about and engaged in the data investigation process and I am excited to help my own students engage in this process. In particular, I learned effective ways of working with big messy data so that I can now also teach my students how to work with big messy data.					
Active Learning & Collaboration					
The PDP engages participants in active learning*					**Score**
Strongly Disagree (0)	Disagree (1)	Neutral (2)	Agree (3)	Strongly Agree (4)	3
How did you engage in active learning during the PDP? I was actively engaged while working through the data investigations in the platform. See pg. 2 for more details.					
The PDP allowed for collaboration with other teachers (Co-workers, Same Content Teachers, etc.)					**Score**
Strongly Disagree (0)	Disagree (1)	Neutral (2)	Agree (3)	Strongly Agree (4)	1
In what ways did you collaborate with your peers? Was this collaboration encouraged to continue after the PDP? The home page refers to collaborative spaces but the only collaboration available in the platform was through discussion forums which were not helpful.					
Duration & Type					
The PDP had the following duration:					**Score**
Single Day (1)	Several days (2)	Several weeks (3)	Several months/semester (4)	School Year (5)	Several Years (6)	4
What was the type* of PDP? What is your preferred type of PDP? The InSTEP PDP is an online PDP that is described as "self-paced & self-directed." So I spent the 2-3 months leading up to my statistics units working through the content on the platform. My preferred type is on p.2					
The PDP aligned with your preferred type of PDP					**Score**
No (0)	Somewhat (1)	Yes (2)			1
Plan for PD Program Evaluation					
The PDP discussed a plan for its own evaluation or you filled out an evaluation form					**Score**
No (0)	Not clearly (1)	Yes (2)			0
Support from Experts & Opportunities for Teacher Leadership					
The PDP provided support from experts on the program					**Score**
No (0)	Not clearly (1)	Yes (2)			2
The PDP discussed opportunities for teacher leadership					**Score**
No (0)	Not clearly (1)	Yes (2)			0
*See back for definitions				**Total Score**	19

Active Learning
Active learning is defined as anything that involves teachers in doing activities and thinking about the activities that they are doing. This could be actively doing a math activity that will later be incorporated in the classroom or reflecting on how new pedagogical knowledge could be incorporated in the classroom. It is not passively sitting in a room while someone lectures for the entirely of the program.
Type of PDP
When considering the type of PDP the whole program should be considered. If the PDP is only one session then just that session should be considered when filling out the evaluation tool. If the PDP is several sessions, like a coaching cycle, then all of the sessions should be considered when filling out the evaluation tool. Additionally they type should be specified i.e. Video club, summer institute, lecutre along with your preferred type of PDP.
Additional Notes
Active learning - The apply and reflect callouts gave me the opportunity to think about the pedagogical moves necessary in order to implement some of my new knowledge in my classroom. Preferred Type - My preferred type of PDP is coaching cycles or multi-session PDPs where I can take what I learn, try it on, and come back to the next session with questions and reflections. The InSTEP PDP somewhat aligns with my preferred method because I was able to revisit the platform whenever I needed to and often it allowed me to build on what I had learned. I do think there could have been a more effective way for me to ask questions and get answers.

The program scored well under content and pedagogical knowledge because the teacher felt like they gained the knowledge they went into the PDP looking to gain. The website provides thorough descriptions of its content as well as providing examples of what that content would look like which is helpful if a teacher was using the tool to preview the InSTEP PDP. The program did not get a perfect score but still scored relatively well in the active learning and collaboration category. The teacher agreed that the program provided active learning but disagreed on the allowance for collaboration. The teacher was able to point to the data investigations as something that provided active learning and they also took note of the "apply" and "reflect" callouts in the platform. It is not "strongly agree" because there were still good portions of the program that required some "sit and get" which is due in part to the fact that it is housed in an online space. The only indication of collaboration on the home page or the about page are the phrases "collaborative spaces" and "engage with InSTEP community members" with no other indication as to what collaboration looks like once a teacher starts the program. Once inside the platform the only collaboration available is through discussion forums which the teacher felt was an inadequate method of collaboration.

The program gives no indication that it has an evaluation plan for improving the PD. There were surveys that the teacher was able to take inside the platform but there was no indication that the results would be used to improve the PDP rather they would just be used to improve the recommendations for the teacher. There is also no indication of opportunities for teachers to take on leadership roles within this program. The website does say that all of the resources are checked by experts in the field so this does indicate that there is some sort of support from experts involved in DS&S education.

Overall, the InSTEP PDP is a solid PDP for this teacher to engage with. It clearly aligns with their learning goal, there is a strong focus on content and pedagogical knowledge, and it attempts to provide active learning in an online space. Because it is in an online space the duration of the PDP has some flexibility. It is possible that teachers could spend a whole school year working through the material. Each page has time estimates which will also help a teacher plan their sessions on the platform. The program falls short in terms of collaboration, evaluation, and opportunities for teachers to take on leadership roles. In the online space collaboration can be challenging to implement and the designers probably spent a great deal of time trying to figure out how to incorporate this aspect of quality PD. One potential solution would be to encourage groups of teachers from the same school to work on the InSTEP platform and then that way they would have co-workers readily available to discuss their work. The plan for evaluation of the program is not explicit on the home page, about page or inside the platform but that does not mean that there is not a plan in place. As mentioned earlier in this section, it is possible that there is some feedback mechanism within the platform that is not available without registering for the program.

The major pitfall for this PDP lies in the lack of opportunities for teachers to take on leadership roles with this program. As the PD on mathematics education field works to start bringing PD to scale, this lack of leadership opportunities is something that needs to be addressed. In terms of the InSTEP PDP, there are a couple of ways that the team can go about creating leadership opportunities for teachers who participate in the PDP. The program could reach out to past participants to see if they want to create content to add to the platform. This content would go through the same vetting process that all the other content went through, but it would be coming from practicing teachers, and it would add to the repertoire of resources

already housed on the platform. Another way the program could "scale-up" and provide leadership opportunities would be to find a way to promote communities of practice that had facilitators that were trained to guide users on the platform. This has the added benefit of addressing the collaboration weakness mentioned previously. The InSTEP PDP is a great option for any teachers whose professional learning goals involve improving their content and/or pedagogical knowledge of DS&S.

Effectiveness of the Evaluation Tool

This use of the *Theoretical Framework for PDP Evaluation* and the associated evaluation tool was effective and gave good feedback to the teacher about whether or not they should participate in the PDP. The evaluation tool did a good job of ensuring that the PDP was looked at in the context of each of the six aspects that indicate quality PD for teachers. It made the teacher think about each aspect individually, but it also had them look at how some of the categories overlapped. Evaluating the InSTEP PDP highlighted the importance of the PD aligning with a teacher's learning goals. The main reason that InSTEP was a good fit for the teacher was because the learning goal lined up with the content of the program. If the goal had been around proof in geometry or algebraic manipulations, then InSTEP would have not been a good fit for the teacher and the goal section of the tool would have made that obvious. The evaluation tool was also able to handle the unique nature of a PDP that is being offered in an online space. The duration section was flexible enough that the teacher was able to decide how long the program would take him and apply that in that section of the tool.

The tool does have several next steps to determine its effectiveness. The first step would be for the author to apply the tool to several different PDPs that have been part of experimental design studies and compare the results of the tool to the results of the study. Alignment here

would be further indication of the tool's effectiveness. The following step would be to have several teachers use the tool on past PDPs that they have participated in. This would allow the tool to be examined as a tool for reflection instead of as a predictor of quality PD. Results from this can be compiled and used as a way to validate the tool's effectiveness or to improve the tool.

Further Applications

More rigorous testing of the evaluation tool is necessary to determine whether it is an effective tool for teachers to use as a way to apply the Theoretical Framework for PDPs Evaluation. The tool should be tested on multiple PDPs by multiple teachers. This data should be gathered and analyzed so that the analysis can be used to make improvements to the current evaluation tool or make recommendations for changes to the tool so that it can be used by, and be beneficial for, teachers. The main goal of the evaluation tool is to provide teachers with a way to use the corresponding framework to easily evaluate their PDP offerings. The framework was designed as a way for teachers to have the necessary tools that will allow them to advocate for high-quality PD that will help them improve their practice and in turn improve student achievement.

CHAPTER 5 – Conclusion

This chapter concludes by discussing current limitations of the *Theoretical Framework for Professional Development Program (PDP) Evaluation* and recommendations for future studies that can help address those limitations. Teachers deserve access to quality professional development (PD) and this framework is designed to be a tool to help them advocate for that PD. The potential of this framework to help bring strong professional development to a greater number of teachers is something that the author believes fills a very real need in the field of mathematics education.

Limitations & Recommendations

The *Theoretical Framework for PDP Evaluation* is designed based on research findings about the apsects of quality PD. Unfortunately, it is still very common for teachers to engage in one-off workshops with short duration or short-term PD as their primary source of professional learning (Darling-Hammond et al., 2017; Langreo, 2022). There is not much access to the kind of quality PD that would score well on the evaluation tool for this framework, but the framework could be used to show that the current one-off workshops do not address all six components of the PDP framework required to help improve a teacher's practice. The associated evaluation tool does address several of the common pitfalls that occur in other evaluation tools, but it still needs to be validated and undergo more rigorous testing.

Measuring the effectiveness of PD is challenging for a variety of reasons (Desimone, 2009). The is no standard method for reporting on the design or results of mathematics professional development (Sztajn, 2011) and that is an external limitation on this framework. Since there is no standard for PDPs in terms of reporting design features, it could be challenging for teachers to use the evaluation tool on all the PDPs they participate in. It may require some

sort of training for teachers to know what to look for and this adds to a teacher's list of work rather than subtract from it. The evaluation tool does not have too broad of a focus as is common in other surveys which can be helpful in ensuring that a PDP is evaluated appropriately. The framework also is open to some interpretation in terms of what constitutes a focus on content and pedagogical knowledge or promotion of active learning and collaboration. This openness to interpretation is both a strength and weakness. Keeping teachers from taking too narrow of a focus on these aspects of quality PD allows for flexibility in the types of PDPs that the framework can be applied to but a lack of understanding about what some part of the framework, such as misunderstanding how active learning is being defined, could lead to misapplication. These limitations lead to the conclusion that even though some common pitfalls of other tools have been addressed, more work is needed to help refine the evaluation tool that is used to apply this framework to PDPs.

Future Research

There are several avenues that research studies could take as work is done to analyze the effectiveness of the evaluation tool and refine it. One such study suggestion was presented in the previous chapter in which teachers are asked to use the tool as a way to reflect on recent PDPs in which they have participated. Another possible avenue of work revolves around bringing PD to scale by using the framework to evaluate teachers experiences with a particular PDP or to help train facilitators of PDPs. The evaluation would be completed anonymously for the facilitators and the feedback would then be analyzed so and changes could be made to improve the program. The evaluation could be done will multiple teachers at multiple sites. PDPs should include all the elements of the framework so facilitators could be trained on the framework and then use it to

ensure that the program is addressing each of the elements when being implemented with teachers.

Conclusion

Improving methods of teacher learning is one of the key avenues that schools in the U.S. can take to improve student learning and achievement (Darling-Hammond et al., 2017; Desimone, 2009; Sztajn et al., 2017). This improvement occurs when teachers are given access to high-quality PDP. The framework proposed in this paper provides teachers with a way to evaluate the PD they want to pursue and in which PD they choose to participate. Teachers are lifelong learners and have a good sense of where they have gaps in their knowledge. They should be setting their own professional learning goals and using these goals as a focal point for finding PD that helps them meet those goals. This framework serves as a way for teachers to determine if a particular PDP aligns with those goals and as a way for them to reflect on a PDP to determine how well the program helped them meet those goals. This framework can also be used by math coaches, school administrators, and district-level personnel as they work to provide their teachers with high-quality PD. For high-quality PDPs to be effectively implemented, policies, research, and practice need to be aligned (Park Rodgers et al., 2007). This framework can be used to focus the discussion on this alignment. Ideally, this thesis will serve as the starting point for bridging the gap between what research says is ideal professional development and what teachers currently experience, by allowing stakeholders to evaluate PDPs through the lens of best practices.

REFERENCES

Allen, J. M., & Nimon, K. (2007). Retrospective pretest: a practical technique for professional development evaluation. *Journal of Industrial Teacher Education*, *44*(3), 27-42.

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond and G. Sykes (Eds.), *Teaching as the learning profession* (pp. 3–31). San Francisco, CA: Jossey-Bass.

Ball, D. L., Thames, M. H., & Phelps, G. (2005, December). Articulating domains of mathematical knowledge for teaching. In *American Education Research Association Conference*.

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom. 1991 ASHE-ERIC higher education reports*. ERIC Clearinghouse on Higher Education, The George Washington University, One Dupont Circle, Suite 630, Washington, DC 20036-1183.

Borko, H. (2004). Professional Development and Teacher Learning: Mapping the Terrain. *Educational Researcher*, *33*(8), 3–15.

Borko, H., Koellner, K., & Jacobs, J. (2014). Examining novice teacher leaders' facilitation of mathematics professional development. *The Journal of Mathematical Behavior*, *33*, 149-167.

Box, C. (2019). *Formative assessment in united states classrooms*. Springer International Publishing.

Breslow, N., & Bock, G. (2020). Evaluating professional learning–a tool for schools and districts. *REL Northeast & Islands.*

Champion, R. 2006. “Surveys and Questionnaires Have Their Pluses – And Their Pitfalls.” *Journal of Staff Development* 27 (3): 61–64.

Clarke, D. (2007). Ten principles from research for the professional development of mathematics teachers. In *Stepping stones for the 21st century* (pp. 27–39). Sense Publishers.

Coles, A. (2019). Facilitating the use of video with teachers of mathematics: Learning from staying with the detail. *International Journal of STEM Education*, *6*, 1-13.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development.* Palo alto, CA: Learning Policy Institute.

Darling-Hammond, L., & Sykes, G. (2003). Wanted, a national teacher supply policy for education: The right way to meet the" highly qualified teacher" challenge. *Education policy analysis archives*, *11*(33).

Dede, C., Jass Ketelhut, D., Whitehouse, P., Breit, L., & McCloskey, E. M. (2009). A research agenda for online teacher professional development. *Journal of teacher education*, *60*(1), 8-19.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199.

Duncan-Howell, J. (2010). Teachers making connections: Online communities as a source of professional learning. *British journal of educational technology*, *41*(2), 324-340.

Earley, P., & Porritt, V. (2014). Evaluating the impact of professional development: The need for a student-focused approach. *Professional development in education*, *40*(1), 112-129.

Elliott, J. C. (2017). The evolution from traditional to online professional development: A review. *Journal of Digital Learning in Teacher Education*, *33*(3), 114-125.

Every Student Succeeds Act of 2015, 20 U.S.C. § 6301 (2015).

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and teacher education*, *19*(6), 643-658.

Flores, M. A., & Swennen, A. (2020). The COVID-19 pandemic and its effects on teacher education. *European Journal of Teacher Education*, *43*(4), 453-456.

Gamoran Sherin, M., & Van Es, E. A. (2009). Effects of video club participation on teachers' professional vision. *Journal of teacher education*, *60*(1), 20-37.

García, E., & Weiss, E. (2019). *The role of early career supports, continuous professional development, and learning communities in the teacher shortage: The fifth report in 'the perfect storm in the teacher labor market' series.* Economic Policy Institute. https://www.epi.org/publication/teacher-shortage-professional-development-and-learning-communities/

Garet, M. S., Porter, A. C., Desimone, L. Birman, B. F., & Suk Yoon, K. (2001). What makes professional development effective? *American Educational Research Journal, 38*(4), 915-945.

González, G., & Vargas, G. E. (2020). Teacher Noticing and Reasoning about Student Thinking in Classrooms as a Result of Participating in a Combined Professional Development Intervention. *Mathematics Teacher Education and Development*, *22*(1), 5-32.

Guskey, T. R. (2003). What makes professional development effective? *Phi delta kappan*, *84*(10), 748-750.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American educational research journal*, *42*(2), 371-406.

Hollebrands, K. F., & Lee, H. S. (2020). Effective design of massive open online courses for mathematics teachers to support their professional learning. *ZDM*, *52*, 859-875.

Jacobs, V. R., Franke, M. L., Carpenter, T. P., Levi, L., & Battey, D. (2007). Professional development focused on children's algebraic reasoning in elementary school. *Journal for research in mathematics education*, *38*(3), 258-288.

Jotkoff, E. (2022, Feb. 1st,). *NEA survey: Massive staff shortages in schools leading to educator burnout; alarming number of educators indicating they plan to leave the profession.* National Education Association. https://www.nea.org/about-nea/media-center/press-releases/nea-survey-massive-staff-shortages-schools-leading-educator

Koc, Y., Peker, D., & Osmanoglu, A. (2009). Supporting teacher professional development through online video case study discussions: An assemblage of preservice and inservice teachers and the case teacher. *Teaching and Teacher Education*, *25*(8), 1158-1168.

Koellner, K., Jacobs, J., Borko, H., Schneider, C., Pittman, M. E., Eiteljorg, E., Bunning, K. & Frykholm, J. (2007). The problem-solving cycle: A model to support the development of teachers' professional knowledge. *Mathematical thinking and learning*, *9*(3), 273-303.

Kurtz, H. (2022, Apr. 14th,) *A profession in crisis: Findings from a national teacher survey.* EdWeek Research Center. https://www.edweek.org/research-center/reports/teaching-profession-in-crisis-national-teacher-survey

Langreo, L. (2022, Oct. 13th,) One-time pd is not effective. Why do districts still rely on it? EdWeek Research Center. https://www.edweek.org/leadership/one-time-pd-is-not-effective-why-do-districts-still-rely-on-it/2022/10

Lee, H., & Mojica, G. (2023). *InSTEP: Invigorating statistics and data science teaching through professional learning.* InSTEP. https://instepwithdata.org/public/

Lee, H. S., Mojica, G. F., & Lovett, J. N. (2020). Examining How Online Professional Development Impacts Teachers' Beliefs About Teaching Statistics. *Online Learning*, *24*(1), 5-27.

Lee, H., Mojica, G., Thrasher, E., & Baumgartner, P. (2022). Investigating data like a data scientist: Key practices and processes. *Statistics Education Research Journal*, *21*(2), 3-3.

Loucks-Horsley, S., Stiles, K., & Hewson, P. (1996). Principles of effective professional development for mathematics and science education: A synthesis of standards. *NISE brief*, *1*(1), n1.

Louws, M. L., van Veen, K., Meirink, J. A., & van Driel, J. H. (2017). Teachers' professional learning goals in relation to teaching experience. *European journal of teacher education*, *40*(4), 487-504.

Lynch, K. B. (2002). When you don't know what you don't know: Evaluating workshops and training sessions using the retrospective pretest methods. *Arlington, VA*.

Marra, R. M., Arbaugh, F., Lannin, J., Abell, S., Ehlert, M., Smith, R., Merle-Johnson, D. & Park Rogers, M. (2011). Orientations to professional development design and implementation: Understanding their relationship to PD outcomes across multiple projects. *International journal of science and mathematics education*, *9*, 793-816.

Marrongelle, K., Sztajn, P., & Smith, M. (2013). Scaling up professional development in an era of common state standards. *Journal of teacher education*, *64*(3), 202-211.

Martineau, J. (2004). *Evaluating leadership development programs: A professional guide*. Greensboro, NC: Center for Creative Leadership.

Matranga, A., & Silverman, J. (2020). An emerging community in online mathematics teacher professional development: an interactional perspective. *Journal of Mathematics Teacher Education*, 1-27.

McChesney, K., & Aldridge, J. M. (2018). A new tool for practitioner-led evaluation of teacher professional development. *Teacher development*, *22*(3), 314-338.

Melhuish, K., Thanheiser, E., White, A., Rosencrans, B., Shaughnessy, J. M., Foreman, L., Riffel, A. & Guyot, L. (2022). The efficacy of research-based "mathematics for all" professional development. *Journal for Research in Mathematics Education*, *53*(4), 307-333.

Meyer, A., Kleinknecht, M., & Richter, D. (2023). What makes online professional development effective? The effect of quality characteristics on teachers' satisfaction and changes in their professional practices. *Computers & Education*, *200*, 104805.

Mojica, G. F. (2010). *Preparing pre-service elementary teachers to teach mathematics with learning trajectories*. North Carolina State University.

Nadelson, L. S., Seifert, A., Moll, A. J., & Coats, B. (2012). i-STEM summer institute: An integrated approach to teacher professional development in STEM. *Journal of STEM Education: Innovation and Outreach*.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston. VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematics success for all.* Reston, VA: National Council of Teachers of Mathematics.

No Child Left Behind (NCLB) Act of 2001, Pub. L. No. 107-110, § 101, Stat. 1425 (2002).

Norton, A. H., & McCloskey, A. (2008). Teaching experiments and professional development. *Journal of Mathematics Teacher Education*, *11*, 285-305.

Park Rogers, M. A., Abell, S. K., Marra, R. M., Arbaugh, F., Hutchins, K. L., & Cole, J. S. (2010). Orientations to science teacher professional development: An exploratory study. *Journal of Science Teacher Education*, *21*(3), 309-328.

Parsons, S. A., Hutchison, A. C., Hall, L. A., Parsons, A. W., Ives, S. T., & Leggett, A. B. (2019). US teachers' perceptions of online professional development. *Teaching and Teacher Education*, *82*(1), 33-42.

Putnam, R., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29*(1), 4–15.

Rienties, B., Brouwer, N., & Lygo-Baker, S. (2013). The effects of online professional development on higher education teachers' beliefs and intentions towards learning facilitation and technology. *Teaching and teacher education*, *29*, 122-131.

Rodesiler, L. (2017). For teachers, by teachers: An exploration of teacher-generated online professional development. *Journal of Digital Learning in Teacher Education*, *33*(4), 138-147.

Rogers, M. P., Abell, S., Lannin, J., Wang, C. Y., Musikul, K., Barker, D., & Dingman, S. (2007). Effective professional development in science and mathematics education: Teachers' and facilitators' views. *International journal of science and mathematics education*, *5*, 507-532.

Stein, M. K., Engle, R. A., Smith, M. S., & Hughes, E. K. (2008). Orchestrating productive mathematical discussions: Five practices for helping teachers move beyond show and tell. *Mathematical thinking and learning*, *10*(4), 313-340.

Swan, M. (2011). Designing tasks that challenge values, beliefs and practices: A model for the professional development of practicing teachers. *Constructing knowledge for teaching secondary mathematics: Tasks to enhance prospective and practicing teacher learning*, 57-71.

Sztajn, P. (2011). Standards for reporting mathematics professional development in research studies. *Journal for research in mathematics education*, *42*(3), 220-236.

Sztajn, P., Borko, H., & Smith, T. M. (2017). Research on mathematics professional development. *Compendium for Research in Mathematics Education*, 793-823.

Takahashi, A., & McDougal, T. (2016). Collaborative lesson research: Maximizing the impact of lesson study. *Zdm*, *48*, 513-526.

Thompson, C., Zeuli, J., Darling-Hammond, L., & Sykes, G. (1999). Teaching as the learning profession: Handbook of policy and practice. *The frame and the tapestry: Standards-based reform and professional development*, 341-375.

TIMSS (2019) *U.S. Highlights Web Report* (NCES 2021-021). U.S. Department of Education. Institute of Education Sciences, National Center for Education Statistics. https://nces.ed.gov/timss/results19/index.asp

Weiss, I. R. (1999). Evaluating science and mathematics professional development programs. *Chapel Hill, NC: Horizon Research*.

White, A. L., & Southwell, B. (2003). Lesson study: A model of professional development for teachers of mathematics in years 7 to 12. *Mathematics education research: Innovation, networking, opportunity*, 744-751.

Wilson, P. H., Sztajn, P., Edgington, C., & Confrey, J. (2014). Teachers' use of their mathematical knowledge for teaching in learning a mathematics learning trajectory. *Journal of Mathematics Teacher Education*, *17*, 149-175.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad and P. D. Pearson (Eds.), *Review of Research in Education, 24,* 173–209.

Zee, M., & Koomen, H. M. Y. (2016). Teacher Self-Efficacy and Its Effects on Classroom Processes, Student Academic Adjustment, and Teacher Well-Being: A Synthesis of 40 Years of Research. *Review of Educational Research*, *86*(4), 981–1015.

APPENDIX

Figure 3.2

Professional Development Program (PDP) Evaluation tool

Professional Development Program (PDP) Evaluation Tool					
Alignment to Professional Goals					
What are your Professional Learning Goals?					
Content or Pedagogical Knowledge					
The PDP focused on developing content or pedagogical knowledge					**Score**
Strongly Disagree (0)	Disagree (2)	Neutral (4)	Agree (6)	Strongly Agree (8)	
What knowledge did you gain from participating in the PDP?					
Active Learning & Collaboration					
The PDP engages participants in active learning*					**Score**
Strongly Disagree (0)	Disagree (1)	Neutral (2)	Agree (3)	Strongly Agree (4)	
How did you engage in active learning during the PDP?					
The PDP allowed for collaboration with other teachers (Co-workers, Same Content Teachers, etc.)					**Score**
Strongly Disagree (0)	Disagree (1)	Neutral (2)	Agree (3)	Strongly Agree (4)	
In what ways did you collaborate with your peers? Was this collaboration encouraged to continue after the PDP?					
Duration & Type					
The PDP had the following duration:					**Score**
Single Day (1)	Several days (2)	Several weeks (3)	Several months/semester (4)	School Year (5)	Several Years (6)
What was the type* of PDP? What is your preferred type of PDP?					
The PDP aligned with your preferred type of PDP					**Score**
No (0)	Somewhat (1)	Yes (2)			
Plan for PD Program Evaluation					
The PDP discussed a plan for its own evaluation or you filled out an evaluation form					**Score**
No (0)	Not clearly (1)	Yes (2)			
Support from Experts & Opportunities for Teacher Leadership					
The PDP provided support from experts on the program					**Score**
No (0)	Not clearly (1)	Yes (2)			
The PDP discussed opportunities for teacher leadership					**Score**
No (0)	Not clearly (1)	Yes (2)			
*See back for definitions				**Total Score**	

Active Learning
Active learning is defined as anything that involves teachers in doing activities and thinking about the activities that they are doing. This could be actively doing a math activity that will later be incorporated in the classroom or reflecting on how new pedagogical knowledge could be incorporated in the classroom. It is not passively sitting in a room while someone lectures for the entirely of the program.
Type of PDP
When considering the type of PDP the whole program should be considered. If the PDP is only one session then just that session should be considered when filling out the evaluation tool. If the PDP is several sessions, like a coaching cycle, then all of the sessions should be considered when filling out the evaluation tool. Additionally they type should be specified i.e. Video club, summer institute, lecutre along with your preferred type of PDP.
Additional Notes