A CASE-STUDY ANALYSIS OF THE ROLE AND INFLUENCE OF
TOOLS IN THE PRACTICE OF A TEACHER(-LEADER) WITHIN THE
CONTEXT OF A PROFESSIONAL DEVELOPMENT PROJECT

by

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To Ethan, you will always be my inspiration to "never give up."

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List of Abbreviations

CGI	Cognitively Guided Instruction
ISD	Intermediate School District
MTF	Mathematical Tasks Framework
NRC	National Research Council
NSF	National Science Foundation
TTLP	Thinking Through a Lesson Protocol
TTSP	Thinking Through a Session Protocol

CHAPTER 1

INTRODUCTION TO THE STUDY

Teachers are inundated with new resources to improve the ways in which they interact with students (e.g., lesson plan structures, lists of content expectations, and curriculum materials). As such, teachers need to make decisions about what to be attentive to and what to neglect. Once a teacher selects a resource for use in her classroom, it then follows that she needs to determine how and in what ways she might use it with her students. Although there is an increasing amount of research regarding how teachers use resources such as curriculum materials, (Brown, 2009; Senk and Thompson, 2003a; Senk & Thompson, 2003b; Stein & Kim, 2009; Tarr et al., 2008), little is known about how or why a teacher decides to use a resource to improve his or her instructional practice beyond being compelled to do so by administration. Furthermore, even less in known about how instructional tools might support a teacher to use new or refined instructional actions suggested by tools in her classroom.

In this study, I analyze complementary tools of action. I articulate what I mean by the phrase *tool of action* in Chapter 3. At present, it is enough to recognize that tools, as defined by this study, are "externalized representations of ideas that are used by people in their practice" (Spillane, 2006). Using this definition, I focus on the particular case of how one teacher who participated in Beyond Implementation: Focusing on Challenge and Learning (BIFOCAL), a middle school mathematics professional development project, took up and used a complementary set of practice-based tools to prepare her for ongoing

learning with respect to her classroom and leadership instructional practices. Toward this

end, I document the critical events that seem to have influenced what she took up, as well

as how the tools appeared to function to scaffold the transfer of specific instructional

actions from professional development to practice and from classroom practice to

leadership practice.

Although I use the term practice throughout this study, it is critical to make clear

that the research team did not conduct observations of the teacher's classroom practice.

Therefore, my claims with respect to classroom practice reflect that I have evidence of

the teacher's understanding of specific instructional actions suggested through the tools

and the corresponding professional development project, as well as evidence of her intent

to use said instructional actions in her classroom practice. On the contrary, the research

team did conduct observations of the teacher's leadership practice. Therefore, I make

claims in this dissertation regarding the teacher's use of the specific instructional actions

suggested by the tools in the teacher's leadership practice.

To arrive at conclusions regarding the teacher's classroom and leadership

practices, I analyzed the teacher's uptake and use of three particular tools: The

Mathematical Tasks Framework with corresponding levels of Cognitive Demand[1] (MTF)

as shown in Figure 3.1, Thinking Through a Lesson Protocol (TTLP) (see Appendices A

and B), and Thinking Through a Session Protocol (TTSP) (see Appendix C). I selected

these tools for analysis for three reasons: (1) they are a complementary set of tools[2] in

that the TTLP and TTSP grew out of the MTF; (2) they were embedded throughout the

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[1] I paired the levels of cognitive demand with the Mathematical Tasks Framework (MTF) because absent of
a way to talk about how the lesson actually unfolds with students (i.e, enacted at a high or low level), the
usefulness of the MTF declines. The levels of cognitive demand, serve the purpose of a common
vocabulary and understanding with respect to what happens as tasks get enacted with students.
[2] I will further articulate the complementary nature of these tools in a later chapter.

professional development project that was the context for this study; and (3) these tools potentially go beyond communication of ideas by facilitating a bridge between research and practice.

By tracing critical events along the teacher's professional trajectory, I seek to understand how and in what ways one potential teacher-leader takes up a set of tools with merit for supporting the practice of teacher leadership provided to her through practice-based mathematics professional development. Toward that end, this research seeks to analyze:

- What surrounding critical events appear to provoke a teacher to take up specific instructional actions suggested by tools used in practice-based professional development?

- In what ways did a complementary set of such tools scaffold the transfer of specific instructional actions from professional development to a teacher's practice?

- How did the use of these tools scaffold the transfer of specific instructional actions that a teacher claimed to use with students to her work with colleagues?

Tools in Education

Consideration of tools to support instructional practice is gaining momentum within education research, but this is not a new concept. In Recommendations Regarding Research Priorities, the National Academy of Education (1999) argued that:

Tools—including student assessments, curriculum and professional development materials, software programs, questionnaires for probing community attitudes, and protocols for observing classrooms of professional meetings—are powerful carriers of theory and knowledge. Carefully designed tools that educators find

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useful in their practice can become a powerful means of changing educational

practice (p. 35).

Although one might argue whether or not to characterize each of the resources listed

above as tools, the point is that there is a trend in education to use research and past

experiences to create usable artifacts intended to carry embedded knowledge.

Even with such rhetoric around tools, a decade later, the educational community still

knows little about what makes a tool useful, that is, what enables a tool to be usable by a

teacher to support movements in her practice toward that of the intent of the tool

developer.

Furthermore, research has yielded evidence that tools alone may not affect

practice in substantive ways. For example, the assumption that curriculum materials

designed to communicate change in practice would do so has been found to be

problematic. That is, research findings have repeatedly shown that simply having a

standards-based instructional resource does not guarantee standards-based instructional

practices are used in the enactment of the resource (Ball & Cohen, 1996; Chval, Chavéz,

Reys, & Tarr, 2009; Senk and Thompson, 2003a; Stein & Kim 2009; Stein, Grover, &

Henningsen, 1996; Tarr et al., 2008). One finding from these studies and others is that

even good tools are still reliant upon the user—a conclusion that is not surprising given

decades of cognitive science research around mediated action within activity systems (see

Cole & Engeström, 1993; Feuerstein, 1990; Pea 1993; Vygotsky, 1978; and Wertsch,

1998). Additionally, this research points to a need to develop methods to help teachers

move specific instructional actions, suggested to them in a variety of ways, into their

practice.

Uniting Cognitive Science and Tools in Education

At the intersection of studies on teachers' use of curriculum materials and cognitive science research around tools is the work of Matthew Brown. Brown (2009) connects what psychologists have learned about tools as mediating objects with what educators have learned about teachers' use of curriculum materials to create a framework for using curriculum materials to transform teachers' instructional practice. At the heart of Brown's research is the notion of *teaching as design*. Brown writes, "Teachers must perceive and interpret existing resources, evaluate the constraints of the classroom setting balance tradeoffs, and devise strategies—all in the pursuit of their instructional goals" (p.18).

Brown's words, grounded in the context of the classroom, are illustrative of what Wertsch (1998) characterized as the "irreducible tension" that exits between actor and tool. That is, the constant give and take between what a tool has to offer the actor and what the actor possesses that might inform, or impact the effectiveness of, the tool. Resulting from this ongoing interaction between actor and tool, Brown argues that it is relevant to unpack how the actor (i.e., the teacher) perceives, interprets and utilizes tools.

Brown characterizes curriculum materials as tools; in my work, the tools are a complementary set of tools designed to scaffold the ways in which teachers plan and reflect on their enactment of instructional materials. The teacher in my study, Helen Emerson[3], serves as a conduit to tell the story of the functionality of these three specific, yet complementary, tools of action, the MTF, TTLP, and TTSP. A representation of my conceptual frame, shown in Figure 1.1, illustrates the relationships between and among

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[3] Helen Emerson is a pseudonym for the actual name of the teacher who participated in the professional development project that is the context for this study.

the tools, as well as the interaction between the tools and the teacher in an effort to

scaffold specific instructional actions within her classroom and leadership practices.
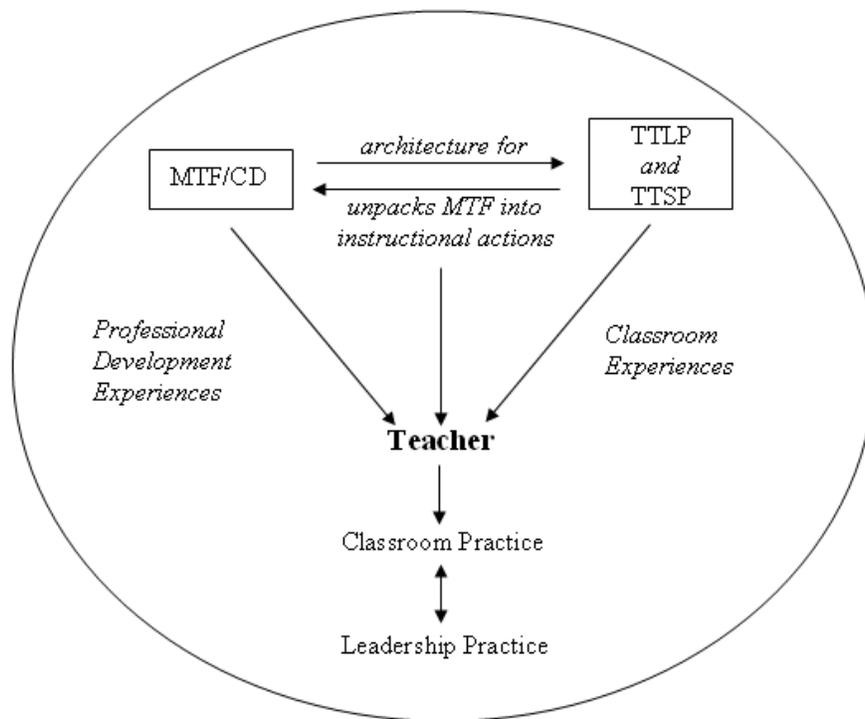
Figure 1.1. Relationship among Teacher, Tools, and Practice.

In Figure 1.1, one can see the complementary relationship between the MTF and the

TTLP and TTSP, a relationship that I elaborate in Chapter 3. Also visible is how I have

conceived of the potential movement of specific instructional actions suggested by the

tools to the teacher, the teacher serving as an agent by whom the suggested actions from

the tools are either inserted within or omitted from the teacher's classroom and leadership

practices. Finally, the teacher, the tools, and her practices are situated within the larger

contexts of the teacher's other professional development and classroom experiences.

Contributing to What is Known about Teacher Leadership

The role of *teacher-leader* has become extremely common in education in today's

schools. Increasingly, administrators at the district and school level turn to teachers for

their expertise to assist with a variety of educational issues and thus, deem those "experts" as teacher-leaders. Additionally, as noted by York-Barr and Duke in the following excerpt, researchers of education policy increasingly are recognizing the expertise of teachers as an integral and necessary component of education restructuring.

> Three models of education restructuring have been described: technical, professional, and client focused (Elmore, 1990). Of these, the professional model most directly explicates the pivotal role of teachers in efforts to advance education. In contrast to the technical model, which values most highly knowledge that is generated through systematic inquiry by external specialists (usually researchers), the professional model values teacher knowledge and judgment grounded in practice, as well as equally externally generated knowledge. In the professional model, the daily realities of teaching—variety, uncertainty, and ambiguity—are recognized, and the need to exercise teacher judgment in addressing these realities is understood. It follows, then that teachers hold tacit or craft knowledge needed to inform and lead improvement initiatives. (York-Barr & Duke, 2004, p,256).

As such, principals are turning to teacher-leaders to take on critical roles with regard to school improvement efforts. However, researchers have only begun to unpack what it might mean to support potential teacher-leaders in effective ways as they develop their practice of teacher leadership. Furthermore, considering the content-specific needs of mathematics teacher-leaders is almost unheard of in current literature.

In *Teacher Learning: New Policies, New Practices* (1996), McLaughlin and Oberman explain how and why the current system built to support teacher professional learning must evolve based on what is know about learning and effective change. They, and many of the contributors to their book, posit that what is known about student learning can and must be transferred to adult learning in order for effective change to take hold. They describe a synergy between teacher learning and educational reform in which the two are dependent upon each other, a relationship that cannot flourish simply by telling teachers what to do. Instead, their perspective is to put teachers in a space where

they can construct their own new knowledge and understanding with "support."

Unfortunately, the editors and contributors do not explain what this type of support could

or should look like in practice.   Also, they do not suggest ways to manage the high

demands of providing such professional support.

By analyzing how a complementary set of tools scaffold the transfer of specific

instructional actions suggested by the tools to a teacher's classroom practice, this study

attempts to understand ways in which tools might also scaffold teacher leadership

practice. My assertion that this may be possible is an extension of McLaughlin and

Oberman's theory that educators should take what research has pointed to with regard to

effective student learning and apply that to teacher learning. Therefore, just as

mathematics teachers need to be knowledgeable of pedagogy and content with respect to

student learning of mathematics, it follows that mathematics teacher-leaders need to be

knowledgeable of pedagogy and content with respect to teacher learning of mathematics

teaching. Unfortunately, current literature on teacher leadership tends not to take

seriously the importance of content knowledge and pedagogical content knowledge with

respect to mathematics teacher leadership. This study hopes to illuminate the significant

role that content plays in the practice of teacher leadership through analyzing how

content specific tools function in one teacher's practice and as such, prompt an ongoing

conversation that focuses on content-based teacher leadership.

<div align="center">**Limitations of this Study**</div>

As is in all studies, this study has particular limitations. Primarily, it is a single

case study of how a teacher interacted with a set of particular tools within the context of a

multiyear professional development series. Although this study uses one teacher as a

conduit to tell this story of how a complementary set of tools functioned to prepare her

for future learning regarding her practice, the study is not about this particular teacher.

Instead of being about Helen, this study is about what prompted the take up and use of

tools in Helen's classroom practice and, in turn, how her take up of tools in classroom

practice influenced her leadership practice.   I make no claims that Helen's take up and

use of tools in the ways described in this study are generalizable to other teachers in other

contexts only that her actions might inform future research pertaining to the development

of tools and of professional development that integrates tools in intentional ways.

Again, this dissertation study is an effort to understand how and in what ways a

complementary set of practice-based tools functioned to scaffold teacher leadership by

first initiating learning with respect to specific instructional actions of classroom practice

and then carrying the teacher's knowledge of these instructional actions into her evolving

leadership practice. As such, a limitation of this study is that the original project team did

not perform classroom observations that could have acted to confirm that the instructional

actions suggested by the tools actually appeared during student instruction. To this end,

the study is only able to make claims to suggest that the teacher understood specific

instructional actions embedded within the tools and demonstrated intent to use these

actions in her classroom practice.

Just as this study has limitations, so do the tools. The designers of the tools did

not create these tools to function in the absence of other resources, nor did they create the

tools to be self-enacting.   The designers did, however, attempt to bridge the separate, yet

potentially connected worlds of research and practice in novel and profound ways.

Understanding whether and how such tools mediate connections between instructional

and leadership practice for this teacher has the potential inform ongoing learning within the field. Having said this, I do not make claims that these tools are *the* tools to accomplish transfer of ideas from professional development to practice, merely that there are features of these tools that might inform the development of future tools. Furthermore, it is critical to recognize that these tools functioned within the larger context of a professional development project in which the teacher and her peers regularly read and discussed instructional cases, did mathematical tasks, and planned and discussed lessons with colleagues and the project team using the tools.

Organization of the Chapters of this Dissertation

I have organized this document into six chapters. In Chapter 1, I familiarize the reader with a problem endemic to teacher education, how to scaffold the transfer of ideas from professional development to practice. I also introduce the work of Matthew Brown, as his work with curriculum materials as tools has certainly influenced my thinking around how tools might function so support teacher learning. Finally, I articulate my thinking regarding the interaction between a complementary set of tools and a teacher and one potential manner in which this interaction might affect ongoing learning with regard to instructional practice.

Chapter 2 is a literature review the blends the three contexts that informed my conceptual and analytical frames for this study. The review begins with an overview of recent policy-based efforts to influence practice. I divide this portion into three parts: policymakers, curriculum developers, and teacher educators. Following this discussion of policy is a review of cognitive science literature related to transfer of learning. It begins with a brief historical review in which I highlight early theories on transfer

including those by Thorndike and Judd. Next, I include a discussion of more recent views of transfer that reside within situated cognition. I conclude this section on learning theories by articulating the way in which I use activity theory as an analytical frame for this study. I then return to teacher leadership literature and extend the discussion that I began in Chapter 1.

I describe my methods of analysis in Chapter 3. Specifically, I explain how I use interview data to structure my analysis of tools in Helen's practice. I elaborate the notion of critical event, a notion I use to tell this story of how practice-based tools of action function within a corresponding professional development series to prepare a teacher for ongoing learning around effective use of specific instructional actions. In this chapter, I also articulate what I mean by the phrase *tool of action* and orient the reader to the tools of this study, as well as the context in which the tools were employed.

Chapters 4 and 5 contain the findings of this study. Chapter 4 focuses on the primary critical event I identified through my analysis of interview data, that of the Case of Catherine Evans and David Young (Smith, Silver, & Stein, 2005b). In this chapter, I describe Helen's take up and use of tools using the Case of Catherine and David as a lens to trace the ways in which specific instructional actions embedded within the tools moved into Helen's classroom and leadership practices. Chapter 5 includes my findings related to two supporting critical events, Natalie's lesson debriefing of the Oak Tree task and an exchange between Helen and an interviewer during one of the session-planning interviews using the TTSP.

I discuss my findings and suggest potential avenues for future research in Chapter 6. Within this discussion, I connect the tools analyzed in this study to a similar type of

tool apparent in other mathematics education research projects. I also suggest

implications of this study regarding the design and evaluation of professional

development, especially in relation to teacher leadership practice. I conclude this chapter

with a theoretical proposition that findings from this study might potentially inform

another problem endemic to educational research, that of scale with respect to reform

efforts. I ground this conversation of scale in the work of Elmore.

CHAPTER 2

**PRACTICE-BASED PROFESSIONAL DEVELOPMENT AS
A LEVER FOR TEACHER LEARNING**

This chapter reviews the literature on mathematics reform relevant to the

questions this dissertation seeks to address, primarily focusing on what has been learned

over the past three decades. First, it provides a retrospect on reform efforts in

mathematics education which includes a summary of the roles that policymakers,

developers of instructional materials, and teacher educators have attempted to assume.

Embedded within this retrospect is an argument regarding why practice-based

professional development is a valid lever for the type of instructional change called for in

many of the most current reform efforts. Second, this chapter explores ways in which

tools have been conceptualized in the areas of education and psychology. The chapter

concludes with a consideration of why, given numerous calls for and attempts at

mathematics reform, efforts have not been successful and suggests a theoretical proposal

for mathematics reform that is grounded in content specific, practice-based professional

development that is scaffolded by the inclusion of tools to support teacher learning, both

instructional and leadership.

Mathematics Reform—A Retrospect

Much has been attempted in the United States to align mathematics instruction

with the *vision* of mathematics instruction that is shared by many mathematics education

reformers, and is inherent in the notion of developing "mathematical proficiency"

(National Research Council, 2001). In an effort to align this shared vision of instruction with actual instruction that occurs in classrooms, many entities including policymakers, developers of instructional materials, and teacher educators have tried to influence teaching and learning in a variety of ways. Yet, there is considerable evidence that these efforts with alignment have fallen short. Citing evidence from the TIMSS Video Studies, for example, Stigler and Hiebert (1999) write, "Whereas U.S. educators have sought major changes over relatively short periods of time…Japanese educators have instituted a system that leads to gradual, incremental improvements in teaching over time (p.109)." By seeking short-term panaceas in U.S. education reform, a system for teacher learning has been created that is heavily reliant on sporadic and superficial trainings in which "workshop handouts, ideas, and methods provide brief sparks of novelty and imagination" (Ball & Cohen, 1999, p.4), but are void of opportunities for teachers to grow in meaningful ways that are situated "in and about the practice of teaching and learning" (Ball & Cohen, 1999, p.13). These types of problems with teacher education have also been articulated in national policy documents with respect to teacher education in general (i.e., not specifically within mathematics education). In *What Matters Most: Teaching for America's Future* (1996), a report of the National Commission on Teaching and America's Future, the authors write that the system of teacher development in the United States consistently lacks structures to support the development of high quality teachers noting limited time with colleagues and sporadic professional development that is removed from the work of teaching as reasons for America's ongoing struggle to improve teacher quality. This finding was corroborated more recently in *Professional Learning in the Learning Profession: A Status Report on*

Teacher Development in the United States and Abroad (2009), a report of the National

Staff Development Council,

In addition to the ubiquitous problem of minimally supportive structures within

education systems across the United States, there is a general lack of coherence that

exists within the U.S. education system. One problem with coherence has been

documented by TIMSS researchers concerning the development of mathematical ideas

within curriculum materials in the United States (Schmidt, Houang, & Cogan, 2002).

The mathematical ideas within many existing curriculum materials tend to be

disconnected and unsupportive of building comprehension of mathematical content and

processes. Cohen and Hill (2001), who studied education reform in California throughout

the late eighties and nineties, identified a similar, but possibly more problematic, lack of

coherence that exits among multiple types of reform-related resources including

curriculum materials, policy documents, and professional development opportunities for

teachers. This lack of coherence among policy documents and instruments aimed at

changing instruction is problematic because it creates situations in which many

individuals with diverse understandings of content, instruction, and students must try to

interpret and synthesize large amounts of seemingly conflicting, yet sometimes

complementary information (Cohen & Hill, 2001).

Recognizing the problematic nature of such discontinuities in policies, The

National Commission on Teaching and America's Future wrote (1996):

> A haphazard hodgepodge of policies has left schools without clear, compelling
> standards connected to the means to achieve them. Consequently, educators in
> different communities—and even in classrooms within the same building—often
> teach toward very different ends, with little help in building a powerful,
> cumulative learning experience for their students (p.9).

Some of the most recent discontinuities among policy documents have likely materialized, because states, under pressure of the federal government, want *more content* taught *more quickly* to *more students* (Reys et al., 2007).[4] Although mathematics education reformers, in agreement with state legislators, often argue that more students should have access to mathematics in a timely manner, the means with which the reformers envision this work may seemingly conflict with state documents. Reformers believe that if fundamental mathematical concepts are taught well it will enable students to build connections among content and develop a deeper understanding of both the big mathematical ideas and the discrete facts that are abundant in state lists of expectations. Unfortunately, without appropriate and focused professional development it is left to the lone teacher to decide how to negotiate these seemingly competing expectations, a type of individualism which has been documented throughout the twentieth century as being counter-productive to moving the practice of teaching forward (Cohen & Hill, 2001; Elmore, 2002; Elmore, 1996; Lortie, 1975; Ma, 1999; Spillane, 2006; Stigler & Hiebert, 1999).

The following three sections seek to elaborate the ways in which policymakers, developers of instructional materials, and teacher educators have attempted to reform mathematics teaching and learning during the later part of the twentieth century as well as the first decade of the twenty-first century. Though the story to date is not one of systemic success, much has been learned from both the successes and failures of what has been tried.

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[4] Additional examples of the increased demand on teachers to teach students more mathematical content more quickly can be found by reviewing state expectation documents (e.g., the State of Michigan Grade Level Content Expectations for grades K through 8, as well as the State of Michigan High School Content Expectations).

Policymakers

Policymakers, including legislators and professional organizations, have attempted to influence instruction through publishing policy documents and passing laws. Laws have mainly focused on specifying the content to be taught or outlining requirements for additional teacher training while policy documents have focused more attention on conveying a means or process by which to teach mathematical content.

Legislation

A consistent feature in many of the state laws that emerged throughout the eighties and nineties is a set of rewards and punishments for schools or districts that are heavily dependent on students' performance on accountability measures such as standardized tests. With respect to policymakers overemphasis on the current "carrot and sticks" system that exists within the American educational system Elmore (2007) writes, "Federal and state accountability policies are overinvested in testing and sanctions and underinvested in the kind of support for human capital required to meet the targets set by the accountability system (p.31)." Elmore's disdain for current accountability policies, as well as recognition of the need to build human capital is an idea that is of critical importance and is innately connected to Lortie's pivotal observations regarding teachers' behaviors (i.e., privatization of classrooms) and the system's response to those behaviors in the seventies. Clearly, the American educational system was, and is, simply not structured to scaffold the professional behaviors which potentially have the power to transform the field.

Though teachers, schools, and districts are compelled to meet achievement standards at escalating levels due to No Child Left Behind (NCLB) legislation, little is

being done to regulate, monitor, or support the implementation of these laws. For

instance, certification offices continue to ignore the quality of pre-service teacher

education, as well as in-service professional development opportunities for practicing

teachers. These offices remain focused on simply whether or not individuals have

credentials stating that they did, in deed, complete the number of hours required by law to

achieve certification or to remain certified.

The unsystematic nature in which state agencies regulate teacher certification is

likely to promote inconsistency in training and expertise among novice teachers, thus

leading to inequitable learning experiences for students across the United States. The

National Council of Teacher Quality (NCTQ) conducted a study in 2008 with the issue of

inequitable learning experiences for elementary students in mind. The study reviewed

the preparation of elementary mathematics teachers in the United States. A major finding

of the report is that state requirements add to the confusion and inequitable certification

of elementary mathematics teachers. The researchers found that the quality and quantity

of the coursework varies greatly by state, and by teacher education programs within

states. Furthermore, there was not consistency in state certification tests. Each of these is

an issue of great concern when the goal is equitable and effective mathematics instruction

across the nation. The report concludes, "even at the most superficial level—defining the

type of mathematics preparation that elementary teachers should have in terms of

coursework, standards, and/or licensure test expectations—there is not consensus in the

states" (NCTQ, 2008, p.34). Thus, with regard to initial certification, the status quo is that

state requirements for the number of hours of coursework in mathematics and/or methods

for elementary teachers varies and appears to be rather arbitrary; passing scores, as well as content on the state certification tests, are also inconsistent (NCTQ, 2008).

The story does not improve when considering in-service teacher training. In fact, some might say, the story gets worse. Teachers and administrators receive little guidance as to what might be a quality professional development experience and as such, often choose the most efficient or convenient ways to meet requirements. With little regulation over the content and quality of professional development, almost anyone can provide learning experiences for teachers that can count toward a teacher's accumulation of continuing education units (CEUs). For instance, any mathematics teacher in Michigan can submit a proposal to present at the annual meeting of the Michigan Council of Teacher's of Mathematics, a prime venue in which many teachers collect CEUs. With so many presenters, and only seat time as a requirement, the learning experiences vary greatly in this type of context.

Professional development such as this can lead to teachers selecting a series of disconnected learning experiences with minimal, if any, follow through or accountability at the classroom level (Little, 1993). In addition to the fact that so many of these opportunities for teachers to acquire CEUs are only modestly regulated, most focus on attracting individuals, rather than teams of teacher colleagues. This focus on individualism is problematic because it is likely to be counter-productive to forming collegial bonds, like those identified by McLaughlin and Talbert (2001) in their research on professional learning communities, which have the potential to support educational reform. Instead of states offering guidance as to what might constitute productive learning opportunities for teachers, they generally only require teachers to complete

ongoing learning requirements to avoid losing their certification. Such requirements, designed originally with good intent, have become diminished in many cases to nothing more than bureaucratic red tape, instead of the potentially powerful learning experiences they could be.

Professional Organizations

The following summarizes past reports and standards documents that have attempted to influence mathematics education policy primarily through the written word. In 1989 NCTM published the *Curriculum and Evaluation Standards for School Mathematics*. In this document, the organization argued for a more holistic view of mathematics instruction than was evident in most classrooms. It described an investigative approach to mathematics education that included the use of calculators, even in early elementary grades, as well as the use of manipulatives to help students make sense of abstract concepts by first exploring mathematical situations using concrete materials. Much to the dismay of many mathematics education reformers, the document sparked questions and controversy but did not appear to significantly impact instructional practice.

Roughly a decade later in April of 2000, NCTM released a new policy document entitled *Principles and Standards of School Mathematics (PSSM)*. This document built a strong, more focused argument for interweaving content and process standards. The content and process standards were elaborated by grade band and included examples of how mathematics content and processes develop over time for students. Though this clearly was an attempt by the organization to elaborate standards in much more concrete

ways, it still existed primarily as a written document. Again, with this publication came

questions and controversy but little impact on policy or practice.

Since the release of the *PSSM* in 2000, the NCTM has supplemented its standards

with corresponding professional development including content-based institutes for

teachers. Still, the NCTM does not have the capacity to provide high quality practice-

based professional development to the entire country, thus furthering the need for a

refined system of professional learning for mathematics teachers. The organization has

recognized this need and has called for the development of a system to link research and

practice that makes research accessible and relevant to the work of practitioners. In 2005,

a task force representing the organization wrote:

> Many efforts to improve the teaching and learning of mathematics have
> succeeded in limited settings. It is heartening that some mathematics programs
> funded by the National Science Foundation have seen positive results. If the
> profession is to move beyond these and other "pockets of wonderfulness" it must
> create a new vision for turning the best we know into common practice. We must
> learn to gather and disseminate what has been learning to support local schools,
> districts, and states/provinces as they so the hard work of implementing new
> programs in their communities (NCTM, p.3).

In the excerpt above, the task force draws attention to undersized successes in

mathematics education and seems to realize that localized and/or small-scale efforts, like

the ones NCTM and other professional organizations have been traditionally positioned

to offer the profession, is not enough.   To address this persistent problem in education,

they call for a system, which they elaborate on to include tools, such as research briefs, to

communicate research-based practices to classroom teachers and other stakeholders.

Still, the focus is centered on communication and does not appear to explicitly address

how NCTM might scaffold the take up of the research-based practices by teachers into

their classrooms.

Other organizations also contribute to the proliferation of mathematics education policy documents in the United States. In 2001, the National Research Council convened a committee of researchers to review, synthesize, and communicate existing research that could potentially inform mathematics teaching and learning in kindergarten through eighth grade. "Mathematical proficiency" is a captivating phrase, as well as a conceptual framework, that grew out of this synthesis of mathematics education and cognitive science research. Though the phrase, mathematical proficiency, sounds rather provocative in and off itself, the words do not stand alone in *Adding It Up;* they are accompanied by a braided 5-strand rope to further communicate the message of what mathematical proficiency is, as well as what it is not. In the rope illustration each strand is identical in nature so as not to convey that any strand is more important than another. The author team also uses descriptive words such as "interwoven and interdependent" to further emphasize the interconnected nature of each of the strands (NRC, 2001).

The five strands of mathematical proficiency are:

- *conceptual understanding*—comprehension of mathematical concepts, operations, and relations
- *procedural fluency*—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
- *strategic competence*—ability to formulate, represent, and solve mathematical problems
- *adaptive reasoning*—capacity for logical thought, reflection, explanation, and justification
- *productive disposition*—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

(NRC, 2001, p.116)

Though the pictorial representation, as well as the full conceptualization of the five strands of mathematical proficiency emerged following the birth of the mathematics

standards movement in the United States, it is apparent that the strands of mathematical proficiency are not separate from, but rather are an additional way to make known the message that began with the release of the 1989 standards.

The notion of the strands of mathematical proficiency is both simple and complex. Though each strand makes a unique contribution to mathematical proficiency, the authors argue that mathematically proficient people are well rounded in their ability to see, use, and make sense of mathematics. The synergistic nature of these strands is critical and attempts to communicate a message that is the antithesis of at least one unfortunate outcome of the "math wars." That is, instead of situating the mathematical goals of procedural fluency and conceptual understanding as oppositional, the authors of *Adding It Up* argue that these two strands, along with three others, work together to support a greater outcome—mathematical proficiency. Thus, the authors clearly argue that neither procedural fluency nor conceptual understanding alone makes a mathematically proficient student. Regrettably, there continues to be evidence that our current educational system privileges procedural fluency over any of the other strands. Citing an exploration of the NAEP results performed by Silver and Kenney (2000) the NRC team writes,

> In general, the performance of 13-year-olds over the past 25 years
> tells the following story: Given traditional curricula and methods
> of instruction, students develop proficiency among the five strands
> in a very uneven way. They are most proficient in aspects of
> procedural fluency and less proficient in conceptual understanding,
> strategic competence, adaptive reasoning, and productive
> disposition. Many students show few connections among these
> strands." (NRC, 2001, p.136).

While PSSM, the 2000 standards document from NCTM was clearly designed to speak to an audience consisting mainly of teachers, *Adding It Up* was intended to attract a

more scholarly oriented audience. Both attempted to transmit a similar message through written text combined with pictures or various types of authentic examples to illustrate points. Though these documents have accumulated a following of prophets that continue to spread their interpretation of the authors' intended message, both have had minimal impact on actual classroom practice at any level of scale in the United States.[5] Thus, *Adding It Up* and *PSSM* have met the same fate as other past policy documents. Though they aim to communicate a very powerful message to mathematics teachers, as well as mathematics teacher educators, they go amiss upon implementation.

The writing and distribution of policy documents connected to professional organizations and national reports has clearly met a similar fate to that of legislation. Though professional organizations, such as the National Council of Teachers of Mathematics (NCTM), have made numerous efforts to inform and influence educational policy regarding instructional goals and teaching practice through their publications, negligible change has come as a result of these efforts. The TIMSS Video Studies, as well as Cohen and Hill's research on the mathematics standards movement in California have been able to document this phenomenon. Both large-scale studies have contributed empirical evidence to the educational research community that professional development, via the publication and dissemination of policy documents, leads to minimal (and possibly detrimental) impact on teaching and learning when delivered in the absence of corresponding practice-based professional learning experiences (Cohen & Hill, 2001; Stigler & Hiebert, 1999).

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[5] The writing and distribution of the *National Mathematics Panel Report*, as well as the *Common Core Standards Initiative*, both which reiterate the need for developing mathematical proficiency as defined by the authors of *Adding It Up* is being taken as evidence that *PSSM* and *Adding It Up* have not reached a high level of impact on practice.

This problem of implementation should serve as a critical reminder to reformers that they must remain cognizant that awareness is not equivalent to understanding. In fact, in the TIMSS Video Studies there was evidence that although teachers claimed awareness of policy documents and reform efforts, their implementation of such efforts were weakly connected to and, at times, in opposition to the reformers intent. In summary of such findings Stigler and Hiebert write, "Teachers can misinterpret reform and change surface features—for example, they include more group work; use more manipulatives, calculators, and real world problem scenarios; or include writing in the lesson—but fail to alter their basic approach to teaching mathematics (1999, p.107)." The authors go on to say, "…reform documents that focus teachers' attention on features of 'good teaching' in the absence of supporting contexts might actually divert attention away from the more important goals of student learning. They may inadvertently cause teachers to substitute the means for the ends—to define success in terms of specific features or activities instead of long-term improvements in learning (Stigler & Heibert, 1999, p.107).

Cohen and Hill (2001) built upon such findings stating that "one implication of this idea is that policy should be distinguished from the instruments deployed in its support" (p.6) explaining that, in the case of California's reform efforts, the announcement of the policy was the 1985 Mathematics Framework for California Public Schools and that the learning experiences for teachers are the instruments that determine to what extent the policy is achieved in practice. Together, these pivotal studies issue a warning that is fundamental to systemic improvement in mathematics teaching and learning. That is, in order to achieve the ideas intended by the reform documents,

teachers and teacher educators need experiences that are grounded in the work of teaching and are scaffolded by well-aligned tools (e.g., curriculum and assessment materials, policy documents, etc.) that support such work. Clearly, helping teachers move from ideologies, frameworks, and even authentic examples is much too complex to be realized in the absence of real practice. Thus, without connected and coherent professional learning experiences that help teachers and teacher educators to connect such ideas to their own practice little impact on the system is likely to be achieved.

Developers of Instructional Materials

In addition to efforts made by policymakers to move instruction toward the development of mathematically proficient students, developers of instructional materials have emerged as important players in mathematics education reform. This originated with the theory that good materials (i.e., good tools) will lead to good instruction.   Following the release of the 1989 Curriculum and Evaluation Standards, the National Science Foundation (NSF) funded the development of K-12 mathematics instructional and assessment materials aligned with these recommendations. According to the *Materials for Middle School Mathematics Instruction: Program Solicitation* guide (1989) provided by NSF, author teams interested in applying for funds needed to be attentive to the following:

- Prepare **course material** for a complete middle school mathematics curriculum;
- Explore and improve on **teaching methods**, possibly including new uses of technology and new applications of mathematics, appropriate for presenting the new material to middle school students;
- Develop **strategies and materials for teachers** to improve their understanding of mathematics and introduce them to more effective methods of instruction; and

- Formulate **assessment methods and materials** so that teachers can evaluate and adjust the learning environment to best suit the need of the students. (p.4; bold in original)

In summary, NSF was expecting the curriculum developers not only to create written instructional materials, it was expecting them to change classroom practice. However, as Cohen and Hill (2001) documented in their studies of program implementation of mathematics curriculum materials in California throughout the eighties, in order for teachers to report changes in their teaching practices, they appear to need extended time to learn the curriculum materials as well as time to consider how to implement them in their practice. Time for teachers to engage in this sort of work was not explicit in NSFs request for proposals.

Resulting from this initial request, twelve sets of aligned instructional materials were published: three elementary; four middle school; and five high school. Though many of the materials came with optional professional development to support initial implementation of the programs, the preliminary support was often short-lived (Battistich, Alldredge & Tsuchida, 2003; Romberg & Shafer, 2003). Quickly mathematics education reformers learned that implementing standards-based instructional resources was only part of the challenge, the real effort was in helping teachers implement the programs as intended by the authors and sustaining such programs through continued support for veteran teachers and ongoing initial training for teachers new to the programs (Senk & Thompson, 2003a). Below are summaries of two studies that identified the fidelity of implementation as a contributing factor to student learning outcomes.

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Fidelity of implementation, the extent to which a curriculum is used in the way it is intended, is a primary way to consider the impact of instructional materials on teachers' practice. While the intent of enactment of the instructional materials is ideally embodied within the written materials of the curriculum, it is up to the teacher in interaction with the text and students to enact the materials in ways that are true to this intent. Ball and Cohen (1996) describe the interaction among the three (i.e., teachers, students, and materials) within a larger context as the enacted curriculum. The following is a summary of what research has yielded with respect to shaping the enacted curriculum.

Battistich, Alldredge, and Tsuchida studied *Number Power: A Cooperative Approach to Mathematics and Social Development*, an elementary school program designed to align with the NCTM standards. As part of the design of their study, the research team developed three testing conditions: (1) Curriculum Materials with Staff Development; (2) Curriculum Materials Only; and (3) Control Group using Traditional Materials. One of the findings from the study was that the group who received staff development as part of their first two years of implementation enacted a higher percentage of the lessons from the text than the other two groups (Battistich, Alldredge, & Tsuchida, 2003). The research team also found that students in the classrooms in which the teachers received staff development performed better overall than the other two groups on an assessment of students' number sense, a primary focus of the curriculum materials (Battistich, Alldredge, & Tsuchida, 2003).

To better understand these differences, the research team interviewed the teachers to explore a set of factors the researchers thought might have influenced teachers'

implementation of the materials. Data from these interviews yielded evidence that the teachers who received staff development found the curriculum materials less confusing than those who used the same materials without support. Related to this finding might be that the teacher's who received staff development also showed an increase in their understanding of the mathematical goals of the program. To describe this phenomenon the research team writes:

> The teachers who received staff development generally followed the lesson plans and taught most of the lessons in the order presented in the book…Curriculum only teachers more often altered the lessons and more often taught them out of sequence ((Battistich, Alldredge, & Tsuchida, 2003 p.156).

Thus, the research from this study points to the finding that curriculum materials alone do not sufficiently convey the intent of the authors of those materials; because of this disconnect, materials alone are likely to struggle to influence substantive change in classroom instructional practice.

Thomas Romberg and Mary Shafer conducted a related study at the middle school level in which they analyzed the effect of *Mathematics in Context (MiC)* on student outcomes. Although their initial findings pointed to *MiC* having positive effects on students' achievement, the authors noted that there were several other factors that likely influenced these data. Romberg and Shafer (2003) named three additional factors that they believe impacted the results of this study: (1) the influence of prior student achievement; (2) classroom opportunity to learn with understanding; and (3) the method of instruction used with the curriculum. While prior student achievement is unlikely to be related to fidelity of implementation, the other two factors, classroom opportunity to

learn with understanding and the method of instruction, are both likely to be tied to how teachers interpreted the curriculum materials. Once again, this finding suggest that the use of innovative curriculum materials is not, one its own, enough to yield substantial changes in teachers' classroom instructional practices.

Reformers experience with standards-based curriculum resources is a vivid example of how having primarily a good tool, is not sufficient to guarantee impact on instructional practice. A recent study of both traditional and standards-based middle-grades mathematics curriculum resources further substantiates this claim (Tarr et al., 2008). In this study the researchers examined how materials were implemented at the classroom level. The purpose was to analyze the extent to which all students learned within a standards-based learning environment. They did this by selecting and defining five characteristics or practices that would be in line with the NCTM standards.[6] The researchers documented, "…a standards-based learning environment was more prevalent among teachers using NSF-funded curriculum. "However, it is also clear that although NSF-funded curricula may encourage or facilitate use of these standards-based practices, they are obviously not sufficient in yielding High levels" [of practices consistent with a standards-based learning environment] (p.266). Clearly, support to use any materials well is a necessity if the instructional goal is focused on preparing students to become mathematically proficient beings.

Teacher Educators

Content courses have been another method for impacting teachers' instructional practice. It is grounded in the belief that more content-centered coursework leads to

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[6] Though the practices/characteristics identified by the authors as being typical of a standards-based learning environment are not equivalent to the five strands of mathematical proficiency, they are instructional practices that are likely to support the development of mathematical proficiency.

more content knowledge and thus a greater ability to effectively convey content to students. The notion that more mathematics courses lead to improvements in instruction must be assessed critically. Though it is the case that Mathematical Knowledge for Teaching (MKT), which consists of such knowledge types as common content knowledge, pedagogical content knowledge, knowledge of content and teaching, has been documented to be positively correlated with student achievement in mathematics (Hill, Rowan, & Ball, 2005), it is not the case that completion of more content courses by teachers automatically leads to improved student achievement in the K-12 classroom.

The misconception that knowledge for teaching can be defined solely by the number of mathematics classes one takes was explored by the authors of *Adding It Up*. The authors cite the National Longitudinal Study of Mathematical Abilities (NLSMA), a project conducted in the 1960s, as finding "essentially no association between students' achievement and the number of credits a teacher had in mathematics at the level of calculus or beyond (Begle, 1979 in NRC, 2000, p. 374). Though other studies conducted since the NLSMA, such as Ma (1999), have demonstrated similar findings, researchers and legislators regularly argue to use this measure (i.e., the number of content courses completed by a teacher) in both qualitative and quantitative studies, as well as embed more mathematics courses into teacher preparation programs.   This mindset continues the numbers game of accumulating credits without purpose that began with requirements set by policymakers. Although teacher content knowledge is inextricably linked to student achievement by the very fact that one cannot teach content they themselves do not understand, the fallacy that more content courses automatically leads to a deeper mathematical knowledge for teaching is also problematic.

Transitioning to Practice-Based Methods of Teacher Education

Recognizing that the content knowledge needed for teaching is a difference that makes a difference in student achievement, some teacher educators, both pre-service and in-service, are beginning to reframe content courses for teachers so that the content instruction is customized to help teachers within grade bands understand the mathematical content they are responsible for teaching more deeply, in turn making it more meaningfully tied to the work of instruction. Though teacher educators are beginning to make this shift, the NCTQ found in their 2008 review of elementary teacher preparation programs, several universities continue to treat the mathematical needs of all of their students the same. That is, "they do not distinguish the needs of the elementary teacher from the needs of the future accountant or lawyer" (p.24). In addressing this problem the author team writes,

> The mathematics content coursework that elementary teachers need is neither pure mathematics nor pure methods, but somewhere in the middle. It imparts the foundational knowledge of elementary mathematics topics that is helpful to teaching in and of itself, as well as bridging to instruction in the elementary classroom. It is about why you do what you do, what parts are dictated by the mathematics, what by convention, what for efficacy (and why it is efficacious), possible alternative methods, and so on (NCTQ, 2008, p. 28).

One example of the type of practice-based content instruction consistent with the recommendations of the NCTQ is the content institutes developed by the University of Michigan- Dearborn. Theses courses push elementary and middle school teachers to explore the mathematics they teach beyond the set procedures people commonly know so that they are better prepared to help students understand why these procedures work, to make sense of and assess student thinking, and be able to ask meaningful questions of students that guide them to mathematical discoveries. Courses such as these that are

aligned with suggestions made by the National Council on Teacher Quality (2008) are one step to improving the quality of K-12 mathematics instruction.

While the focus of the institutes is mathematical content, instructors of these courses model pedagogical moves that are indicative of a standards-based learning environment in an effort to help connect the learning of content to teachers' own instructional practice. Data from one project in which teachers from high needs schools participated in these institutes shows a correlation between the number of content courses teachers attended and student achievement (Tackett, 2008). Thus, it appears this type of content course that is designed to deepen, not just broaden, teachers content knowledge while connecting the learning of mathematics to teachers practice is potentially useful in the overall goal of developing mathematically proficient students. However, there are still far too few content courses of this nature offered to teachers (NCTQ, 2008) and even fewer qualified people to facilitate them considering the number of elementary and middle school teachers in the United States.

Another version of practice-based professional development is the design and enactment of series (i.e., multi-day sessions) that center on instructional or pedagogical moves while keeping mathematical content clearly in focus. This type of professional development situated in practice is consistent with what Silver, Smith, and Stein initiated through the QUASAR Project. Both types, content focused and pedagogically focused practice-based professional development, are relatively new to education and are very different from the brief and sporadic, theme oriented professional development workshops with which many are familiar. Cohen and Hill (2001) describe these more superficial activities that tend to exist on the fringes of reform efforts as "…activities that

in some ways embodied reform yet were not linked to one another, planned around students' response to activities, or designed to develop a mathematical idea in depth" (p.5). Though such types of activities are sometimes compelling to teachers, they do not give teachers opportunities to unpack the core elements of teaching. They are not situated in content, the way students think and reason about content, or within teaching strategies that go much beyond fads. The true problems and complexities of teaching practice are avoided (Lampert, 2001) and in turn, impact is minimal. Clearly, teacher educators are moving in a productive direction as they leave behind "make it and take it" workshops toward more long-term efforts to improve mathematics teaching and learning. But how might this change take place given limited resources and little time? And, what types of tools might function to scaffold such work?

In conclusion, policymakers, curriculum developers, and teacher educators have all made efforts to move mathematics teaching and learning through pathways each perceived would be productive. Policymakers sought to *communicate* change through legislation and policy documents. Curriculum developers sought to *communicate* change by supplying teachers with non-routine mathematical tasks that provide opportunities to teach for mathematical proficiency. Finally, teacher educators sought to *communicate* change through content, both pedagogical and mathematical. The problem that exists is that all have all tried to *communicate* change, not to scaffold ongoing learning within practice. By this I mean, the stakeholders mentioned above have, for the most part, tried to tell teachers what they should do and what they need to know. Although teacher education has begun to shift, probably more than policymakers and curriculum developers, there still are relatively few opportunities for teachers to learn from and

within their practice over time through working on the work of teaching mathematics.

Furthermore, where attention has begun to shift to practice-based professional

development experiences change is inefficient. Thus, through this study, I seek to

explore the role tools could potentially play in decreasing current inefficiencies through

providing a bridge from practice-based professional development to practice.

Leveraging Practice-Based Professional Development

Prior to describing the research base that informed my conceptual framework of

how tools might act to scaffold the transfer of ideas from professional development to

practice, I would like to return to the central finding of Cohen and Hill's study of

California's mathematics reform efforts. The excerpt below appears in *Learning Policy:*

When State Education Reform Works.

> …California's effort to improve teaching and learning did meet with some
> success, but only when teachers had significant opportunities to learn how to
> improve mathematics teaching. When teachers had extended opportunities to
> study and learn the new mathematics curriculum that their students would use,
> they were more likely to report practices similar to the aims of the state policy.
> These learning opportunities, which often lasted for three days or more, were
> not typical of professional development in U.S. schools….The shorter-term
> professional development of most other teachers was keyed to special topics,
> like diversity in mathematics classrooms and cooperative grouping. These
> shorter-term learning opportunities, which were typical of professional
> education in California and elsewhere, did not allow teachers to learn about
> either student curricula or their work on assessments, and these teachers did not
> report practices close to reformers' goals. (Cohen and Hill, 2001, p.2)

What is critical to recognize about this quote is that it is evidence that practice-based

professional development is more than a conceptually sound idea, it is empirically sound.

As such, it is the very type of professional development that has the potential to transform

teaching and learning in the United States. Unfortunately, even with evidence such as

that found in the California mathematics reform study, too few teacher educators provide

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this type of learning experience for pre-service and in-service teachers. Additionally, even if every mathematics teacher educator was competent, confident, and able to provide such professional develop opportunities, the demand would still far outweigh the system's capacity to provide this type authentic learning experience for every mathematics teacher in the United States. Thus, a need for practice-based tools with the capacity to: (1) focus teachers attention to study and learn ways to enact their instructional materials by providing outside "expertise" and (2) create a bridge from professional development to practice emerges. Having such tools could support the current system for practice-based professional development, which, as of now, is designed only to handle small-scale efforts to improve practice.

Practice-Based Professional Development

Silver and his colleagues on the QUASAR project, along with mathematics reformers in California in the early nineties, were some of the first to envision and implement what we now call practice-based professional development. In a paper Silver (1994) presented to the International Congress on Mathematics Education (ICME), he suggested that mathematics educators center their work with teachers on building collaborative communities in which teachers could share and reflect on practice. He believed that this might be a way of providing quality professional development that is substantive and productive for supporting shifts in instructional behaviors. In his vision, "teachers would come to see themselves as being joined with colleagues within their school in an effort to provide quality mathematical experiences for their students. Teachers would plan together, discuss each other's teaching practice, develop consensus on ways to evaluate their students' thinking, and support each other through difficult

points in the change process" (p. 321). In this excerpt Silver describes what practice-based professional development could be.

Currently, over a decade later, an increasing number of educators who work with in-service teachers provide collaborative experiences like the one proposed by Silver; unfortunately, instructional change is still moving too slowly. Instructional change is complex and takes an enormous amount of effort and time from all parties involved, especially teachers. Not to mention, very few people, compared to the number of mathematics teachers in the United States, are trained to support teachers through the challenging, and at times deeply emotional process of changing or refining their instructional practice.

Fortunately, the teacher education community has a growing set of resources to support the type of focused, analytic work Silver describes in the excerpt above. These resources consist of concrete examples of Professional Learning Tasks (PLTs), protocols for planning and for discussion, case studies, as well as many other supporting artifacts that may be used as professional development tools (Ball & Cohen 1999; Smith, 2001; Smith & Bill 2004; Smith, Silver, & Stein 2005a; Smith, Silver, & Stein 2005b; Smith, Silver, & Stein 2005c). The time has come to study how these tools and resources like those mentioned above might support an over-extended and inefficient system of change.

Tools to Scaffold Learning

"[Tools] not only radically change his [man's] conditions of existence, they even react

on him in that they effect a change in him and his psychic condition."

--Luria, 1928, p.493

What is a Tool?

In order to evaluate the capacity of tools to support teachers' evolving instructional and leadership practices, an understanding of what a tool is, as well as how it functions needs to be considered. The Oxford English Dictionary (OED) defines a tool as "a mechanical implement for working upon something, as by cutting, striking, rubbing, or other process, in any manual art or industry…" This definition limits a tool to something that is mechanical in nature and suggests that the tool must have some level of physical impact on another object. For the purposes of this paper a tool must not just be mechanical, but also cognitive or psychological (Vygotsky, 1978) in nature. Indicative of the quote from Luria at the opening of this section, this leads to an inevitable interaction between man and tools, as well as tools and man, one that has the potential to affect how man thinks, reasons, and performs within a given context. To consider a tool from this perspective, it is helpful to explore how cognitive and social psychologists have conceptualized tools with respect to learning.

Vygotsky, a Russian social psychologist, was one of the first to attempt to conceptualize tools using a cognitive perspective. His refined conception of tools emerged out of a need to describe tools that were not just directed at the objects of nature (i.e., material tools), but also those tools that mediate humans' psychological processes (Kozulin & Presseisen, 1995). Vygotsky (1978) referred to these specialized tools as psychological tools claiming that they influence the ways in which humans process information. He believed that there are more and less complex psychological tools ranging from counting fingers for calculating simple arithmetic to the use of algorithms to solve more complex mathematical problems. The notion of psychological tools was of

particular interest to Vygotsky due to his theory that higher mental processes, such as solving mathematical tasks, were functions of mediated activity. In the case of mathematics, Vygotsky considered algorithms as the psychological tools that mediated the solving of numerical problems and were the corollary to language in relationship to speech.

Since Vygotsky's work with tools in the early 1900's other psychologists have further refined what can be meant by the term tool. With ongoing refinement of the term, there has come increased flexibility and popularity in its use in educational research. In 2006, James Spillane, borrowing from earlier conceptions of tools by Wertsch, an educational psychologist, and Norman, a cognitive psychologist, used the term tool to describe "externalized representations of ideas that are used by people in their practice" (p.18). This way of conceptualizing tools is unique and useful in that it considers tools as something greater than an idea to serve a purpose. In this view, tools exist as set of synthesized ideas in coordination with one another to accomplish something rather complex, "practice." Additionally, the notion of tools as "externalized representations" enables their use by others, beyond who created the tool.

The notion that tools are usable by many is especially intriguing because, as a result of this feature, a tool may be conceived as an artifact that can travel beyond a specific context. That is, the tool is not dependant entirely on the constraints of any given situation; numerous people may be able to use the tool in diverse contexts. Thus, users of the tool can interact with it to perform their practice (as well as have the tool act upon the user) in ways that are sensible and strategic, even among heterogeneous environments.

Tools as Mediating Artifacts

Cole and Engeström (1993) use an evolving conceptualization Vygotsky's triangular model of a mediated act to describe the result of an interaction between a subject and an object. The most basic Mediational Triangle, shown in Figure 2.1, consists of a subject, instrument (mediator), and object in which one appears at each of the three vertices of a triangle. The subject acts on the object through the instrument. The more sophisticated Mediational Triangle, shown in Figure 2.2, is Engeström's expanded conception of the original and takes into consideration three features of context (i.e., rules, community, and division of labor), as well as the connections among them, the subject, artifact, and object.

INSTRUMENT

SUBJECT   OBJECT
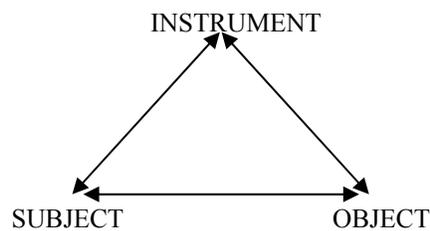
Figure 2.1. Common Triangular Representation of Vygotsky's Mediated Act.

INSTRUMENTS

SUBJECT   OBJECT ——→ OUTCOME

RULES   COMMUNITY   DIVISION OF
                                  LABOR
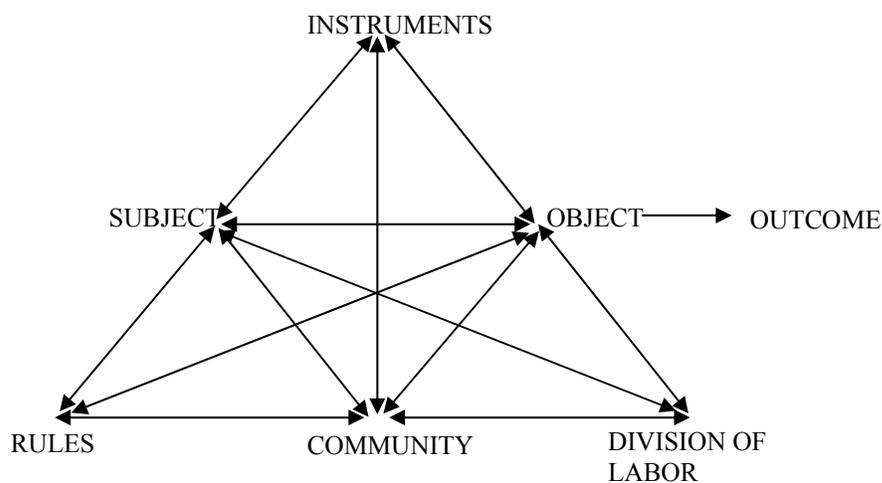
Figure 2.2. The Expanded Mediational Triangle. Adapted from *Learning by expanding: An activity-theoretical approach to developmental research,* by Y. Engeström, 1987.

The expanded version of the Mediational Triangle is one that has developed over time and takes into account the context within which a mediated act occurs. By accounting for multiple variables, the expanded Mediational Triangle is likely to more authentically represent the interactions that unfold and their consequential influences on a mediated act. Leont'ev, Engeström, Cole, and other researchers who have worked to expand Vygotsky's original notion of mediated acts view the inclusion of context as critical. These psychologists see the addition of context as a refocusing of the system away from individual action toward collective action (Engeström, 2001), a necessary but complex notion.

By focusing on a tool as a mediating artifact, one assumes that there is something about the tool that changes the interaction between the subject and object—either enhancing or diminishing this relationship to an extent. Whether this interaction is enhanced or diminished through the supplementary tool, the subject must evaluate whether to use and in what ways to use the tool in future interactions. The subject may consider such issues as:

- Does the work become easier or harder with the inclusion of the tool?

- Does the tool support or undermine what the subject is trying to accomplish?

- Does the tool unpack or in some way compensate for the complexities of a given task?

- For what purposes, and in what instances might the tool be useful?

Though this is not a comprehensive list of all that a subject may consider, these questions offer a window into what might influence the subject's choice to include or exclude a tool. Another, but slightly different, question to ask is: In what ways does the tool (i.e., mediating artifact) affect the subject? This question suggests, much like the quote from

Luria that appeared at the beginning of this section, that there is a bi-directional flow from subject to tool to object and back again.

Bi-directional flow through the mediational triangle is not a novel idea. Throughout the twentieth century, psychologists such as Luria, Vygotsky, and Feuerstein have considered not only the impact of tool on object, but also the impact of tool on subject. Feuerstein (1990) has done this through his work with mediated learning experiences (MLE) in which he and his colleagues studied the impact of tool-rich and tool-deprived learning experiences on children with perceived learning disabilities. Feuerstein's work has documented that the inclusion of tools, through a mediated learning experience, can significantly impact the ways in which children interact with their environment, thus changing what they are able to learn.

More recently, Wertsch (1998) also wrote about bi-directional flow. He stated:

…skills emerge through the use of mediational means. From this perspective, the emphasis is on how the use of particular cultural tools leads to the development of particular skills rather than on generalized abilities or aptitudes.
This is not to say that there are no such things as generalized abilities and aptitudes that distinguish one individual from another, but it is to warn against the temptation to mistake facility for using a particular set of cultural tools for some kind of general aptitude or intelligence (Wertsch, 1998, p.46).

This quote further supports the notion of bi-directional flow between the tool and the subject. But more specifically, it suggests that a tool has the potential to function as teacher (or outside expert) to an extent, thus enhancing the way in which the subject and object interact over time. If one accepts this function of a tool, it is possible that a tool, as an "externalized representation of ideas" could not only assist someone in their practice, it could also enhance their practice over time with ongoing interaction with the tool.

Matthew Brown (2009), in his work regarding "teaching as design," notes a similar type of bi-directional flow with regard to teachers' use of tools (i.e., curriculum materials. He states, "…the teacher-tool relationship involves bi-directional influences: how curriculum artifacts, through their affordances and constraints, influence teachers, and how teachers, through their perceptions and decisions, mobilize curriculum artifacts" (p.23). Through this relationship, the tool influences the object just as the object influences the ways in which the tool is used. Thus, how the subject perceives, interprets, and utilizes the tool becomes important to analyze when trying to determine the impact of the tool on the user's practice. To this end Wertsch (1998) writes,

> The essence of examining agent and cultural tools in mediated action is to examine them as they interact. Any attempt to reduce the account of mediated action to one or the other of these elements runs the risk of destroying the phenomenon under observation. But, from time to time, it may be productive to abstract these moments, or aspects, as part of an analytic strategy, and this is what I often do. While we might isolate one element for an analysis, we need to keep in mind that these elements are phenomena that do not really exist independently of action (p.25).

Clearly, tools do not act in isolation of the subject using them or apart from the object to which the tool is applied. However, there are also attributes, constraints and affordances (Wertsch, 1998), of the tool that must also be considered. And, it is these constraints and affordances that may be best studied in isolation of the subject. Wertsch (1998) conceives of affordances from the perspective of an optimist. He describes this perspective as "half-full." From the "half-full" perspective there are several aspects of human activity that a tool has the potential to enable. Norman (1988) characterized this perspective using the perceptual cues inherent in everyday objects ranging from paperclips to pliers and beyond. Norman described that the appearance of tools send messages to the user concerning for what purposes the tool is designed.

In addition to the "half-full" perspective, Wertsch also described a pessimistic orientation to tools as mediating artifacts. From the pessimistic or "half-empty" perspective, Wertsch realized that there are also likely to be constraints embedded within tools which in some way limit the potential activity accrued by the object-tool interaction. Though it is likely that both constraints and affordances are inherent within specific tools, Brown (2009) noted that constraints may not be problematic to the task at hand. Instead, he writes, "these constraints can be interpreted in terms of how they define the nature of the task and how they provide clear boundaries that define activity (p.20). Thus, constraints may serve to focus the user, in turn supporting the task at hand. A tool that is open, with few constraints, could have the opposite impact, thus undermining the task at hand (i.e., the purpose for using the tool).

Transfer and Tools

Transfer has a long history as an issue of interest to psychologists and educators. Many theories and conceptualizations have been offered, but debates continue to the present day. In fact, over the past two decades a debate has reignited that initially began in the early twentieth century with Edward L. Thorndike. As part of the more recent debate, learning theorists have been actively questioning and theorizing about what transfer is and how it should be assessed (Bransford & Schwartz, 1999; Tuomi-Gröhn & Engeström, 2008). Although my study is not about assessing transfer but rather about investigating how tools might act to scaffold transfer, it is critical to establish first what I mean my transfer. After establishing what transfer is within the context of this study, I articulate how I use transfer, paired with activity theory as a conceptual frame for data analysis.

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This portion of the literature review has three parts. I begin this section with a brief historical review of transfer. Then, I describe a more recent approach to transfer as "preparation for learning" (PFL) (Bransford & Schwartz, 1999), as well as discuss a pivotal study on boundary crossing. Finally, I elaborate my analytical framework which binds aspects of activity theory, specifically the Mediational Triangle and notions associated with boundary crossing, to the view of transfer as preparation for learning.

A Historical Perspective on Transfer

In the early nineteen hundreds Edward L. Thorndike began to question formal instruction in which "Practice was assumed to have general effects; for example, people were assumed to increase their 'general skills of learning and attention' by learning Latin or other taking subject matters" (Bransford & Schwartz, 1999, p.62). Instead, Thorndike believed that transfer of learning was dependent on the need to apply past knowledge to learn another subject, and even this was rare. His work demonstrated that people could perform well on a test of content that they had practiced and still not be able to demonstrate that learning given a new situation. To this end, Thorndike and Woodworth write (1901):

> Improvement in any single mental function need not improve the ability in functions commonly called by the same name. It may injure it. Improvement in any single mental function rarely brings about equal improvement in any other function, no matter how similar, for the working of every mental function-group is conditioned by the nature of the data in each particular case (p.250).

Out of Thorndike's theory of transfer, a system of education developed in which curricula is designed to teach lower level skills with plenty of drill and practice prior to moving to instruction on higher level tasks. This formed out of the assumption that students would only be able to transfer the skills they developed from working on the

"basics" to more non-routine tasks that required additional thinking. Thorndike's notion was one that grounded education in procedural understanding prior to moving to more conceptually based ideas.

Contrasting Thorndike was Charles Hubbard Judd. Judd had a slightly more innovative perspective on learning and transfer that resided within his notion that education was a process of establishing "higher mental processes" which could be applied to related content.   At the core of Judd's theory of transfer was an underlying conception that "transfer does not occur effortlessly and mindlessly, as a reflex" (Tuomi-Gröhn & Engeström, 2008, p.21) but rather that transfer requires that teachers "actively and purposefully teach for transfer, and students must thoughtfully learn for transfer…" (Kilpatrick, 1992, p.11). While Thorndike was skeptical of wide-ranging transfer within and across subject areas, Judd viewed transfer as something probable and productive for enhancing learning.

More recently situative views, as opposed to cognitive views, of transfer have become more prevalent in research. James Greeno and Jean Lave have been two theorists in the forefront of this trend. The situated perspective on transfer is one that takes into consideration the context surrounding potential transfer. Relevant to this dissertation is an elaboration on a situative view of transfer presented by Greeno, Smith, and Moore (1993) in which they describe a series of interactions that affect the likelihood for transfer. They write:

> For a practice to be learned in one situation to transfer to another situation, the
> second situation has to afford that practice and the agent has to perceive the
> affordance. If a learned practice is to transfer, it has to be learned in a form that is
> invariant across changes in the situation or that can be transformed as needed ,

and transfer depends on an ability to perceive the affordances for the practice that are present in a changed situation" (p.102).

More simply said, for transfer to occur, past learning must be usable and relevant to the new situation. Relevance and usability must be determined in part by the agent. Furthermore, prior learning must to be general enough or flexible enough so that the agent can apply it in a new situation. In this dissertation study, the tools are what serve as flexible instruments that I argue, when perceived by the teacher as relevant, scaffold the transfer of ideas from professional development to practice and from classroom practice to leadership practice.

This manner of conceptualizing transfer is different from cognitive views in that cognitive views are much more constrained. Lave, a critic of cognitive theories of transfer writes, "The cognitive view represents the static quality of transfer in experimental practice; it is treated as a process of taking a given item and applying it somewhere else" (1988, p.37). Stemming from this constrained view of transfer is a concern from both situative and cognitive theorists that transfer is too hard to prove, thus leading to extensive evidence of transfer failure (Detterman & Sternberg, 1993). The point to moving toward a more situative and development view of transfer is not to prove that transfer exists by making it easier to prove but to define transfer and assessment of transfer in manners that are usable for ongoing research and learning.

A More Recent Perspective on Transfer

Bransford and Schwartz (1995) wrote, "One of the most important benefits of research on transfer is the window it provides on the value of different kinds of learning experiences" (p. 62). However, we can only learn about the effectiveness of those learning experiences if we ground our research in a common conception of transfer that is

assessable.   To this end, Bransford and Schwartz (1999) propose a theory of transfer that they ground in "preparation for future learning" (PFL). Such a view is in alignment with Engeström's theory of expansive learning and developmental transfer (Tuomi-Gröhn & Engeström, 2008. Building from a transformative view of transfer, as PFL and developmental transfer do, "the focus shifts to assessment s of people's abilities to learn in knowledge-rich environments" (Bransford & Schwartz, 1999, p.24).

To illustrate a need for this conceptual shift in what transfer is Bransford and Schwartz use the example of incoming elementary teachers. The authors begin by stating that there is no manner by which teacher education programs can completely prepare pre-service teachers for the complexities of teaching students on a daily basis. Thus, they argue, the measure of transfer should not be whether new teachers can apply all of the methods they learned in their teacher education programs, but to what extent these novice teachers are prepared to learn from the new context in which they are situated (i.e., a classroom in a school within a district). One way to consider this shift in how we define and measure transfer is as a move from summative assessment to formative assessment of transfer.

In developing a theory of transfer as preparedness for future learning, Bransford and Schwartz studied Broudy's notion of "knowing with." "Knowing with," is an extension of two other ways of knowing which include "knowing that" (replicative knowledge) and "knowing how" (applicative knowledge) (Bransford and Schwartz, 1999). Broudy writes that "knowing with" is grounded in the fact that each of us "thinks, perceives and judges with everything that he has studied in school, even though he cannot recall these learnings on demand" (1977, p.12).

Armed with Broudy's theory of "knowing with," the researchers designed their own study in which they used contrasting cases[7], as a means to "know with," to explore how such cases might function to prime learning. Although they recognized the limits of contrasting cases to serve as a means for transfer, they also recognized the potential power of cases to provoke future learning. The authors wrote:

> One is unlikely to be able to remember each of the contrasting cases, and experience with a set of cases will not necessarily allow one to induce principles that guide unaided problem solving. Nevertheless, experiences with contrasting cases can affect what one notices about subsequent events and how one interprets them, and this in turn can affect the formulation of new hypotheses and learning goals (Bransford & Schwartz, 1999, p.70).

Schwartz and Bransford (1998) set their study within the context of helping college students better understand memory concepts. Although the researchers did not expect that case study would alone be useful, they hypothesized that the case analysis paired with additional information from an outside expert might make a difference in what students would be prepared to learn in future situations (Bransford & Schwartz, 1999). Their data yielded results confirming this hypothesis. Based on three testing situations: (1) students who only studied the two contrasting cases; (2) students who studied the two contrasting cases with a corresponding lecture (i.e., outside expertise) to support their learning; and (3) students who wrote summaries of memory concepts and attended the lecture, those who participated in the second scenario (i.e., cases with lecture) performed significantly better on a subsequent transfer test. In summary, it appears that the cases prompted an opportunity for transfer which the lecture scaffolded by providing additional outside knowledge. This finding is similar to one that I discuss in Chapter 4.

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[7] Contrasting cases are two or more situations which can be compared to one another. Perceptual learning theorists view these types of cases as guides people use to notice and differentiate experiences.

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Separate from, but related to the work of Bransford and Schwartz and inextricably tied to Tuomi-Gröhn & Engeström's work in developmental transfer is that of boundary crossing. Star and Griesemer (1989), in their pivotal article on boundary crossing, conceive of boundaries as the implicit and explicit lines that exist between and among the divisions of labor within a social world (i.e., social system). Star and Griesemer give the example of a series of boundaries that exist among a set of scientists, ranging from amateurs to faculty-level researchers, studying vertebrate zoology. In their study, they focus on the ways in which a museum staff functioned to use boundary objects so that ideas and knowledge collected by the scientists representing different social worlds could cross existing boundaries and become usable by more stakeholders.

One way in which the researchers document the travel of ideas and knowledge is through boundary objects (Bowker & Star, 1999; Star & Griesemer, 1989). Boundary objects are the tools and resources that are transferable and understandable by those with varying levels and types of expertise that are working within "several intersecting social worlds". The authors write, "Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites (Star & Griesemer, 1989, p.393). In this dissertation study, the tools serve as boundary objects acting to build a bridge between the worlds of educational research and classroom practice.

Embedded within the idea of boundary crossing are several other related constructs. Two of these related constructs are that of "brokers" and "boundary encounters," both of which were proposed by Wenger (1998). Wenger conceives of a broker as someone able to translate across communities of practice, facilitate

coordination and open new possibilities for the development of meaning. In my study, the staff of the Intermediate School District (ISD) serves as brokers coordinating and promoting collaboration between the research world and that of classroom practice.

Wenger also began to develop the notion of a boundary encounter. He discussed such encounters as meetings, conversations, and visits that provide connections. In my study, I expand Wenger's idea by modifying his definition of a boundary encounter to be something more particular than just an event that builds a connection. In my work, I define a boundary encounter to be something that provokes a reconsideration of thinking or practice (i.e., a critical event). Thus, a boundary encounter is not merely an interaction that forms a connection to someone or something outside of one's existing social world, it changes the way the actor functions or considers her own social world.

In my study, the idea of transfer as something that is ongoing intersects with activity theory and boundary crossing. Thus, I have formulated my analytical framework to include each of these notions. The following is a description of how the theories outlined above come together to provide a way to analyze the many interactions, but especially the interactions that a tool appears to have mediated, that occurred throughout the professional development project that is the context for my study.

Analytic Framework: A Merger of Ideas Situated in Transfer

The analytical framework for this study grounded in Bransford and Schwartz's notion of transfer as preparation for future learning which, as stated earlier, aligns with a developmental perspective on transfer more recently elaborated by Tuomi-Gröhn & Engeström (2008). Using this development approach to transfer, I do not try to prove or disprove transfer from a traditional perspective that constrains itself to applying learning

from one situation to another situation without the influence of additional stimuli. Instead, I seek to show how tools, which serve as mediating instruments, scaffold transfer by creating a bridge between research and practice.

Engeström's Mediational Triangle (1987; 1995; 2008) illustrates the structure of a human activity system that makes visible my analytic framework for this study. Figure 2.3 below shows Engeström's structure for a human activity system with addendums pointing to the roles people, artifacts, and processes took on within this study with respect to classroom practice.

INSTRUMENTS
MTF and TTLP

SUBJECT
Helen

OBJECT
Classroom Practice

OUTCOME
Formative assessment

RULES
Math task, case, then modified lesson study

COMMUNITY
Other teacher leaders

DIVISION OF LABOR
Teacher leaders, graduate students, and primary investigators
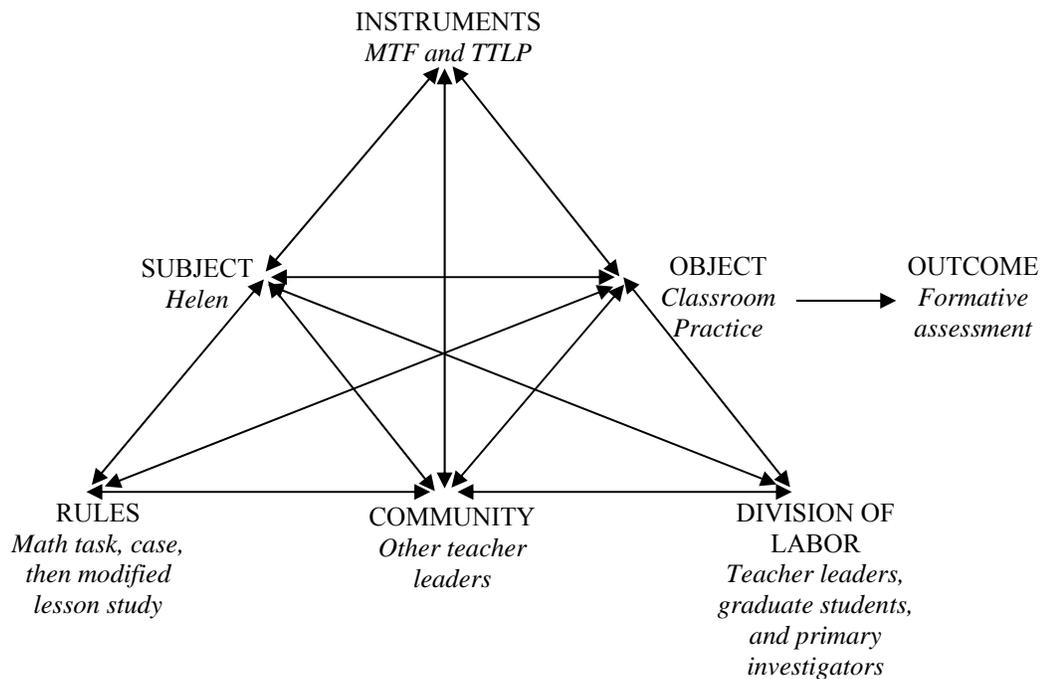
Figure 2.3. Activity System for Classroom Practice. Adapted from *Learning by expanding: An activity-theoretical approach to developmental research,* by Y. Engeström, 1987.

In this figure, the interactions among Helen and the other members of her classroom practice activity system are visible. Helen serves as the subject of this system. The context in which Helen operates is the professional development sessions. Within the sessions, there were rules, community, and divisions of labor, each likely influencing

Helen's opportunities to learn to use specific instructional actions elaborated in the tools. The rules are the structure of the professional development sessions. Most sessions followed the same structure in which teachers completed a mathematical task, read and discussed a case study of practice, and then participated in modified lesson study. The community with whom Helen interacted is the other teachers (i.e., potential teacher-leaders). Finally, there is a division of labor among the potential teacher-leaders, the graduate students, and the primary investigators, each of which worked to fill related but substantially different roles over the course of the project.

The tools, the Thinking Through a Lesson Protocol (TTLP) and the Mathematical Tasks Framework (MTF) serve as the instruments or mediating objects that act to scaffold transfer of ideas from the professional development to Helen's classroom practice. Finally, Helen's classroom practice is the object of the mediated action. The outcome, which I will describe in my findings, is Helen's evolving understanding of specific instructional actions suggested by the tools and by supporting activities in the professional development sessions.. This figure represents the activity system for Helen's classroom practice with respect to the professional development project. Shown later, in Figure 2.4, is the complementary activity system for Helen's leadership practice.

INSTRUMENTS
MTF, TTLP, and TTSP

SUBJECT
Helen

OBJECT
*Leadership
Practice*

OUTCOME
*Formative
assessment*

RULES
*Math task, case,
then modified
lesson study*

COMMUNITY
*Cohort 2 district
colleagues*

DIVISION OF LABOR
*Teacher leaders, graduate
students, and teacher
colleagues*
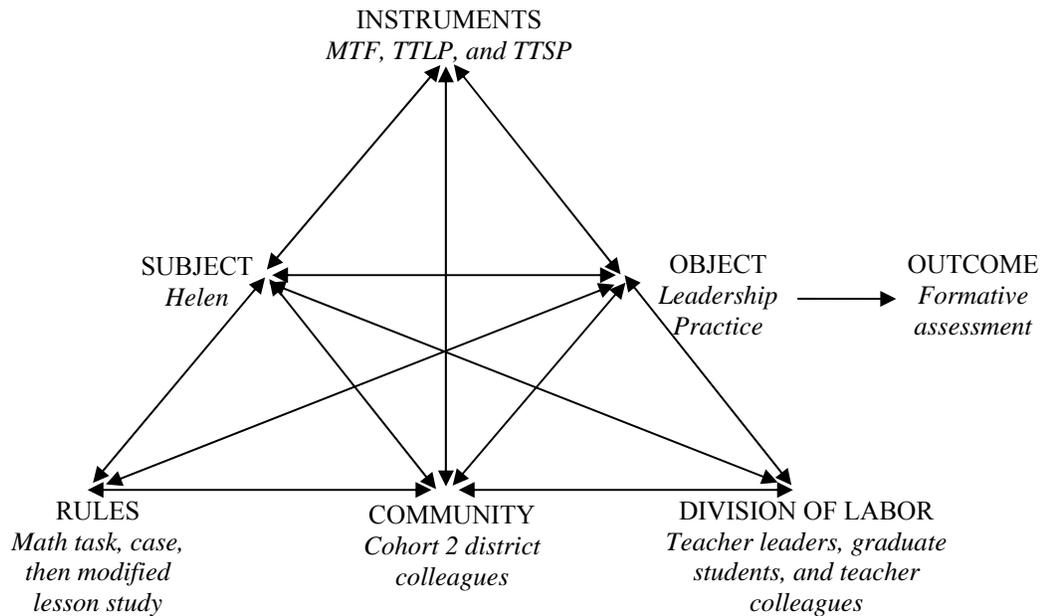
Figure 2.4. Activity System for Leadership Practice. Adapted from *Learning by expanding: An activity-theoretical approach to developmental research,* by Y. Engeström, 1987.

Helen's two activity systems do not differ greatly. The changes reside in only four of the nodes on the triangle. First, and most significant, is that the object of this activity system in Helen's leadership practice. It is through the additional tool, the Thinking Through a Session Protocol (TTSP), that attention is placed on this practice. However, the MTF and TTLP still potentially operate as instruments of influence on Helen's leadership practice. There is also a shift in community from that of other potential teacher-leaders to that of other colleagues from Helen's district, teachers to which she provided support. The final change is the removal of primary investigators from the division of labor. This is not because the primary investigators were no longer part of the project but rather that their presence was not visible at the district-based sessions in which Helen enacted professional development.

Using Helen's two interacting activity systems, I focus my analysis on the way in which Helen interacted with the tools and claimed to use the specific instructional actions suggested by the tools in her classroom practice. Next, I consider how and in what ways Helen talks about and uses corresponding instructional actions in her leadership practice. I analyze observations of professional learning experiences Helen provided for colleagues, as well as interviews in which Helen described her use of corresponding instructional actions throughout leadership activities. I do this by first identifying critical events (i.e., boundary encounters) in which it appears that developmental transfer was initiated. I based my decision to proceed in this manner on Tuomi-Gröhn & Engeström's theory of developmental transfer in which they explain that transfer must be initiated when individuals or groups begin to question practice. They write:

> Expansive learning [developmental transfer] is initiated when some individuals and groups involved in a collective activity take the action of questioning the existing practice. This can lead to an escalating process of debate and collaborative analysis of contradictions in the current state of affairs, which may lead to a projective modeling of a developmentally new form of the activity, in which contradictions are resolved (p.30).

Next, I used the critical events that seemed to prompt questioning of existing practice to trace points in the teacher's professional trajectory in which she appeared to put specific instructional actions suggested through the tools and supporting professional development into her practice. Furthermore, I link the identified instructional actions to the tools (i.e., MTF, TTLP, and TTSP) to analyze the ways in which the tools acted to scaffold ongoing learning with regard to Helen's practice. After focusing on Helen's classroom practice, I analyzed Helen's leadership practice. Again, I used the lens of the critical event to identify ways in which her classroom practice seems to have transferred to her leadership practice, thus creating a new form of practice in a related activity

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system. These are precisely the two actions that Tuomi-Gröhn & Engeström (2008) identify as events critical for transfer. They state:

> In our framework, two actions are critical for transfer, namely implementation of the new model in practice and consolidation/proliferation of the new practice. In other words, we are interested in: (a) the transfer of new models into practice (implementation); and (b) in the transfer of local innovations and new forms of practice into other activity systems and organizations (proliferation) (p.32).

Although the models described above address how Helen interacted with the tools and the larger context of the professional development, they do not directly address how and why the tools function to scaffold transfer. Thus, I integrated the notion of boundary crossing throughout the existing activity systems for classroom and leadership practice. First, I viewed the tools, which function as mediating agents, as boundary objects (Bowker & Star, 1999; Star & Griesemer, 1989) that connect the worlds of research and practice. Recall, the developers, university faculty, created these tools within the social world of research. However, the project team used them to ignite change in the world of practice. It is my theory that the tools communicated knowledge from research (i.e., outside expertise) in a manner that was relevant and usable to the teacher. Thus, they acted to bridge these separate but interacting worlds in potentially transformative ways. Second, I viewed the ISD consultants, one of which I became prior to the end of the project, as boundary crossers or brokers (Wenger, 1998) that crossed between the university members of the project team and the middle school teachers. Finally, I used Wenger's construct of boundary encounters to name the critical events that unfold throughout Helen's professional trajectory from teacher to teacher-leader.

A concluding note:

One might notice that I did not include case studies that the project team used during the professional development sessions as one of the tools or mediating agents. Although many consider case studies to fall within the realm of tools for practice-based professional development, they did not meet the definition of tool for this project. Recall, the definition of tools upon which I have based this study is Spillane's definition which stem's from early conceptions of tools from the work of Wertsch and Norman. Using this definition, people use tools in their practice to accomplish something they would not have been able to do as effectively in the absence of the tool. Cases, though they are likely to influence practice, do not function to create a bridge from professional development to practice. That is, they do not suggest actions be taken on the part of the teacher. Cases merely provide a visual, a mental image, to consider what a practice might look like. As such, I did not classify the cases as tools. Having said this, I did analyze how the cases appeared to function as a supporting resource to prompt Helen's take up and use of the tools.

A Novel Approach to Teacher Leadership

As a result of nearly ignoring the diverse needs of content focused teacher-leaders, the discussion of teacher leadership in the majority of existing literature has remained stalled at a superficial level, masked by oversimplification. This tenet is evident in books commonly read by administrators on the practice of teacher leadership. In general, books on teacher leadership devote numerous pages to discussing the need for teacher-leaders in educational systems; the rationales as to why such positions are necessary vary and little is said about the knowledge base teacher-leaders should possess.

A common argument in current literature stems from an economic perspective (i.e., reductions in funding create a need to delegate leadership roles among teachers). Other arguments are grounded on instructional reform (e.g., teacher leaders are needed to support the instructional reforms necessary to improve public education). Finally, some state affective reasons as to why teachers should take on leadership roles (e.g., teachers feel powerless and need more autonomy and/or responsibility; there are not structured paths for teachers to grow professionally without leaving the classroom). The list above does not exhaust all of the reasons that are given in the literature as to why the educational system needs teacher leadership, but these reasons are representative of additional arguments.

Though the arguments vary as to the purpose of teacher-leaders, making a case for the need for teacher-leaders is the primary focus of the vast majority of books and articles on teacher leadership. Additionally, there are two other common arguments that are also popular: Success stories of teachers who have effectively led their colleagues in a "heroic" way;[8] and "how-to" guidelines for administrators that hope to employ teacher leadership to support school improvement-type initiatives. Unfortunately, success stories, reasons why teacher leadership is needed, and general "how-to" guidelines for identifying, recruiting, and supporting teacher-leaders is not enough. Conversely, suggesting that this type of literature is enough undermines the complexities of teaching. To protect against oversimplification of the use of teacher leadership to support

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[8] *Heroic* is a term used by James Spillane to describe instances where individuals or small cadres of leaders at a school have stepped up to lead. Spillane goes on to explain that this heroic stance toward leadership may lead to pockets of great educational change. However, it is fragile and dependent on a small number of people. He contrasts this to a distributed stance toward the *practice* of leadership that involves more stakeholders and emphasizes the importance of interactions between and among stakeholders that have the potential to support sustainable improvements to the system.

educational systems, there must be further research that unpacks the expertise and support structures one needs to be an effective teacher-leader within a specific content area.

Beyond containing surface-level information regarding the implementation of teacher leadership within a system, some resources for implementing or sustaining teacher leadership may actually foster misconceptions regarding the work and effort entailed in supporting teachers in such roles. *Awakening the Sleeping Giant: Helping Teachers Develop as Leaders; Connecting Teacher Leadership and School Improvement; Developing Teacher Leaders: How Teacher Leadership Enhances School Success; Best Practices for Teacher Leadership: What Award Winning Teachers Do for Their Professional Learning Communities; and Uncovering Teacher Leadership: Essays and Voices from the Field—*Each of the titles above appear in a publisher's advertisement regularly sent to school principals and central administrators selling the idea of teacher leadership. A cursory reading of these titles may illicit images and ideas of teacher leadership that are alluring, or even seductive, given the pressures many educators face with regard to high accountability demands combined with minimal time and resources to meet such demands. Images and ideas of teacher leadership that might arise are:

- Teachers are inherently leaders, they just need the opportunity to lead
- Any teacher can be a teacher-leader
- Teacher leadership is a quick fix
- Teacher-leaders can help with school improvement
- Teacher leaders can manage professional learning communities
- Teacher leadership hinges on building capacity within individuals

Although the points above could probably be debated rather successfully by those that believe such rhetoric, as well as by those who do not, my belief is that missing from

these points are two aspects of teacher leadership that are necessary to consider if long term improvements in teaching and learning can be possible. These considerations are (1) teacher leadership is a complex practice that has its genesis within classroom instructional practice; it is not a role and (2) teacher leadership practice can be enhanced when scaffolded by tools grounded in the context of a specific content area.

The first consideration, that teacher leadership is a complex practice that originates within classroom instructional practice, is a notion that has become increasingly recognized in recent years (Carol & Mumme, 2007; Mills, Silver, Gosen, Seally, & Devine, 2008; National Council of Supervisors of Mathematics, 2008). Some depictions of teacher leadership in this way use the instructional triangle as seen in Figure 2.5 (Cohen, Raudenbush, & Ball, 2003) as an anchor for the practice of leadership.
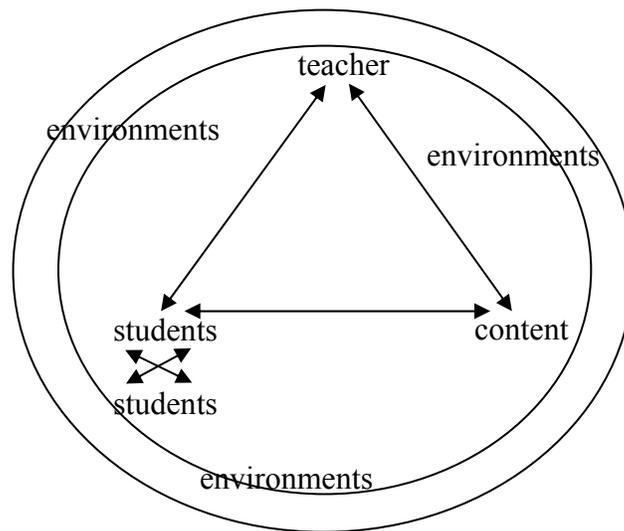
Figure 2.5. The Instructional Triangle. Adapted from "Resources, instruction, and research," by D.K. Cohen, S.W. Raudenbush, & D. L. Ball, 2003, *Educational Evaluation and Policy Analysis, 25*, 119-142.

The instructional triangle transfers rather seamlessly when considering the curriculum of professional development designed to support teacher leadership capacity. The primary reason that the two ideas seemingly layer so well is that both are centered on

the notion of interactions within an environment. In the case of practice-based

professional development for mathematics teachers, participants (i.e., teachers) study the

interactions among teachers, content, and students. Though this may be accomplished

through various types of professional learning tasks such as explorations of mathematical

tasks, episodes of teaching, and illuminations of student thinking (Smith, 2001; Cohen &

Ball, 1999) the core of the curriculum is the interactions, specifically the complex nature

of problems of practice (Lampert, 2001). When considering how the instructional

triangle transfers to leadership practice one needs to consider the "content" of teacher

leadership practice being the original instructional triangle. Thus, the revised

instructional triangle for leadership becomes the interactions among teacher-leaders,

other teachers, and the content (i.e., the original instructional triangle). An illustration of

this relationship is shown in Figure 2.6.[9]

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[9] This illustration has been simplified for ease of interpretation. Though the ovals suggesting environments
have been removed, it is still assumed that the Instructional Triangle for Leadership exists within sets of
environments. Additionally, only the frame of the original Instructional Triangle is depicted in the
"content" vertex of the Instructional Triangle for Leadership. All aspects of the original Instructional
Triangle should be assumed.
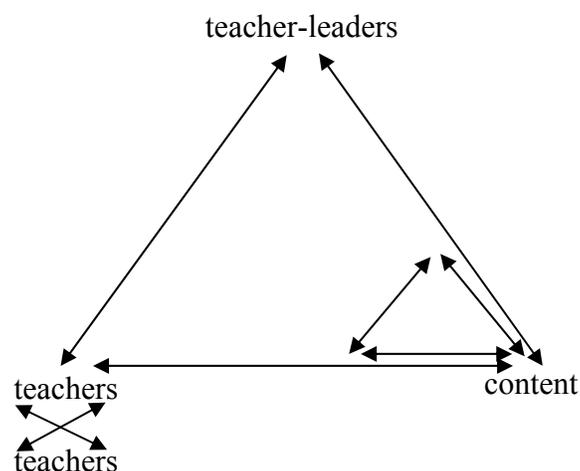
Figure 2.6. Instructional Triangle for Leadership. Adapted from "Resources, instruction, and research," by D.K. Cohen, S.W. Raudenbush, & D. L. Ball, 2003, *Educational Evaluation and Policy Analysis, 25*, 119-142.

Though the development of the practice of teacher leadership is likely to require work with individuals, the focus could remain on how those individuals interact within a larger environment (e.g., colleagues and resources). In this system, teacher-leaders, those who initially work on improving their practice with outside support, would be given the opportunity to increase their mathematics teaching proficiency prior to working with colleagues. After a period of extended (e.g., one year or more) analytic study of their own classroom instructional practice paired with intentional tools, the teacher leaders could begin working with colleagues, helping them to develop an analytic stance on their instructional practice. This transition could be initially scaffolded by working closely with mathematics teacher educators and corresponding professional development tools to help build the teacher-leaders' competence and confidence.[10] Although such tools would

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[10] The outside "experts" and professional development tools suggested in this context are likely to function similar to "boundary objects," a notion conceptualized by Star and Griesemer (1989). Boundary objects in the case of teacher leadership practice, the outside "experts" and professional development tools, live at the margins of two "worlds," that of research and that of practice. The tools and the people that cross from research to practice and back again carry with them data that are likely to inform each context.

initially serve to scaffold the teacher-leaders' own classroom practice, they could later act to scaffold the teacher-leaders' ability to work with colleagues.

If we recall Spillane's definition of a tool, "externalized representations of ideas that are used by people in their practice" it is rational to conceive that the intentional use of tools could be used to enhance one's leadership practice. This is logical because of the "externalizable" feature of tools. That is, a tool is an entity that is not within an individual, but rather something that becomes concrete and usable by others—beyond it's creator. Thus, a tool has the potential to carry within it knowledge; this is not to say the tool is self-enacting in any way and it is critical to note that appropriate training must accompany the tool during early attempts to use it productively. Simply, the tool exists as a carrier of knowledge that one, separate from and possibly less skilled than the creator of the tool, can utilize to transform her practice.

Summary

The tools that I analyze in this study: (a) the Mathematical Tasks Framework (MTF), (b) the Thinking Through a Lesson Protocol (TTLP), and (c) the Thinking Through a Session Protocol (TTSP) exist to support teachers' practice at two levels, classroom practice and leadership practice. Considering the use of tools to support instructional practice is called for in current literature. For instance, within *Adding It Up*, the National Research Council (2001) suggests the focused use of tools of instruction to help teachers develop proficiency in teaching mathematics. Notably, the report warns against supplying teachers with a list of routines or solutions to common problems of instruction, this is likely in response to early notions that tools (e.g., well designed

curriculum materials) can function productively in the absence of a knowledgeable user.[11]

Instead, the author team proposes that teacher educators situate teachers in authentic

explorations of instructional issues and use data and resources to analytically reflect on

those issues in order to develop and/or refine teachers' ability to make warranted

decisions. Though the report does not address tools with relationship to leadership

practice, if one accepts that the genesis for teacher leadership practice resides within

developing a sound instructional practice, it is only sensible to conclude that it might be

possible for tools to support leadership practice in similar ways.

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[11] See Brown, 2009; Henningsen & Stein, 1997; Senk & Thompson, 2003a; and Tarr et al., 2008 for an expanded analysis on the enactment of curriculum materials.

CHAPTER 3

METHODS OF INQUIRY FOR STUDYING TOOLS AS INSTRUMENTS TO SCAFFOLD TRANSFER

In this chapter, I outline the methodological processes that underlie my writing of this dissertation case study. I begin by introducing the design of the study, first by reiterating my research questions and the rationale supporting them. Next, I unpack the contexts of this study, both the professional development project and the individual teacher who served as the conduit by which I tell this story of tools grounded in practice-based professional development. Embedded within the discussion of the context of the professional development project will be a description of the tools used by the professional development project. Additionally, I describe my evolving roles with respect to this study as well as the nature of the existing data set I conclude by attending to issues regarding the validity of this study.

After introducing the reader to the context of this study, I describe my process for analysis in two phases. The first phase centers on the identification of instructional actions and critical events that appear to be relevant to Helen Emerson,[12] a secondary mathematics teacher and teacher-leader who is the conduit through which I tell this story of take-up and usage of practice-based tools. To this end, I describe how I used data from three project-impact and two session-planning interviews to identify instructional actions and resources that appear to be relevant to Helen, as well as pinpoint critical

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[12] Helen Emerson is a pseudonym for the teacher who is the subject for my case study. I have substituted pseudonyms for all teacher and district names.

events along her professional trajectory from teacher to teacher-leader. In the second

phase, I elaborate why I used the identified instructional actions, resources, and critical

events as evidence to trace movement of ideas and resources from professional

development to practice and from classroom practice to leadership practice.

Research Questions and Rationale

I have designed this study to be a case of how tools, specifically tools of action

paired with a complementary conceptual tool, function to scaffold transfer of specific

instructional actions from professional development to practice and from classroom

practice to leadership practice. Toward this end, my research seeks to analyze:

- What surrounding critical events appear to provoke a teacher to take up
  specific instructional actions suggested by tools used in practice-based
  professional development?

- In what ways did a complementary set of such tools scaffold the transfer of
  specific instructional actions from professional development to a teacher's
  practice?

- How did the use of these tools scaffold the transfer of specific instructional
  actions that a teacher claimed to use with students to her work with
  colleagues?

The conceptual frame for this study is based on the notion that tools, as

externalized representations of ideas that are used by people in their practice (Spillane,

2006, p.18), assist someone in accomplishing a task. Using this general definition of

tools, this study seeks to analyze how and in what ways a complementary set of tools,

composed of both a conceptually based tool and a tool of action, function to prepare

teachers to understand and to be prepared to enact new or refined instructional actions.

For the purposes of this study, a conceptually based tool is one designed to hold

together the components that make up a larger idea. In addition to providing a structure

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for an idea, conceptually based tools are likely to have the capacity to supply a common language for group discussion and analysis and may also offer a classificatory or sorting component. In educational research, conceptually based tools, often referred to as frameworks, are more common than tools of action. An example of a well-known conceptually based tool in mathematics education is the Cognitively Guided Instruction (CGI) framework designed by Carpenter, Fennema, Franke, and Levi that attempts to articulate the development of children's computational fluency. Unlike a conceptually based tool, a tool of action is one that suggests specific instructional actions be planned for with the intent to enact with students or colleagues. Thus, tools of action go beyond illustrating research-based understandings or images of practice; they suggest actions for the user to take on within her practice. In this way, tools of action have the potential to provide a bridge from *ideas about what to do* in practice to *what to actually do* in practice. While conceptually based tools have a clear purpose in education, once a teacher has come to understand a conceptual tool the learning is likely to stop. However, together, conceptually based tools and tools of action have the potential to prepare teachers for future learning with respect to instruction as the tool of action has the potential to help teachers move from *learning about* to *learning to do*.

I used a case study method to analyze the classroom[13] and leadership practices of one participating teacher in a middle school mathematics professional development project. Case study, as defined by Yin (1994) is "an empirical enquiry that investigates a contemporary phenomenon within its real life context especially when boundaries between phenomenon and context are not clearly evident" (p.13). I selected this approach

[13] The use of the phrase classroom practice is used not to suggest that the research team observed change in the teacher's classroom but rather that there is evidence of the teacher's understanding of and intent to use the specific instructional actions suggested by the tools during her classroom lessons with students.

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because it enabled me to systematically unpack the complexities that reside within the context of professional development, thus providing a lens for understanding ways in which tools of action and the instructional actions embedded within them could be used to inform classroom and leadership practice.

Specifically, I used an instrumental case study approach, one of the two methods described by Stake (2000). An instrumental case study, unlike an intrinsic case study, is conducted to "provide insight into an issue or to redraw a generalization" (Stake, 2000, p. 437). While single cases are not in and of themselves generalizable given a statistician's take on the word (e.g., in terms of samples and universes), they are analytically generalizable (Yin, 2003). That is, researchers may use case studies to generalize findings to theory much as a scientist generalizes experimental results (Yin, 2003; Miles & Huberman, 1994; Eisenhardt & Graebner; 2007).

Context of the Study

The context of the study is a mathematics professional development project focused on supporting middle school teachers' use of a standards-based set of mathematics instructional materials beyond its initial implementation. The theory grounding the design of this professional development project was Fullan's notion (2004) that educators are likely to encounter plateaus as they attempt to address reform initiatives, but that these periods of minimal growth are not necessarily barriers to change. Instead, such plateaus might mark points at which teachers are primed for learning opportunities that are capable of prompting and supporting them to grow professionally.   Fullan writes, in order to overcome the obstacles created by such plateaus, "What needs to be sustainable is not particular practices but rather the capacity

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and process of continuous problem solving and improvement" (p.9). The project planning team designed the professional development sessions that are the context for this study to build such capacity in its participants.

The project team that collaboratively designed this professional development opportunity for teachers consisted of a university faculty member, a mathematics consultant from a county-based K-12 intermediate school district (ISD), and graduate students who served as research assistants on the project. The university faculty member is an internationally recognized researcher within the field of mathematics education. Along with being a primary investigator on this project, his prior work led to the development of some of the resources and tools used in this project. He co-authored the narrative case studies used in the professional development sessions and co-developed the Mathematical Tasks Framework with corresponding levels of cognitive demand (MTF).

The ISD mathematics consultant is a nationally recognized mathematics educator. She served as a primary investigator on this project as well as the lead facilitator at the professional development sessions. Prior to her involvement in this project, she taught high school mathematics for nineteen years. She also had been a curriculum director for a medium-sized metropolitan school district. This consultant's prior knowledge of student achievement data with respect to districts new to using standards-based instructional materials to teach mathematics was the impetus for focusing the project around Fullan's notion of an "implementation plateau."

The team of graduate students on the project, of which I was one, shifted over time. However, five graduate students representing the fields of mathematics education

and teacher education were relatively consistent members of the project team. These students were active members of project. They helped to collaboratively plan the design and enactment of the professional development, informed the selection of and adaptation of tools and resources used in the project, and regularly studied the project. As a result of their studies, the graduate students also co-presented findings from the project in papers and at national conferences.

Why this Project and these Tools?

BIFOCAL, the project that is the context for this study, is particularly interesting because it combined a variety of practice-based professional development resources and approaches to help teachers both to improve their classroom practice and to begin to support their colleagues' growth with respect to mathematics teaching and learning. In addition to integrating several practice-based resources within its design structure, such as cognitively demanding mathematical tasks and narrative case studies of classroom instruction, the project also used tools to help focus teachers' attention toward specific instructional actions that are generalizable beyond a particular lesson or session context. Two primary tools were used by the project team to help teachers focus on key instructional issues: the Mathematical Tasks Framework (MTF) (Stein & Smith, 1998; Stein, Smith, Henningsen, & Silver, 2009) and the Thinking Through a Lesson Protocol (TTLP) (Smith & Bill, 2004; Smith, Bill, & Hughes, 2008). While the MTF and TTLP are closely related, the TTLP created out of a perceived need on the part of the developers to make more explicit and help teachers implement the instructional actions suggested only implicitly within the MTF (Silver, E.A., & Smith, M.S, personal communication, May 20, 2010), they provide somewhat different affordances to the

project and its participants. In the text that follows, I describe the individual tools, as well as the relationship among the tools and the cases.

The first tool used by the project team was the MTF, a conceptually based tool. The team intended to use this tool primarily to articulate a common vocabulary for purposes of discussion and to communicate the ideas embedded within the tool itself and the corresponding levels of cognitive demand. The project team used Case of Catherine Evans and David Young (Silver, Smith, & Stein, 2005b) to provide an image of the MTF in practice. This case, in particular, partially through its dual case design, "provides a way of attaching to the MTF a really solid example of positive and negative flow of a task [i.e., supporting and undermining cognitive demand] through the lesson" (Smith, M.S. personal communication, May 20, 2010. The second tool the project team introduced was the Thinking Through a Lesson Protocol (TTLP), a tool of action. The purpose of using the TTLP was to attempt to scaffold transfer of instructional actions from the professional development to teachers' classrooms. The project team inserted a third tool, the Thinking Through a Session Protocol (TTSP), during the third year of the project. The participants did not use the TTSP as they had used the MTF and the TTLP. Instead, the participants were exposed to the TTSP indirectly. The project team used the TTSP only as an interview protocol to learn what the teacher-leaders had considered when planning their site-based sessions.

The Cases

The BIFOCAL project attempted to build instructional capacity within the potential teacher-leaders by integrating case analysis of classroom episodes with modified lesson study during the professional development sessions. The reasoning

behind the use of cases was their non-personal, yet practice-based nature. That is, the cases used in the project were not studies of any particular teachers participating in the project; they simply served as opportunities to create mental images of practice using cognitively demanding mathematical tasks and thus, opportunities to discuss the enactment of cognitively demanding mathematical tasks in middle school classrooms. The cases depicted scenarios of practice—teachers interacting with students around mathematical content. While a strength of a case is to provide an image of practice, a constraint of a case is that it is "really thick with particulars" and does not provide a clear path for users to more generalizable instructional issues (Smith, M.S., personal communication, May 20, 2010). Thus, while cases have the capacity to illuminate what to do in practice, they alone do not help teachers move from ideas to action within practice.

The project team included modified lesson study to create a bridge from the particulars of a case to general instructional issues experienced by teachers in their classrooms. Ideally, modified lesson study supported by a tool of action, the TTLP, would scaffold transfer of teachers' reconsiderations of practice that emerged from the case analyses (non-personal) to the teachers' own classrooms (highly personal). Although cases are likely to inform classroom practice and are strong resources embedded within a larger context, they fall short of offering teachers and professional developers a way to do something within practice. Because the cases merely provide ideas, they *communicate* what could be in practice. Still, they do not function in actionable ways. That is, the cases do not suggest ways in which instructional actions visible in the cases may be taken up and used in practice.

The Mathematical Tasks Framework and Levels of Cognitive Demand

The MTF is a conceptual framework that's primary function is to hold together the notion that the cognitive demands of mathematical tasks are subject to change throughout a lesson depending on what the teacher and students do with the task in practice. Cognitive demand refers to "the kind and level of thinking required of students in order to successfully engage with and solve the task" (Stein, Smith, Henningsen, & Silver, 2009, p.1) . As such, paired together, the MTF and corresponding levels of cognitive demand provide a structure and common vocabulary around which teachers, researchers, and those in between can analyze practice through a common lens.

The MTF, shown in Figure 3.1, illustrates the phases that mathematical tasks pass through as they unfold during classroom instruction. Researchers on the Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR)[14] project designed this framework to guide their analyses of how teachers used mathematical tasks within lessons to create opportunities for student learning. The MTF corresponds to the levels of cognitive demand in that the levels of cognitive demand name the way in which a task exists at any particular phase in the MTF. Depending on what a teacher does with a task at each of these phases, she has an opening to alter the task creating different kinds of opportunities for students to learn mathematics.[15] The researchers found that these learning opportunities for students ranged from memorization of mathematical facts to something much more rigorous which they named "doing mathematics." QUASAR researchers report two major findings from using the MTF and levels of cognitive

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[14] The QUASAR project was a multiyear project in which middle school teachers from urban districts used cognitively demanding tasks in their classrooms to support the development and implementation of a form of instruction designed to build mathematical proficiency.

[15] For an extended explanation of the four Levels of Cognitive Demand see Stein, Smith, Henningsen, & Silver, 2009).

demand to analyze lesson enactment: (1) mathematical tasks with high-level cognitive

demands were challenging to implement well and (2) students appeared to learn more in

classrooms when teachers enacted tasks with students at high levels of cognitive demand.

From these findings, the research team hoped to use the MTF and cognitive demand to

help teachers select and implement mathematical tasks based on what teachers intended

students would learn (i.e., the mathematical goals) from engaging in the lesson.
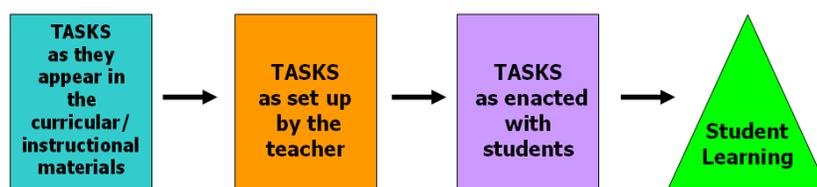
Figure 3.1. The Mathematical Tasks Framework. Adapted from *Implementing standards-based mathematics instruction: A casebook for professional development (2nd ed.)*, by M.K. Stein, M.S. Smith, M.A. Henningsen, M.A., & E.A.Silver, 2003, New York: Teachers College Press.

Out of the work of the QUASAR project in which researchers used the MTF and

cognitive demand as a tool of analysis mainly for researchers, BIFOCAL, the project that

is the context for this study, used the MTF as a tool of analysis for teachers. The project

team introduced the MTF as a way for teachers to think about and reflect on their

enactment of cognitively demanding tasks. The project team selected the MTF with

corresponding levels of cognitive demand as a tool for this project because the central

focus of the project was to improve teachers' use of cognitively demanding tasks in an

effort to positively affect student achievement. The MTF offered a common language for

teachers to use when discussing the enactment of mathematical tasks in cases, as well as

their own lessons through modified lesson study scaffolded by the TTLP.

The Thinking Through a Lesson Protocol (TTLP)

The follow excerpt appeared in *Thinking through a Lesson: Successfully Implementing High-Level Tasks*, an article written by the authors of the Thinking Through a Lesson Protocol.

> The purpose of the Thinking Through a Lesson Protocol is to prompt teachers to think deeply about a specific lesson that they will be teaching. The goal is to move beyond the structural components often associated with lesson planning to a deeper consideration of how to advance students' mathematical understanding during the lesson. By shifting the emphasis from what the teacher is doing to what students are thinking, the teacher will be better positioned to help students make sense of mathematics (Smith, Bill, & Hughes, 2008).

Clearly, the intent of the TTLP is to significantly change the manner in which a teacher thinks about a lesson prior to implementing it with students in hopes that this will affect the actual implementation of the lesson. The shift in emphasis that the authors refer to above, from what the teachers does to student thinking, is visible through the questions the TTLP prompts the teacher to consider while planning. For example, the TTLP prompts the teacher to anticipate multiple ways to solve a specific task and then to consider which of these methods her students are likely to use, as well as what errors the students might make. Through this opening set of questions on the TTLP, the tool of action transmits a message that planning should be grounded in student thinking and that the lesson should be planned to react to student thinking in appropriate and productive ways so that students' opportunities to learn mathematics are optimized. Furthermore, the TTLP goes beyond communication of a message in that it suggests specific instructional actions for the teacher to take in preparation for the lesson. While the questions referenced above come from the first part of the TTLP, Selecting and Setting Up a Mathematical Task, it is important to note that each of the other two parts,

Supporting Students' Exploration of the Task and Sharing and Discussing the Task, are also composed of questions that prompt the teacher to consider and then use students' thinking during the lesson (see Appendices A and B for the complete list of questions on the two versions of the TTLP used during this project).

Although the TTLP, not unlike the MTF, acts to hold together ideas, I argue that a significant affordance of the TTLP is that it has the potential to provide an additional level of support for teachers that is absent from the MTF. The additional level of support comes from the questions the TTLP prompts a teacher to answer; the TTLP provides a focused structure for planning that suggests the inclusion of a specific set of generalizable instructional actions within practice. Thus, while an affordance of the MTF is that it is concise and as such, easy to reference its components, a constraint of the MTF is that it does not articulate the multitude of instructional actions embedded within the selection and facilitation of cognitively demanding tasks. This is why the TTLP, a tool of action, is a complement to the more conceptually based MTF.

Margaret Schwan Smith, a collaborator on the MTF and the primary author of the TTLP described the relationship between MTF and TTLP saying, "the MTF served as the architecture for the TTLP" (Smith M.S., personal communication, August 4, 2009). She, along with her colleague, Edward Silver, have also described the creation of TTLP. They have described the genealogy of the TTLP by saying that the TTLP evolved out of using the MTF as a tool and recognizing that it, when paired with other resources such as the narrative case studies, reaches people and helps them to notice things about teaching. However, in using the MTF as part of ongoing professional development, they did not see evidence that teachers' understanding of the MTF translated into their practices (personal

communication, May 20, 2010. Therefore, Smith, with colleagues at the University of

Pittsburgh, designed the TTLP as a way to bring the framework into practice, a sort of

"plan for action to operationalize ideas" from the MTF (Smith, M.S., personal

communication, May 20, 2010).

While the complementary nature between these tools may not be obvious initially,

it is readily discernable upon closer investigation. That is, an inherent connection exists

between the tools that enable one to support the other as teachers learn to make sense of

and use them within their practice. This relationship between these tools is illustrated in

Figure 3.2.
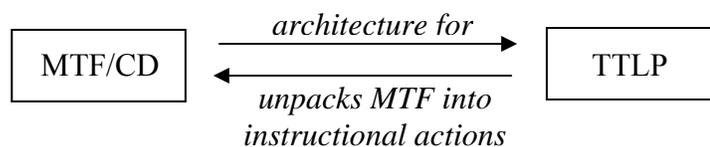
Figure 3.2. Complementary Relationship between the MTF and the TTLP.

One way in which this relationship is visible is through the questions the TTLP

makes explicit, many of which the MTF tacitly assumes. For example, within the first

phase of the MTF sits the mathematical task as it appears in instructional materials (refer

to Figure 3.1). This phase assumes that a teacher has selected a task she believes will

support the goals of the mathematics lesson. Thus, there is also an assumption that the

teacher first identified appropriate mathematical goals aligned with the cognitive demand

at which she intends to enact the task. The TTLP does not assume the selection of

mathematical goals, but instead, explicitly asks the user of the tool, "What are your

mathematical goals for the lesson (i.e., what is it that you want students to know and

understand about mathematics as a result of this lesson)?" In doing so, the TTLP

prompts the user to consider what, in particular, it is that she wants students to learn from the task. This question goes beyond asking the teacher for typical instructional goals that state what students will be able to do by asking the teacher to consider what it is students will understand. This is a slightly different question with potentially profound affects on students' opportunities to learn mathematics. It is a question that, when not made explicit, is easily overlooked during typical lesson planning.

Another example of a way in which the TTLP makes explicit an assumption of the MTF is evident with respect to the enactment of the task, the third phase of the MTF. This phase serves to remind teachers that their enactment matters—their instructional decisions are critical. Again, the MTF sends a more tacit message than that which appears in the TTLP. In the TTLP, there is a series of questions that step teachers through the enactment of a task with students. The TTLP asks the user of this tool to be explicit about what she is doing "as students are working individually or in small groups." Other questions the TTLP asks of teachers at this point in the protocol suggest to teachers that they consider questions that include, but are not limited to, those that focus student thinking, assess student thinking, and encourage students to share their ideas with peers.

The Thinking Through a Session Protocol (TTSP)

The parallel relationship between the TTLP and the TTSP is recognized more easily than that of the more tacit, yet complementary, relationship that exists between the MTF and TTLP. To begin, The TTSP is composed of many of the same questions that appear on the TTLP; the primary difference between the tools is a shift in focus. Whereas the TTLP focuses on teachers' instructional practice, the TTSP focuses on

teachers' leadership practice. Thus, instead of asking, "What are the mathematical goals of the *lesson*?" the TTSP asks, "What are the mathematical goals of the *session*?" Moreover, rather than asking questions to assess students' thinking, the TTSP prompts its user to ask questions to assess teacher thinking. The difference between the two tools is not for whom they are designed, but rather what type of work they are meant to support, teacher classroom or teacher leadership practice. Because the TTLP and TTSP are inextricably linked, the claim may also be made that the TTSP complements the MTF in the same ways I described above with respect to the TTLP. The relationship that exists among the three tools is shown below in Figure 3.3.

architecture for

| MTF/CD | → TTLP | ←→ TTSP |

unpacks MTF into
instructional actions
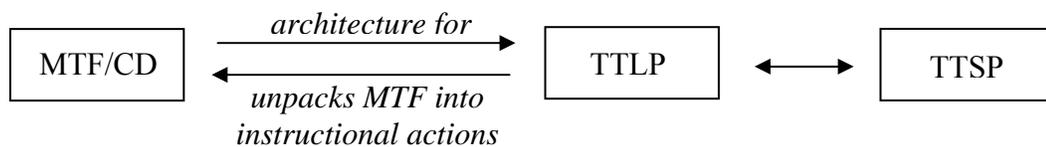
Figure 3.3. Complementary Relationship among the MTF, TTLP, and TTSP.

Together, the three tools, the MTF, TTLP, and TTSP combine to create a set of complementary tools, each that function individually, but are inextricably connected in their design for the purpose of creating a more holistic approach toward improving teacher instructional and leadership practice. The three tools act to inform one another, but they also potentially act to inform the teacher. Figure 1.1 illustrated a possible relationship among these tools, the teacher, and her practices. It becomes the work of the teacher to interpret these tools and apply them to her practice within the context of her other experiences, whether related to professional development or to classroom experiences. In the end, the tools themselves are not self-enacting; the user can constrain or increase the possibilities that one may achieve with support from the tool.

Timeline of the Project

       The professional development project existed formally over three school years. It launched in the spring of 2003 and concluded in the spring of 2006. During that time period the Cohort 1 group (i.e., Veterans) met for seven full-day sessions and a two-day summer retreat during Year 1 (Veterans only), six full-day sessions during Year 2 (Veterans with Cohort 2 participants), and four full-day sessions during Year 3 (Veterans with Cohort 2). The timeline of events and corresponding dates of data collection are shown in Figures 3.4a, 3.4b, and 3.4c.
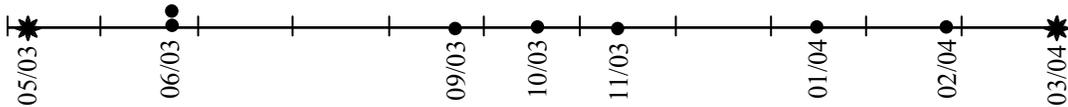
Figure 3.4a. Project Sessions May 2003 through April 2004.
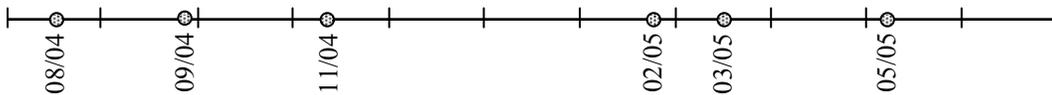
Figure 3.4b. Project Sessions August 2004 through July 2005.
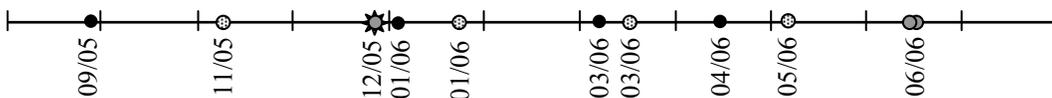
Figure 3.4c. Project Sessions and Interviews September 2005 through August 2006.

● Veteran Cohort (Cohort 1)
◉ Veteran Cohort and Cohort 2
○ Interview
✹ Critical Event

       In addition to the four combined full-day sessions for Veterans and Cohort 2 teachers during Year 3 of the project, there were four half-day sessions when only the Veteran's met. The project team designed the "closed" (i.e., for Veterans only) sessions

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to enable collaborative planning of the countywide sessions with the Veterans. These "closed" sessions alternated with the countywide sessions that were open to all participants. While project team members came to these sessions equipped with a draft agenda and potential tasks for the countywide professional development sessions, the Veterans were instrumental in formulating the plan that the lead facilitator enacted with their colleagues, the Cohort 2 participants. In addition to being a collaborative forum for planning, the Veteran meetings were also an opportunity for the potential teacher-leaders to share and reflect upon their planning and facilitation of district-based professional development sessions tied to the countywide project.

A Typical Session—Learning to Use the Tools

Although the tools of the professional development project (i.e., the MTF, TTLP, and TTSP) are the focus of this study, it is important to make known that the project team did not use these tools as isolated methods to prepare teachers for future learning. Instead, the tools resided within a larger context, the professional development sessions. These sessions typically were composed of a regular series of professional learning tasks—PLTs (Smith, 2000) designed to provide opportunities in which the potential teacher-leaders could learn the underlying concepts embedded within the tools and to use the tools to support improvements in their practice. Thus, although I argue that the tools scaffolded the teacher-leaders learning in profound and unique ways apart from what might have been achieved in the absence of the tools or by one particular type of tool, I must also recognize that corresponding activities (i.e., the PLTs) likely supported and facilitated participants' use of the tools. The following is a summary of a typical session design during the first two years of the project.

During the first two years of the project, the years in which the first cohort of teachers began to use the Mathematical Tasks Framework (MTF) and Thinking Through a Lesson Protocol (TTLP) with respect to their own classroom and leadership practices, sessions typically followed a regular design structure. This structure consisted of: (1) doing and discussing a mathematical task, (2) reading and discussing a case study that used the mathematical task explored earlier in the session, and (3) designing lessons collaboratively using the TTLP. This three-part structure blended two practice-based approaches to professional development: case analysis and modified lesson study.

The project team used the cases with corresponding mathematical tasks as opportunities to build aspects of teachers' mathematical content knowledge, as well as serve as the basis for focused inquiry with respect to classroom instruction. In this manner, the cases and tasks served as what Grossman and McDonald (2008) refer to as "pedagogies of investigation." The project team used the modified lesson study as a method "to apply to their [teachers'] own practice the insights acquired from the case analysis" (Silver, Ghousseini, Charalambous, & Mills, 2009, p. 250). Thus, the modified lesson study provided a way to help teachers move from ideas about practice to actions within practice; in this way, the modified lesson study served as a potential "pedagogy of enactment" (Grossman and McDonald, 2008). The TTLP, the tool of action that teachers used while they collaborated to plan lessons, was the primary structure used by the project team for the intent scaffolding the transfer of specific instructional actions explored during the professional development sessions to the teachers' practices, bridging one context to the next. In the two sections that follow, I describe how the tools were introduced to participants and unpack one session as an example to elaborate the ways in

the TTLP and MTF were embedded within the larger context of the entire professional

development project.

The Tools as Introduced to Participants

The project team formally launched the MTF (see Figure 3.1) with corresponding

levels of cognitive demand and TTLP (see Appendix A) to participants at the second

session of the project, the summer 2003 retreat, and used them in some capacity at each

session after that point. Because teachers used these tools at all but the first of several

professional development sessions[16], the project team considered these tools to be

features of the project design. The two-day summer retreat was designed to familiarize

Cohort 1 participants (i.e., Veterans) with the overarching goals of the professional

development project, engage teachers in doing cognitively demanding mathematics tasks,

and begin to build a collaborative culture for teacher learning. To strengthen

participants' understandings of the project and to begin to develop a shared language, two

of the three tools to be analyzed in this study were embedded into the design of the

retreat. These tools, the MTF (Stein & Smith, 1998; Stein, Smith, Henningsen & Silver,

2000) with corresponding levels of cognitive demand, and the TTLP (Hughes & Smith,

2004; Smith & Bill, 2004; Smith, Bill, & Hughes, 2008), offered the project team visual

and written representations of ideas and common ways of communicating these ideas.

Although the project team had introduced the MTF in May 2003, they devoted the

June retreat to further developing teachers' understanding of the framework and its

implications on practice. The goal for the morning session was stated "To help teachers

deepen their understanding of the MTF/task demand by giving them more examples in

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[16] The research team introduced the MTF at the first session in May 2003 but significantly more time was devoted to its use in practice at the second session.

different settings and to focus attention on these ideas within their own teaching practice, in particular, the impact of teacher actions on task demand for students (annotated agenda, June 2003).[17]

To accomplish this goal, the project team planned to use a narrative case of teaching as the context for discussing task appearance in materials, teacher set up of the task, teacher enactment of the task with students, and opportunities for student learning of mathematics—each of the components of the MTF. The project team used the narrative case for the purpose of explicating issues associated with cognitive demand of tasks, as the case task was enacted differently (i.e., in ways that either supported or undermined the cognitive demand of the task) by one teacher with two groups of students. In addition to the case, a poster-sized visual representation of the MTF was hung in the classroom so it could be used to further clarify and discuss the phases and intended meaning of the MTF. Teachers explored the MTF, along with corresponding notions of cognitive demand from multiple perspectives throughout the two-day retreat.

The Thinking Through a Lesson Protocol (TTLP), was introduced on the second day of the retreat. The TTLP was not a planned intervention when the project team initially designed the opening sessions. The primary facilitator brought the TTLP to the team because she felt that the teachers' planning time at the first session was not productive—not because teachers did not use the time to plan but because their planning lacked focus on substantive issues (Project Planning Team Notes, May 2003).

The TTLP is composed of a series of several questions that teachers ideally ask themselves prior to enacting a lesson with students. Given the number of questions on

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[17] The wording, "to help teachers deepen…" is not incorrect, teachers were briefly introduced to the notions of the MTF and levels of cognitive demand at the initial session in May 2003. However, at that time no tools were introduced to support teachers' understandings of these concepts.

the TTLP, in addition to the fact that it represents a non-familiar method for planning lessons, the project team decided to orient the teachers to the tool prior to its deployment at the professional development session (Project Planning Team Notes, May 2003). . The project team initially shared the TTLP with teachers through a presentation format. Teachers then had opportunities to interact with the TTLP that did not require them to use it to plan an entire lesson (annotated agenda, June 24, 2003). For instance, during one activity teachers focused solely on section two of the protocol and used it to consider how they might support student learning for two sample students. Toward the end of the day, after completing a series of activities structured to acquaint teachers with the tool, teachers collaboratively planned a whole mathematics lesson with a grade-level colleague using the TTLP as a template for their work. For homework, prior to the next session in September 2003, the project team asked teachers to enact these lessons in their classrooms. The expectation was that teachers would reflect on and share their lesson enactments at the first session of the 2003-2004 school year.

Beginning with the October 2003 session, the project research team began to have teachers use an adapted version of the TTLP (see Appendix B) when collaboratively planning lessons at the sessions. The project research team did not change the intent of questions on the adapted version. The focus remained on teachers' use of cognitively demanding mathematical tasks. Instead, the research team prompted teachers' attention to a subset of questions. The team decided to adapt the original TTLP in this way because some teacher participants began to write extensive plans that were several pages in length. Thus, the team became concerned that some teachers might become frustrated with the professional development given the amount of time they appeared to spend

completing the TTLP outside of the sessions. Additionally, there was some evidence from the teachers' lesson debriefings that they were struggling to answer particular questions substantively. The team predicted that this might be due to the number and variety of questions on the protocol (Project Planning Team Notes, October 2003).

The final tool of the project was the Thinking Through a Session Protocol (TTSP) (see Appendix C). The project research team began to use the TTSP with teachers during the third year of the project in November 2005. The team opted to create this parallel tool to the TTLP because it appeared, considering district-based and countywide session observations, that teacher-leaders struggled to facilitate focused sessions with their colleagues (Project Planning Team Notes, November 2005). The planning team designed the parallel tool for planning professional development (i.e., the TTSP[18]) sessions using the TTLP as a guide. Though introduced relatively late in the project, it was not entirely foreign to participants upon its induction as it is well aligned to the TTLP. Just as the intent of the TTLP is to support teachers in planning lessons to enact with students, the purpose of the TTSP is to support teachers in planning professional development experiences to enact with colleagues.

The TTSP, much like the TTLP, was an unplanned intervention conceived out of a perceived need. Following Year 2 of the project, the project team was disappointed by the limited leadership capacity they observed among Veteran participants. For example, most Veteran participants appeared to take little initiative in designing or enacting district-based sessions. When Veterans did organize district-based sessions, the meetings often lacked explicit goals and agendas (Session-planning interviews, 2005). In addition,

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[18] Smith and her colleagues later created their own version of the TTSP. Their version is not identical to the one the project planning team created and used but it is very similar. Both research teams built their respective TTSPs by modifying Smith's TTLP.

with respect to the countywide meetings, the Veterans appeared apprehensive to facilitate small table-group discussions of the same mathematical tasks and cases that they engaged with the prior year as participants. As a result of minimal engagement in leadership practice with respect to the Veteran participants, the planning team modified the TTLP to address planning of professional development.

In an attempt to support the Veterans more explicitly during the third year of the project, the planning team shared the TTSP with the teacher-leaders from the Veteran Cohort. The project team did this by using the TTSP to pre-brief the professional development sessions planned and enacted by the Veterans. Project planning team members met with individual veterans prior to the district-based sessions and used the TTSP as an interview protocol to learn about what a Veteran had and had not considered prior to implementing the upcoming professional development.

A Typical Session—Unpacked

The session described below occurred the first year of the project in September 2003. Although this session was situated at the beginning of the school year, it was the fourth full day of collaborative work for the Cohort 1 teachers. The purpose for unpacking this session is not to suggest that others follow this particular routine for session enactment.   Rather, it is to illustrate the embedded nature of the MTF and TTLP within the larger context of a full session.

The goals of the fourth professional development session, as recorded on the annotated agenda (September 2003), were to help teachers: (a) sharpen their focus on the mathematical goals of a lesson (unit/year) and the instructional decisions they make to advance those goals during each of the phases of a lesson, (b) think about the ways in

which their instructional decisions might support the development of students' conceptual understanding of a mathematical concept and, in particular, the ways in which a students' knowledge of and flexibility with and among multiple representations of a concept contributes to their conceptual understanding of that concept, and (c) focus their attention on evidence of student learning during a lesson. These goals are preliminary indicators of the embedded nature of the MTF and TTLP within the larger project. The goals listed above include connections to the MTF and TTLP. To begin, the primary goal of the session is to support teachers in their ability to identify mathematical goals and to use those goals to guide their instructional decisions. This aligns with the TTLP in that the first question asks teachers to articulate what they want students to learn by the end of the lesson. Furthermore, this goal aligns with the MTF in its reference to the phases of the lesson (i.e., task as appears, as set up, and as enacted) and the need to make instructional decisions focused on mathematical goals throughout those phases.

The session itself was composed of four parts: the introduction, doing the mathematical task, reading and discussing the case, and planning using modified lesson study. During each part of the session, the participants and the project team directly and indirectly referenced the MTF and TTLP. This session began with a brief recap of the previous sessions which the lead facilitator launched. Instead of telling the participants what they previously studied, the facilitator asked, "What continues to bubble up for you with respect to what we discussed at the June retreat? (audio recording, September 2003). After a long pause and some joking regarding the length of time that had passed since the last session, the participants began to share some ideas. For example, one participant mentioned that tasks differ with respect to what students have an opportunity to learn.

Another participant, a principal, noted that she did not realize there could be a disconnect between the tasks as set up by the teachers and the tasks as enacted with students. What is notable about these comments is that both use vocabulary from the MTF and cognitive demand even though the participants were not prompted to use such language. Following these comments, the facilitator reminded participants that the group had spent "a fair amount of time" discussing strategies that are likely to maintain the cognitive demand of a task as it is enacted with students. Although the teachers seemed as if they did not recall the list to which the facilitator referred, many began to look through their bound grid notebooks for a reminder (audio recording, September 2003). At this time, the facilitator posted a large version of the list on the wall for all to use. This list of strategies eventually became known by the group as "scaffolding strategies." The scaffolding strategy list was a consistent and ongoing piece of work the evolved throughout the first year of the series.

Following the introduction of the session, another facilitator launched the mathematics task that the teachers would later read about the enactment of in the narrative case study. The majority of the discussion centered on the first of three problems from the opening activity of *The Case of Randy Harris* (Smith, Silver, & Stein, 2005a). This task is shown in Figure 3.5. While working on the task, the facilitator prompted the participants to think about the problem visually so as to resist using a known algorithm. He also told the participants to consider the mathematics that is involved in solving this problem and, in particular, what students need to know to solve the problem in the manner the case teacher is trying to get students to use (i.e., reasoning build from the diagram) (audio recording, September 2003). By asking these questions,

the facilitator attempted to connect the teachers' work on the task to the larger goals of the session that centered on identification of appropriate mathematical goals and the use of instructional actions that support these goals as the task moves through phases within a lesson. By connecting to the goals of the session, the facilitator also made connections to the tools, the MTF and TTLP.

Shade the portion of the area of the rectangle that represents .725.

What fractional part of the area is shaded?

What percentage of the grid is shaded?
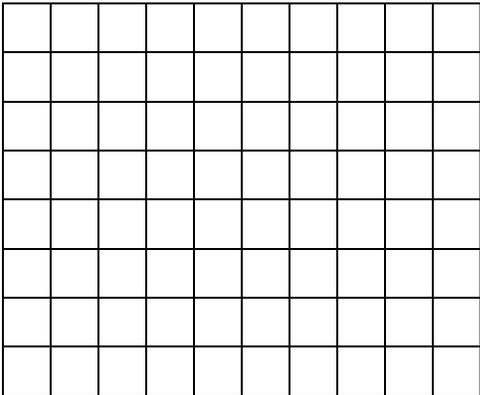
Figure 3.5. The Opening Task for "The Case of Randy Harris." Adapted from *Improving instruction in rational numbers and proportionality: Using cases to transform mathematics teaching and learning* (Vol. 1), by M.S. Smith, E.A. Silver, & M.K. Stein, 2005a.

Once teachers had approximately fifteen minutes to work on the task, the facilitator began a discussion of the multiple solution strategies used by the group. He noted that although many of the teachers looked for "convenient chunks" as they solved the task, how they did this was different. He articulated that while the group might argue that the strategies the teachers used were the same, they were also different in some way. This facilitation move is important to note because it prompted the participants to try to consider what was special or unique about certain strategies. In doing so, it also provided

teachers an opportunity to try to think about others' strategies, much like the TTLP suggests with respect to student thinking.

As the facilitation continued, participants discussed how they used the diagram to reason mathematically. In summarizing the conversation, the facilitator asked, "The way the problems are worded gets us to think about them visually; what is the value in doing this" (annotated agenda, September 2003)? One participant responded, "it forces us to understand percent." The facilitator then asked, "How is this different from just giving kids a ten by ten grid and asking them to identify one-fourth?" To which, another participant responded, "Real life isn't always in hundreds or tens" (audio recording, September 2003). Out of this exchange emerged an opportunity for the facilitator to summarize two big ideas: (1) non-routine tasks, like the eight by ten grid in the Randy Harris case, when enacted in ways that maintain the cognitive demand of the original task, can provide different types of opportunities for mathematical learning than those tasks that are more routine or memorization-based and (2) using a diagram enables the teacher a window into student thinking that other forms of representation might not. Again, both of these ideas are consistent with the concepts and instructional actions that are suggested by the MTF and TTLP.

The third part of the session consisted of teachers reading and discussing the Randy Harris case. Recall, the mathematical task described above is the same task that students explored in the case. The project team designed three focus questions to which the facilitator used to frame the group conversation of the case. The focus questions were: (1) What are the teacher's mathematical goals for the students? (2) In what ways did these goals influence his instructional decisions in each phase of the lesson? and (3)

What evidence do we have from the case that the teacher may have reached his mathematical goals? Once again, there is evidence of a consistent focus throughout the session.

The first focus question used by the project team gives teachers an opportunity to practice articulating mathematical goals in ways that are likely to be different from what they typically do in practice. Thus, asking this question about mathematical goals provides a way for the project team to help the teachers learn to use the TTLP as intended by the authors. The second question sets teachers up to consider the flow of the task throughout the lesson. More specifically, it sets up a discussion in which teachers might engage with issues associated with the maintenance or undermining of cognitive demand. Thus, this question has the potential to scaffold both teachers understanding of the MTF and their use of the TTLP. Finally, the third focus question is an opportunity for the project team to create in experience in which teachers use evidence to reflect on practice. Though this is not a question that appears explicitly on the TTLP, reflecting on teaching practice suggests a process that teachers might also apply to their own practice—a strategy that has the capacity to prepare teachers for future learning.

During the facilitation of the case, teachers were able to recognize the mathematical goals of the lesson. For example, they noted that the case teacher did not want his students to rely on algorithms only. They cited evidence in which the case prompted his students to use visual diagrams so that his students' could develop a deeper understanding of the relationships among decimals, percents, and fractions. The teachers also noticed that the case teacher provoked his students to think beyond the numerical symbols, to make sense of what the symbols meant (annotated agenda, September 2003).

While the teachers seemed prepared to identify mathematical goals, they seemed less prepared to answer the other two focus questions. During the remainder of the case discussion, the teachers focused on concerns they had regarding the instructional actions that the case teacher took while enacting the task with his students. Although the participants veered from the original set of focus questions, the case still provided an image of what instruction using cognitively demanding tasks could look like. However, the case did not provide a way for the teachers to take specific instructional actions into their own practices.

The final portion of the day was devoted to modified lesson study, a method to scaffold transfer of instructional actions suggested through the professional development to teachers' own classrooms. The project team allowed approximately an hour for teachers to debrief the lessons they planned using the TTLP and recently enacted in their classrooms and to begin to plan another lesson using the TTLP. During the debriefings, members of the project team sat with small groups to facilitate the conversations. The purpose of providing each group with a facilitator was to push the conversations toward issues related to the MTF and the TTLP. For example, during one small group conversation a facilitator asked whether it was easy for the teacher to anticipate students' misconceptions; anticipating student misconceptions is a prompt on the TTLP. Another facilitator tried to learn what teachers' considered doing differently in their classrooms because of what they learned from this enactment, connecting to issues of cognitive demand. Although the small groups did not have identical conversations, the facilitators worked to prompt the teachers to consider instructional issues consistent with the MTF and TTLP.

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After teachers debriefed their lessons, they selected a new lesson from their materials to plan using the TTLP. Teachers sat in groups of two to three to begin planning. At many of the sessions, teachers did not finish their plans that day. Instead, they completed their plans, mainly individually, back in their home districts. The teachers consistently enacted these lessons prior to attending the next session and shared their experiences with colleagues over the course of the project.

From this summary of a typical session, one should begin to develop an understanding of the context in which the project team and the teachers used the tools over time. Again, my intent in unpacking a typical professional development session from this project is not to suggest one particular way in which these tools, or similar types of tools, should be used. Instead, my hope is that, by describing the context in which these tools were used, the reader may become familiar with how the teachers learned to use these tools and thus, became knowledgeable users of the tools throughout the project.

The Project Participants

The original participants were twelve teachers, representing four school districts in a densely populated Midwestern county. The mathematics consultant from the ISD recruited these teachers to participate in the project. To do so, she identified districts that had been using a standards-based instructional series for at least a year. Next, she spoke with principals from those districts to identify potential teacher-participants, one of the criteria being teachers who might take on mathematics leadership roles in their districts. From the list of potential candidates, she and the principals worked together to build a

cadre of teachers willing to participate (Mills, V.L, personal communication, March 2009).

This selection process led to the development of a cadre of teachers that had been using standards-based instructional mathematics materials for varying amounts of time, from a little over a year to over eight years; two of the teachers had participated in pre-publication studies to refine the instructional materials. Some of the teachers were relatively new to the profession, only in their second year of teaching at the time the project started, while other participants came to the project with over twenty years of teaching experience. There was great variability with respect to teaching experience in this cohort group of teachers, which later the project team named the Veteran Cohort (i.e., veteran with respect to their participation in the project), but they shared a common desire—to become more skilled at using their standards-based instructional resources with students. At the time of selection, the research team only had a loosely developed vision that these teachers would become teacher-leaders in their districts, a vision that evolved throughout the course of the project.

The Case Teacher for this Study

As noted earlier, the professional development project that is the context for this study began with twelve participating teachers, each volunteers. For the purpose of this study, one of those teachers will be analyzed with respect to (1) the ways in which she took up and used the tools grounded in this practice-based mathematics professional development project and (2) her use of such tools to support (or undermine) the exchange/transfer of ideas from her classroom practice to her leadership practice.

I selected Helen Emerson as the subject of this case study for several reasons: (1) she is typical of many teacher leaders in that she was put into the role of teacher-leader based on her teaching experience and perceived content knowledge, but has received little direction from her district regarding how she might go about effectively supporting colleagues; (2) data are available about Helen's classroom, as well as her interaction with colleagues—both fellow teacher leaders and teachers over several years; (3) data from Year 1 suggest that although Helen appeared to have a strong mathematical background, she struggled with how to effectively enact standards-based instructional materials; (4) data from Year 1 suggest that though Helen's job was to support her colleagues, she had few resources (conventional and intellectual) from which to pull to enable her to do so; and (5) these data show that Helen made growth, in terms of leadership practice.

At the origin of the professional development project Helen was a 7th grade teacher and a secondary mathematics specialist in Devingston Community Schools, a suburban school district in a Midwestern county. Helen had a limited class load with release time devoted to supporting the district's needs in secondary mathematics when she became involved with the project that serves as the context for this study. She was in her twelfth year of teaching mathematics, but only her third year at the middle school, as shown in Figure 3.6; prior to 2001 Helen had taught mathematics in the high school. Helen was relatively new to her role as a teacher-leader and had only begun to explore ways in which she might support her colleagues in Devingston.

Helen begins teaching
high school
mathematics
(year 0)

Helen begins
teaching middle
school mathematics
(year 10)

Helen begins
participation in
this project
(year 12)

Figure 3.6. Helen's Professional Timeline.

During the initial two years of the 3-year project, Helen attended eleven out of

fifteen sessions. During the third year of the project, she attended each of the four

Veteran only sessions, as well as each of the four countywide sessions. In addition to

attending nearly all of the countywide sessions throughout the span of the project, the

case teacher co-planned and co-facilitated four[19] out of five district-based professional

development sessions that occurred Years 2 and 3 of the project within her district.

Throughout the project, Helen was an active participant.

My Role

My role in the professional development project was multifaceted and evolved

over time. At the opening session in May 2003, I was a new graduate student assigned to

the project. Prior to returning to graduate school I had been a middle school mathematics

teacher for four years and had had no experience planning or enacting professional

development; my only experience with professional development had been as a

participant and never in a practice-based setting. I was a novice with few expectations

and even fewer ideas about how to make the project a productive opportunity for

classroom teachers.

Throughout the project, my knowledge base and experiences grew. Over a two-

year time period I took several courses that resided at the intersection of research,

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[19] Helen did not participate in planning and enacting one of her district-based sessions during the 2005-
2006 school year because she was on maternity leave. This leave also accounts for Helen's absence at two
of the countywide sessions during the same school year.

professional development, and mathematics. These two years correspond with the first two years of the project. During the third year of my studies, my role in the project shifted dramatically. While I continued as a graduate student at the university, the intermediate school district (ISD) with which the university collaborated for this project hired me as a full-time mathematics consultant. At that time, my role in planning and enacting the professional development increased. Previously, with respect to the project and this study, I had been a participant-observer to the planning and primarily an observer to the enactment; with my new role, I became a participant-observer at both levels.

As an ISD mathematics consultant, I facilitated sessions for the Veterans, participated in collaborative planning with my supervisor (beyond what occurred at the project team meetings), selected resources, and contacted participants. I also transitioned from an outsider (i.e., member of the research community) to an insider (i.e., member of the K-12 community). This new role gave me access and opportunities that were not available when I was only connected to the university. My membership in the K-12 community enabled me to communicate with participants not as a researcher, but as supportive colleague. Thus, I became equipped to study this case with unobtrusive access to the site of the study, as well as to the participant whose work would be the lens through which I analyzed tool take up and usage in practice-based professional development. This role also positioned me to more readily understand complex situations within the context of the study given the nature of my relationships with the participants of the project and the project planning team.

Over the course of the project, I learned to juggle three evolving agendas: that of a researcher, a professional developer servicing the case teacher's district, and a colleague. I have listed these agendas not by order of importance, but as they evolved chronologically. As a researcher, I had access to the context of my study by means of being a graduate student researcher on the project. However, I had to regularly negotiate access to the participants by initiating myself into exchanges during small group, whole group, and casual conversations throughout the multiyear project. These exchanges did not constitute formal data collection. I did this to gain access to information regarding the participants' planning and implementation of lessons, as well as their thoughts regarding the efficacy of the project, including its impact on their leadership practices. I also used conversations as a way to build interpersonal relationships with the participants; I wanted to gain their trust. First, I wanted the participants to believe that I, a stranger to them at the onset of the project, would not use information about their teaching or knowledge of content in unethical ways. Second, I wanted them to see my participation in their conversations as useful to their practice.

As an employee of the ISD, my role was not only to study teachers' practice, but also to do all that I could to positively impact their instructional choices in hope of raising student mathematics achievement in the participating districts. I sought to encourage thoughtful planning and analysis of instructional practices; one might perceive this role as that of a mentor. Finally, and most recently, approximately two and a half years following the end of the project, I became a colleague to Helen, the teacher that is the subject of my case study. As a colleague, I regularly plan professional development experiences for teachers with Helen. Thus, I have access to how she plans and delivers

professional development several years after the project ended that is the context of this study.

Working with multiple agendas, even when they do not occur concurrently, makes my work complex. However, this complexity also adds richness to my study. When the project began, I was a novice graduate student and an outsider to the county in which the project was situated. I had minimal familiarity with the districts, and no ties to any of the participants. Thus, I came into the project without preconceptions about what might or might not happen as a result of working with the teachers. Additionally, I had no experiences with or knowledge of the tools that would become the subject of this study. My initial unfamiliarity is a feature that has enabled me to enter the project, and this study from a relatively unbiased perspective. Granted, I am now deeply familiar with the tools of the project, as well as with the districts that participated in the project, but that fact remains that I did not enter the project with the end in mind.

As my role evolved, so did my understanding of the project and the tools the team selected for use in the professional development sessions. By being part of the project team, I had and continue to have access to the intricacies of the project that others might not. For instance, I know why the team selected certain tools. I also have had the opportunity facilitate sessions and small group discussions as teachers, including Helen Emerson, interacted with the tools. I have seen and heard how teachers have responded to the tools over time, which has enabled me to see possible constraints and affordances of the tools that I might have missed had my role been less applied.

The main difficulties of having evolving and sometimes overlapping roles are (1) in distinguishing my memory of experiences from existing data and (2) oppressing my

interest that the project has a positive outcome on mathematics teacher learning. To prevent this study from being an anecdotal recall of select experiences, I have taken seriously the need to code and recode data. I used an iterative process in which I continually compared newly coded data with prior analyses to check for consistency and meaning. Additionally, I systematically reduced the data using interviews to select which data sources I would review and analyze. To suppress my desire for the project to have a positive outcome, I relied on my iterative process for coding to let the data tell the story.

In spring 2009, my role further evolved to that of a colleague of the teacher that is the subject of my case study. At that time, the ISD also hired Helen as a mathematics consultant. Although some neutrality may be lost as a result of my role as an insider, my perspective and insight as an insider also enables me analyze interactions and situations with a level of understanding that an outsider would not be likely to have. In fact, some researcher's view an insider's perspective is "invaluable" in achieving a truthful portrayal of a case study phenomenon (Yin, 2003). Though my role as an insider is likely to have affordances with respect to this study, the costs are minimal as my role has not caused me to take on roles that might compromise my findings or make the study more challenging to complete.[20]

A final issue of having multiple roles in this study is that of voice. For the purpose of clarity, I will use the third person when referring to my role as a member of the project planning and facilitation team and, as a colleague to Helen. I will employ the first person voice when reporting analyses and results as the researcher.

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[20] Yin (2003) sites four major problems with participant-observation, none of which are concerns with regard to my study: 1) perceived need to assume advocacy roles contrary to the interests of good scientific practice 2) desire to become a supporter of the organization 3) participant-observer may require too much attention relative to the observer role (this was avoided by videotaping sessions) 4) the location of the research site is dispersed or otherwise problematic due to location.

Data Records

   The research team collected data related to uptake and usage of tools to scaffold the development of leadership practice over the course of several years. Initial data collection began in May 2003 at the first professional development session and continued through November 2007, at which time the research team conducted a concluding interview approximately one and a half years after the final professional development session. Over the course of the project, data collected consisted of annotated agendas of countywide sessions, teacher lesson plans, end of session reflections, video recordings of countywide sessions, field notes of district-based sessions, project interviews, and district-based planning interviews. The variety and number of artifacts are shown in Table 3.1.

Table 3.1
Data Sources Summary Table

Focus of Data Collection	Types of Data	Person(s) Collecting the Data	Method	Frequency			
				Y_1	Y_2	Y_3	Post
Project Impact	Digital Audio Files, Transcripts, and Interviewer Notes	Project Team Researcher	Individual Interview	1	1	1	1
Project Impact	Digital Audio Files and Transcripts	Project Team Researcher	Focus Group Interview			1	
District-based Session Planning	Digital Audio Files and Transcripts	Project Team Researcher	Individual and with a Colleague			2	
Countywide Professional Development	Annotated Agendas	Lead Facilitator with Project Team Researcher	Collaborative Planning of Professional Development	8	6		
Countywide Professional Development	Video Recordings	Project Team Researcher or Videographer	Direct Observation of Professional Development	8	6	4	
Record of Veteran Sessions	Video Recordings	Videographer	Direct Observation of Professional Development			4	
Classroom Instruction	Teacher Lesson Plans	Teacher	Document Review	2	1		
Personal Reflections	End of Day Reflections			4	3	3	
District-based Sessions	Field Notes	Project Team Researchers	Direct Observation			2	

In addition to the body of data the research team intentionally collected, I gained access to the notebook that belonged to Helen Emerson. Helen's notebook contained her session notes (her work on mathematical tasks and other session activities), copies of narrative cases and articles in which she took notes, and materials from two professional development sessions that she planned and enacted outside of the work of the project.

Although the project team did not systematically collect the notebook and its contents, these artifacts serve as relevant and appropriate sources of data for this study.

Process of Analysis

As characterized by Stake (2000), a case study is a "process of inquiry" as well as a "product of inquiry" (p.436). With respect to this study, the case study is a process as well as a product. To this end, I began my analysis using a grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1998) approach to provide structure and systematic analysis to a relatively large set of extended texts. Having a detailed process for analysis was and is especially important given the dense nature of much of the available data (e.g., field notes, transcripts, and video), as too much narrative can lead one to naturally seek and find simplifying patterns rather than "true" conclusions (Miles and Huberman, 1994). To utilize grounded theory as a process for data examination I proceeded by beginning to apply multiple levels of analysis, each of which sought to add increasing specificity to the themes that would develop through successive open coding, axial coding, and selective coding (Strauss & Corbin, 1998; Harry, Sturges, & Klinger, 2005). Unfortunately, the process described above became increasingly problematic and unfruitful over time.

The process became problematic because I opted to use an existing list of codes that the project team developed collaboratively. My desire to use this list of codes stemmed from the fact that they had been developed, checked for inter-rater reliability, and agreed upon by the project team, thus adding reliability to my study. Unfortunately, the codes did not well align with my study of how and in what ways the teacher took up ideas from the tools of the project.

The team had developed these codes to track instances of particular artifacts, ideas, or events of the project. Thus, some of the codes were too discrete to enable me to see trends pertinent to my study. I sought to identify what the teacher appeared to view as ideas relevant to her practice in order to understand the role of tools in her ongoing learning. Thus, discrete ideas were less useful to my study than broader trends might be. In the text following Table 3.2, the list of preexisting project codes, I describe two examples of how the discreteness of the original project codes could have served as a barrier to seeing the development of trends in the data.

Table 3.2
Preexisting Project Codes

Code	Description
1	Reflections on students' thinking (reasoning, conjecturing, struggles, difficulties)
2	Scaffolding strategies
3	Classroom management (management of time within a lesson, student engagement)
4	Curriculum management (management of time across lessons- pacing, materials)
5	Sharing classroom experiences
6	Connecting mathematical goals to instructional decisions
7	Teacher collaboration
8	District and state policies
9	Multiple solutions-representations
10	Mathematical content of tasks
11	Formative assessment
12	Summative assessment
13	TTLP
14	TTAP
15	TTSP
16	Mathematics Task Framework (MTF)
17	Level of Cognitive Demand (LOCD)
18	Teacher leadership (evidence of and challenges)
19	Non-Bifocal resources for leadership

In the original coding list, the research team separated "multiple solution strategies" from "mathematical content of tasks". The problem with this separation is

that the data indicated that the teacher in my study used multiple solution strategies to deepen her understanding of mathematical content. Thus, separating the two codes obscured this emerging theme. When modifying the original project-coding scheme I merged these codes as one idea. A related example is the project team's decision to separate reflections on students' thinking from formative assessment. Again, my exploration of the data yielded evidence that the teacher "reflected on student thinking" for the purpose of "formative assessment" and then used this information to "connect mathematical goals to instructional decisions." In modifying the existing list of codes, I eventually merged these three ideas to enable me to see readily the development of such themes. Table 3.3 shows the list of modified codes I created using the existing project codes.

Table 3.3
Modifications to Existing Instructional Project Codes

Formative Assessment/Math Goals
• Reflections on students' thinking (reasoning, conjecturing, struggles, difficulties)
• Connecting mathematical goals to instructional decisions
• Formative Assessment
Questioning
• Scaffolding strategies
• Classroom management (management of time within a lesson, student engagement
Multiple solutions-representations
• Multiple solutions-representations
• Mathematical content of tasks
Curricular Knowledge
• n/a
Connections Among Actions
• n/a

Note: The header of each section represents the modified code I used for this study. The bulleted codes represent the original codes used by the project team.

I also modified the tools codes. To do this I added a distinction between implicit and explicit references to tools listed on the preexisting project coding protocol. Additionally, I created codes for an explicit reference to a case study, a mathematical task, or time as a resource. I did this to trace other potential reasons for shifts Helen claimed to make in her practice, reasons beyond the set of complementary tools of the project (MTF, TTLP, and TTSP).

Stratified Coding of Interview Data

Although the existing codes were appropriate for the studies the research team conducted, I determined they were too discrete for the purposes of my study. Thus, I decided to create a revised coding scheme based on stratified open coding of interview data. I used the preexisting project codes but made modifications as was appropriate for my study, as shown in Table 3.3 above. To proceed, instead of organizing the corpus of data into five categories based on time of data collection as I proposed prior to conducting this study, I opted to reorganize my data analysis using a "backward" design, "backward" meaning starting from data collected most recently.

In addition to analyzing the data from end to beginning, I focused on the interview data for this first phase of analysis. I progressed in this manner because the project team designed these interviews to understand and assess what impact aspects of the professional development project had on participants, from the participant perspective. Given the purpose of my study, to better understand how and in what ways a teacher took up and used tools embedded within a mathematics professional development project to scaffold the development of her leadership practice, I found it necessary to employ a method that would identify what, in particular, appeared to resonate with the

teacher. Using the interview data during primary analysis enabled me to gain insight into what ideas, processes, and artifacts were prominent for this teacher. Although a researcher must always be wary of self-report, given the highly-subjective nature of such data, in this case the subjectivity of these data are a feature; the intent is to learn what the teacher was most attentive to that led to shifts in her thinking and practice.

The project research team conducted seven interviews with this teacher, five project-impact and two session-planning. However, audio files and transcripts are only available for five of the interviews. To avoid misrepresentation of ideas by over or under counting particular codes, I collected frequency data using only those interviews with corresponding transcripts. This included three project-impact (two individual and one focus group) and two session-planning interviews. I used the instructional codes I identified from my modified open coding of the cumulative interview conducted in November 2007, approximately one and a half years after the completion of the final professional development session for the project, to code the two remaining project-impact interviews.

The interview data consisted of two categories of responses. The first type is that of reflective responses, from this point forth I will refer to this type of interview as a project-impact interview. The research team collected project-impact data to obtain information regarding teachers' perceptions of the project including what experiences were and were not impactful on their classroom or leadership practices. The second type of data the research team collected was session-planning data. The team collected planning data to document teachers' thinking regarding planning, both classroom and leadership. Though interview data is always a form of self-report, the questions asked

during the interviews were indicative of those found on the Thinking Through a Lesson Protocol (TTLP) and the Thinking Through a Session Protocol (TTSP). Thus, though they are not equivalent to direct observation, they do point to what the teacher is and is not attentive to at a given time in the project. Each of the interviews was semi-structured. The interviewers used a protocol, but were permitted to insert questions as they deemed appropriate given the response of the teacher.

I applied a stratified coding system when analyzing the full set of transcribed interviews. Instead of using a wide variety of open codes, I assigned codes to data based on four major categories and developed additional instructional and tool codes as explained earlier in this chapter. The four category codes I used were: 1) focus of data, 2) type of reference, 3) instructional issue, and 4) reference to a tool or resource. The first category, focus of data, kept a record of when and how often the teacher focused on her own practice or that of others. Such a code was necessary to trace shifts in the teachers thinking regarding classroom and leadership practice explicitly. One reason I did this was draw my attention to possible changes in the way in which Helen thought about her practice, as well as links between classroom and leadership practice. The second category, type of reference, tracked whether the teacher was attentive to a process or product. This code offered insight into whether the teacher focused on particular artifacts or generalizable ideas.   I traced her focus over time to provide further evidence of how and in what ways her practice might be evolving. Typically, teachers attend professional development hoping to take back something to try (e.g., a new activity) in their classrooms. This type of expectation is more primitive than an expectation that assumes professional development is about ongoing learning. I used the third category,

instructional issue, to document what instructional issues or actions the teacher referenced. My intent was not to distinguish among all instructional issues or actions, but rather to notice the frequency to which the teacher referenced themes of instructional issues embedded in the tools of this project. Therefore, some overlap among actions is not problematic as the purpose is not to identify how many times a particular strategy is referenced, but rather trends in how the teacher refers to actions (individually or in sets) over the course of the project. The final category keeps a record of which tools or resources used in the project the teacher references, implicitly or explicitly. Again, I included tools beyond what I determined to be the set of complementary tools of the project (i.e., MTF, TTLP, and TTSP) as a method to track contributing influences on change within Helen's practice. Individually, these four major categories, those I used to create a stratified coding system, tell a particular piece to the larger story. However, holistically, they allow trends to emerge.

Prior to completing my analysis of the interview data another complexity developed. The modified coding scheme I created based on the preexisting project codes did not align well with the two session-planning interviews. This is because the research team used the TTSP protocol to interview teachers prior to their district-based sessions. To adjust for the overlap between this code and the interview format, I opted to revise the code list for the session-planning interviews leaving out TTSP. Additionally, I only used the TTLP codes when: 1) the teacher described a strategy grounded in the TTLP and reminiscent of one she originally used with students or 2) she implicitly or explicitly mentioned use of the TTLP protocol in a session she was planning. Below are excerpts

that exemplify occurrences in which I used the TTLP code for the session-planning

interviews.

In March 2006, Helen discussed her expectation that her colleagues use the ideas

embedded with the TTLP when planning a lesson. It is an example of the latter:

> The other thing that it builds on is that we have already looked at formative
> assessment and using it to inform our practice. And, we are using, when they are
> planning activities, they should be thinking about issues like cognitive demand
> and scaffolding strategies and making mathematics accessible to the students.
> (lines 32-35)

In the excerpt below, Helen referenced a strategy (i.e., asking students to recall a prior

mathematical task to engage them in a current task) she refined while working on

improving her classroom practice. This dialogue occurred during the same session-

planning interview in March 2006 from which the prior quote appeared. Helen shared

with the interviewer how she might access teachers' prior knowledge. She commented:

> But we might also ask questions that are specific to content. Like, I might refer to
> a book. If we are at a graph that is distance versus time I might say, "well
> remember what we did in *Variables and Patterns.*" Kind of have them recall
> activities that we have already done so that they can plan some more. (lines 40-
> 44)

Even though the codes would not have captured this piece of data, to answer my research

questions, it was important for me to track both types of references to the TTLP. The

latter enabled me to learn how Helen used the TTLP with colleagues while the former

illuminated connections that Helen made between her classroom practice and her

leadership practice. Together, these categories of data provided evidence of transfer from

one context in which Helen interacted to another related context.

Out of the complexity described above emerged a second issue with respect to

analyzing the interviews for tool identification. Because the MTF is the architecture for

the TTLP, I realized that when Helen referenced the TTLP, implicitly or explicitly, she also referenced the MTF implicitly. My first inclination was to use the MTF implicit code each time that I employed the TTLP code. However, I quickly realized that this decision oversimplified my process for coding in ways that were likely to skew my conclusions. That is, I feared such a decision might compel over-representation of the MTF and under-representation of the TTLP.

To reconcile the complex situation described above, I set more specific standards regarding appropriate use of each tool code. First, I identified excerpts of text solely as MTF when Helen did not allude to planning within the text. For example, when reflecting on what it takes to help secondary teachers shift their classroom practice Helen commented, "Because when you think about an inquiry-based lesson, there are so many other factors. Like number one, the task. If it's not a good task, or how it is presented…" (project-impact interview, June 13 2006, lines 154-156). I utilized the MTF code for this piece of data because Helen pointed to the importance of the mathematical task. Since mathematical tasks are central to the MTF, this is a clear instance of Helen focusing on this particular tool.

Second, when Helen referenced planning, without alluding to the MTF, I used only the TTLP code. Helen referenced only the TTLP, not the MTF when reflecting on "mistakes" she made when planning a lesson during a focus group project-impact interview in June 2003. Helen shared, "I invited myself into someone else's classroom, so I think I made some incorrect assumptions about what the kids would know and what they would misunderstand." (lines 239-243). Although she did not state that she used the TTLP, identifying misconceptions is a strategy explicitly mentioned in the TTLP.

Finally, when Helen referenced both the MTF and TTLP, implicitly or explicitly, I listed both codes. Helen did this when she described an outcome of her participation in the professional development project. She remarked in an individual interview in June 2006:

> One of the things it [the project] helped me do is to articulate how the mathematics tasks are different, how teaching and learning is different in my classroom and explain things like cognitive demand and multiple solution strategies. (lines 11-14)

In the excerpt above, Helen explained that she understands how to make distinctions among types of mathematical tasks as well as, articulate what makes them unique from one another. Such an understanding is the cornerstone of being able to use the MTF to impact instructional decisions. Additionally, Helen noted that she is able to articulate how teaching and learning is different in her classroom specifically with respect to considerations of cognitive demand and multiple solution strategies—two instructional issues to which the TTLP explicitly draws ones attention when planning a lesson. Making this set of decisions enabled me to distinguish between the two tools for purposes of analysis.

The process described above illustrates the levels of coding and constant comparisons I made between newly coded and previously coded data. This type of constant comparative approach to data analysis is a technique that I employed to increase the reliability of the codes and in turn, the resulting conclusions of my study.

Identification of Actions, Events, and Resources

I initially identified critical events, key instructional actions, and resources (potential tools) by analyzing the transcript of the extended interview that the research team conducted approximately one and a half years after the professional development

sessions for the project had ended. I used this interview as the primary data source for the initial stage of my analysis for two reasons. To begin, this interview was cumulative; its purpose was to collect data on the teacher's perception of the overall impact of the project on her practice. The cumulative nature of this interview made it a particularly useful piece of data for early analysis. Being cumulative, this interview enabled me to learn which instructional actions remained noteworthy to the teacher after she had participated in the entire curriculum. It also offered an opportunity to learn which connections the teacher had made between and among actions by the end of the project. The third feature of this piece of data is its separation in time from the teacher's participation in the three-year long series. Because the research team conducted this interview approximately one and a half years after the final session, I am able to gain insight into what aspects of the project remained in her practice (based on her perception) after she was no longer a participant for an extended amount of time.

Although my original intent was to identify key instructional actions, key events, and potential tools solely from the culminating interview, upon further working with the data I recognized that by limiting my preliminary analysis to the project-impact interviews, specifically the culminating interview, I might overlook a pivotal moment in the teacher's evolution from teacher to teacher-leader. This became visible to me while transcribing a session-planning interview. During that particular interview the teacher had a moment of realization that was not like anything else I had read or heard at that point within the data. Because of this discovery, I decided to analyze the entire set of interviews to determine whether additional critical events might emerge.

My purpose for proceeding in this manner was to enable trends to emerge from the stratified categories and make visible potential moments that led to shifts in the teacher's thinking and/or practice. Doing so would enable me to tell a story that speaks to how and in what ways the teacher used the tools of the project to positively affect her thinking about and planning for classroom practice, as well as how she used this thinking to scaffold her leadership practice. Telling this teacher's story through a series of critical events (i.e., points that provoke reconsideration of practice) makes sense as a unit of analysis. Doing so situates me, as the researcher, to unpack what practices seem to be the impetus for cognitive disequilibrium, thus keeping the teacher engaged in thinking and learning about her practice over the course of several years. The critical events, which I will describe in more detail later, are, in reality, a series of defining moments within this teacher's practice. These events serve to add context, as they were plucked from the typical activities (i.e., the rules within the activity system) of the professional development sessions (i.e., case study analysis, modified lesson study, and session planning) and used to tell a story of how a complementary set of tools functioned within a larger context.

I made the decision to analyze and report results through these events because they add focus and clarity to a dense set of data. Instead of trying to analyze all data, I used what I found in the interviews to center further analysis by (1) tracing developments from my interview analysis through data and (2) systematically reducing the data while retaining validity on potential claims. To identify instructional actions and probable tools I counted the frequency of each particular code. I coded all data for the tools I defined in

my conceptual framework, as well as additional resources to which some might attribute perceived changes in practice through transfer of ideas.

Focus on Critical Events

The concept of critical events has been developed and explored with respect to business and industry for several decades (Bitner, Booms, & Tetreault, 1990; Halinen, Salmi, & Havila, 1999; Havila & Salmi, 1999; Vergragt, 1988). Vergragt, a social scientist who studies innovation in industry, defines critical events as "events within or outside research that are *perceived* by relevant actors as critical, and compel them to take a decision about the course to be taken" (p.490). Vergragt emphasizes the notion of perceived relevance, noting that an actor negotiates this decision to change based on her perceived interests, possibilities, and constraints. Such an understanding of critical events aligns with this case study as I apply critical events to tell a story of transfer grounded in a teacher's evolving understanding of her classroom and leadership practices.

The critical events in this study serve to highlight specifically what prompted the teacher to perceive relevance to her own practice at these moments in time and thus lead to her take-up of tools and eventual transfer of instructional actions from classroom practice to leadership practice. In Figure 3.7 below, I have illustrated this process pictorially.

Figure 3.7. Process of Analysis.

Analysis of Interview Data

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Identification of
Critical Events

Transfer from Professional
Development to Practice

Transfer from Classroom to
Leadership Practice
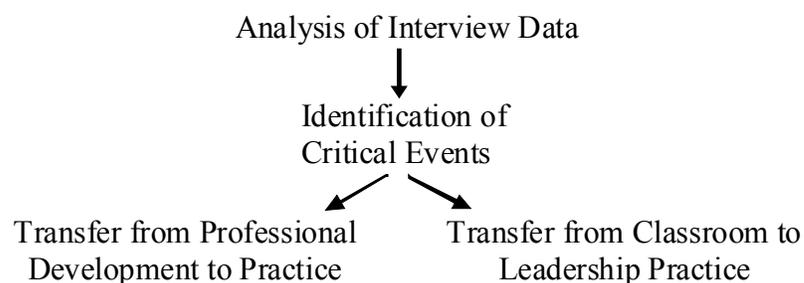
To accomplish this, I explore two specific points of transfer: (1) from professional development sessions to the teachers perceived classroom practice and (2) from classroom practice to leadership practice.

During the process of identifying these events as "critical," I took into consideration the *frequency* with which the teacher referenced specific events, the teacher's *expressions of notable change*, and the teacher's *pivotal reflective moments*. Although these elements varied with respect to objectivity, together they build a more complete and valid argument than any one could do on its own. Frequency of events was the most objective of these three measures. I tracked the number of times the teacher referenced a particular event, explicitly or implicitly.

When documenting expressions of notable change, I looked for excerpts of interview text that included phrases that conveyed a major shift in the teacher's thinking or practice. Examples of expressions of notable change include, but are not limited to, the following phrases: "so that was huge" (interview, November 13, 2007, line 288); "one of the things that nailed it" (interview, November 13, 2007, line 372); and "one of the big things" (interview, November 13, 2007, line 434). I recognized such phrases as expressions of notable change because the teacher used them regularly when emphasizing particular points to the interviewer. Additionally, in the text surrounding these types of phrases the teacher often described a shift in her thinking or practice.

Pivotal reflective moments is, in some ways, the most and the least subjective of the elements I considered when naming a particular event as critical. It is subjective in the sense that the teacher made numerous reflective comments throughout her interviews, many of which one might consider to be pivotal. However, I only identified one of these

comments as a pivotal reflective moment and thus, a critical moment for study. I made this decision because there was a unique quality to this moment. Unlike other reflective moments where the teacher often considered ways in which she might change her enactment of a classroom lesson or her interaction with a colleague within a conversation focused on such thinking, in this instance the teacher paused and removed herself from the ongoing ebb and flow of the interview. Upon pausing, she made a remark outside of the particular point that she had been elaborating to the interviewer. This was, for lack of a better way to describe it, a second order metacognitive move. By second order, I mean she was thinking about herself thinking about practice. No other exchanges of this nature appeared in the data that I analyzed, interview or otherwise.

Reliability and Validity

To establish the validity of my analysis I used a process of triangulation of sources. The three types of triangulation I used are data triangulation, investigator triangulation, and methodological triangulation. Denzin (1978) identified these types of triangulation as a means by which a researcher could strengthen the validity of her claims.

Data triangulation depends on collection of data on a variety of people over a period of time in several settings. I reviewed data for this study from one teacher-leader. However, the research team collected these data over the course of more than four years and in many different settings (e.g., individual interviews and professional development sessions). The longitudinal nature of this data collection is unusual for a case study and adds to the validity of the results.   Investigator triangulation requires that more than one researcher collect data. In this study a team, consisting of university researchers,

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graduate students (including myself), and a mathematics educator representing K-12

education each participated in the collection and analysis of data from this project.

Additionally, methodological triangulation requires that researchers collect and analyze

multiple sources of data. The Data Sources Summary, Table 3.1, illustrates the various

types of methodologies that the project team and I used including document review and

direct observations of the participant. The variety of data collected, as well as the length

of the data collection will support my ability to be able to identify and trace the ways in

which this teacher took up and utilized tools, originating in practice-based professional

development, in her own practice as a teacher and as a teacher-leader. As a result of this

analysis, I will be situated to contribute to theory of educational reform that is grounded

in content specific practice-based professional development focused on the use of a

complementary set tools, including a conceptually based tool and tools of action, to

scaffold the transfer of specific instructional actions from classroom practice to

leadership practice.

CHAPTER 4

FROM PROFESSIONAL DEVELOPMENT TO PRACTICE:
A CASE OF THE ROLE AND INFLUENCE OF COMPLEMENTARY TOOLS

In this chapter, I describe my findings in two phases. The first phase centers on the identification of instructional actions that appear relevant to Helen, the teacher through which I will report this case the role and influence of complementary tools. This includes an analysis of the teacher's evolving thinking around specific instructional[21] actions (i.e., questioning strategies, multiple solutions or representations, and formative assessment) that the tools of this project attempt to make visible in both implicit and explicit ways. I also explain how I used interview data to locate critical events along Helen's professional trajectory from teacher to teacher-leader. In the second phase of my findings, using the lens of the first of three critical events, I report what appears to have provoked the teacher's uptake of specific tools and illustrate the ways in which she used tools, more specifically, the instructional actions suggested by the tools, in preparing for classroom practice and enacting leadership practice. Additionally, I articulate the ways in which the results indicate that tools acted to scaffold the transfer of instructional actions from Helen's work with students to her work with colleagues

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[21] I use the work "instructional" to describe practices the teacher uses in her classroom-based and leadership-based practices. I will use "classroom practice" when referring to the teacher's work with students and "leadership practice" when referring to the teacher's work with colleagues.

Results of the Interview Analysis

Results reported in this section relate to my two research questions: "What surrounding critical events appear to provoke a teacher to take up specific instructional actions suggested by tools used in practice-based professional development?" and "How can a complementary set of such tools scaffold the transfer of specific instructional actions from professional development to a teacher's practice?" First, I sought to identify critical events that appeared to provoke the take up of a tool or part of a tool. Second, I sought to identify specific instructional actions, implicit and explicit, within the tools that the teacher highlights throughout her evolution as a teacher and as a teacher-leader. Taken together, the critical events and the instructional actions tell a story that unpacks the issues and ideas the teacher was attentive throughout her professional journey.

Instructional Actions and Tools

Using the modified coding schemes I described in the methodology chapter, I identified that Helen made 196 references to the following set of instructional codes: curricular knowledge (8); formative assessment/mathematical goals (88); multiple solution strategies or representations (50); and questioning (50). Due to the high frequency with which Helen referenced formative assessment/mathematical goals, multiple solution strategies or representations, and questioning, these three actions emerged as likely foci for the remainder of the project as they appear to be relevant to Helen.

Table 4.1 illustrates the frequency with which Helen mentioned particular instructional actions. In addition to naming instructional actions separately, she made twenty references to connections among these actions across the five interviews.

Table 4.1
Summary of Instructional Actions across Interviews

	Project-Impact Interviews		Session-Planning Interviews			
	11/13/07	**06/14/06** *(focus group)*	**06/13/06**	**03/14/06**	**12/22/05**	**Total**
Curricular Knowledge	8	0	0	0	0	8
Formative Assessment/Math Goals	47	3	12	13	13	88
Multiple Solution Strategies/Representation	37	4	6	2	1	50
Questioning	38	0	6	4	2	50
Total	130	7	24	19	16	196
Connections Among Actions	18	1	1	0	0	20

Connections among actions is a noteworthy theme for two reasons: (1) during the member check, which I will describe later in this chapter, Helen discussed her propensity to make connections among actions and (2) this provides evidence that Helen may have been attempting to synthesize ideas in ways to make them usable within her practice. The frequency with which she referenced connections among actions is visible in Table 4.1.

Available in Table 4.2 is frequency data regarding the number of times Helen referenced resources that could have influenced her preparedness for ongoing learning within her practice. Helen made 151 references to the following set of probable tool codes: case (13); mathematical task (6); Mathematical Tasks Framework (explicit-18 and implicit-30); time/timing (8); Thinking Through a Lesson Protocol (explicit-17 and implicit-46); and Thinking Through a Session Protocol (implicit-13). The following table

illustrates the frequency with which each probable tool code appeared in my analysis of

the interview data.

Table 4.2
Summary of Resources across Interviews

	Project-Impact Interviews			Session-Planning		
	11/13/07	**06/14/06** *(focus group)*	**06/13/06**	**03/14-06**	**12/22/05**	**Total**
Case (explicit)	7	2	4	0	0	13
Mathematical Task	3	0	3	0	0	6
MTF (explicit)	11	1	4	2	0	18
MTF (implicit)	26	0	4	n/a	n/a	30
TTLP (explicit)	8	0	6	2	1	17
TTLP (implicit)	28	5	7	4	2	46
TTSP (implicit)	5	2	6	n/a	n/a	13
Time/timing	5	0	3	0	0	8
Total	93	10	37	8	3	151

Table 4.2 shows the frequency with which Helen referenced probable tools in the

session-planning and project-impact interviews. Along with resources I had classified as

tools going into this study (i.e., MTF, TTLP, and TTSP), I included additional resources

that others might consider tools. I did this to inform my understanding of how other

resources (e.g. case studies and mathematical tasks) within the Helen's classroom and

leadership practice activity systems appeared to support her learning of, and use of, the

tools. While Helen referenced the MTF and TTLP significantly more than the other probable tools, she referenced the TTSP and cases the same number of times. Additionally, she referenced doing and discussing mathematical tasks with nearly the same frequency as cases and the TTSP. This indicates that while cases and mathematical tasks are not tools as defined by this project, they appear to serve a significant role in this teacher's take up and use of the MTF and TTLP.

Critical Events

Three critical events emerged from my analysis of the interview data. The first critical event is the teacher's encounter with the Case of Catherine Evans and David Young,[22] a narrative case written to highlight teachers' use of cognitively demanding mathematical tasks in classrooms. The second critical event is Natalie's (a colleague) debriefing of a lesson that she and Helen began to plan collaboratively at a professional development session. The third critical event is an exchange during a session planning interview in which Helen *consciously* noted parallels between classroom practice and leadership practice. As described in the methodology chapter of this dissertation, I identified critical events based on the *frequency* with which the teacher referenced specific events, the teacher's *expressions of notable change*, and the teacher's *pivotal reflective moments*. An explanation of why I selected each of these events as a lens for telling this story of tools in Helen's practice appears as the intro to each of the three events.

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[22] The Case of Catherine Evans and David Young is one of several narrative cases used in the professional development project that is the context for this study. See Smith, Silver, & Stein 2005a, 2005b, and 2005c for a complete list of the available narrative cases. Researchers on the QUASAR project wrote these cases to illustrate classroom practice through the lens of cognitively demanding mathematical tasks.

Prior to my analysis of these critical events, I have included a description of the member check that I performed with Helen to confirm the instructional actions and critical events I outlined earlier. I decided to include a description of the member check and its findings within this chapter because, in addition to being part of my methodology to validate my findings, the member check also served as evidence to support my findings.

Member Check with Helen

Confirmation of Instructional Actions

After completing my analysis of the interviews to identify critical events and instructional actions, I met with Helen to confirm the results of my analysis. I explained to Helen that the purpose of our meeting was for her to have an opportunity to review what my initial analysis of the interview data yielded. I emphasized to Helen that I was most interested in knowing whether she notices any discrepancies between what I indentified as critical moments and focus instructional actions for her over the course of the professional development project and what she might consider critical moments and focus instructional actions for herself during the same period. I asked Helen to consider modifications, additions, and deletions to my current findings.

During this review of my data analysis, Helen confirmed that she had focused on using questions differently in her classroom and with other teachers—this included facilitating discussions of multiple solution strategies. Helen added that she felt that over the course of the professional development project, she had begun to cluster instructional actions together and make fewer distinctions among them over time, but she was not certain when this process began for her. She stated:

These [actions] were definitely separate at first and then they blended near the end of the project. First it was show and tell [of multiple solution strategies] and then more about formative assessment and goals, but that was later in the project. It [connecting actions] might have started with Natalie. (personal communication, April 2010).

In the preceding quote, Helen mentioned her colleague Natalie. She is alluding to the time in which Natalie shared how she had orchestrated a discussion of her students' multiple solution strategies to a common mathematical task. Natalie's debriefing of her lesson is one of the critical moments that I will describe in more detail later in the next chapter.

Helen's communication of her thinking with respect to instructional actions confirmed what my initial analysis of the interview data suggested. Additionally, her verification that multiple solution strategies, question strategies, and formative assessment began to converge for her over time affirmed my decision to modify the original set of codes that the research team previously developed.

Although Helen confirmed the results of my interview analysis concerning instructional actions, I felt a more illustrative form of evidence might be attainable using another method. I designed an impromptu card-sorting task to help me understand and illuminate the extent to which Helen had made connections among the set of twelve instructional actions that were part of the cumulating interview in November 2007. I made the decision to use the existing set of actions because the project research team had prior data on these strategies and because consistent use of one set of actions would add to the validity of any claims I might make regarding instructional actions.

The following is the list of actions that I wrote on a set of pale yellow sticky notes.

    a. Take students' prior understanding into account when planning instruction.

b. Develop students' conceptual understanding of mathematics.
   c. Listen carefully to students in order to gauge their understanding as they work.
   d. Ask students questions to gauge their understanding as they work.
   e. Pose open-ended questions.
   f. Engage the whole class in productive discussions.
   g. Require students to explain their reasoning when giving an answer.
   h. Ask students to explain concepts to peers.
   i. Help students consider alternative solution paths.
   j. Support students to use multiple representations.
   k. Understand students' written responses.
   l. Conduct a pre-assessment to determine what students already know.

In addition to writing the strategies on the pale yellow sticky notes, I gave Helen a pad of bright yellow sticky notes. My intent of giving Helen the bright yellow sticky notes was 1) to enable her to add in categories by which she might cluster the existing actions and 2) to distinguish among Helen's additions and the original set of actions. I also gave Helen an 8.5 by 14 inch sheet of white paper to record her concept map of actions.

Helen did not use the bright yellow sticky notes to cluster actions as I had expected. Instead, Helen made what she called her "strategy water wheel." She used the bright yellow sticky notes to add clarification. She used the large white sheet of paper to draw a representation of how she is thinking about the actions. Helen's depiction of the twelve instructional actions is shown in Figure 4.1.
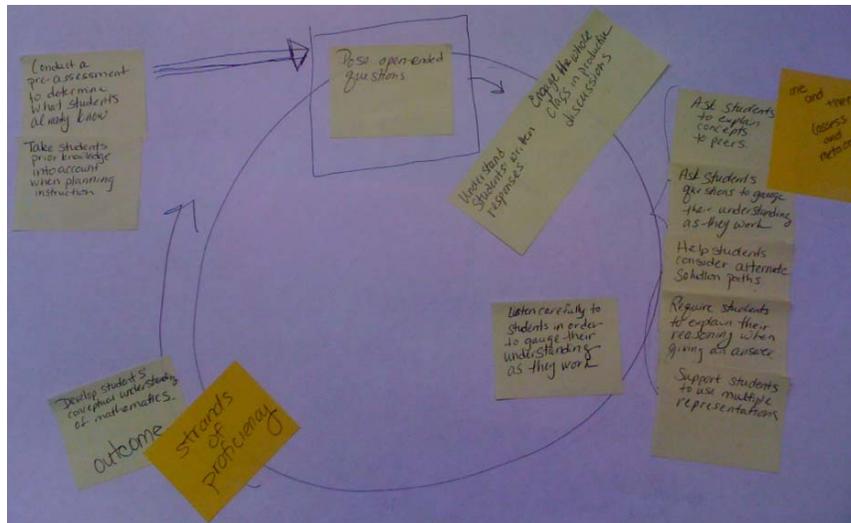
Figure 4.1. Helen's Strategy (Action) Water Wheel.

After Helen completed her representation, she explained her "water wheel" structure to me. Helen began by explaining that prior to, and throughout some of the professional development project, she thought of pre-assessments as paper and pencil assessments that happened *before* a teacher begins a lesson or unit with students. She also explained that she had a similar preconception about accessing students' prior knowledge; again, this would occur before or at the beginning of a lesson or unit. Helen described that her thinking regarding these actions evolved throughout the project stating, "I think of pre-assessment and assessing prior knowledge as ongoing events throughout a lesson. They can be written, but they don't have to be. Asking questions and engaging students in discourse can also be assessment." (personal communication April, 2, 2010)."

After sharing her thoughts about pre-assessments, Helen continued to elaborate the remainder of her "strategy water wheel". Helen explained that she selected a water wheel to represent her thinking "because these things [the actions written on the pale yellow sticky notes] keep the lesson moving towards my goals." Another interesting development that emerged during the card-sorting task was the way in which Helen

explicitly referenced the MTF. She stated that she put a rectangle around the action *pose open-ended questions* to indicate the second rectangle in the MTF. Helen explained that she did this because, especially at the secondary level, teachers do not often start with cognitively demanding tasks in their instructional materials. Helen expressed that it becomes the work of the teacher to pose open-ended tasks if she wants to build conceptual understanding, as well as the other Strands of Proficiency.   She then elaborated that the two actions she clustered near the two o'clock mark on her wheel, *understand students' written responses*, and *engage the whole class in productive conversations* are big things she seeks to do to assess student understanding.

To conclude the conversation, Helen described the five actions she clustered to the right of the representation, around the three o'clock mark on her wheel, as methods to elicit student thinking—actions to make student thinking and reasoning visible to her and other students. Helen explained that she placed *listen carefully to students in order to gauge their understanding as they work* off to the side because that is something that she constantly does while using the other strategies. After Helen explained her wheel, I asked, "So, you talked a lot about formative assessment as you described your wheel, why didn't you talk about multiple representations or questioning strategies more." Helen replied, "I see those as pieces of formative assessment. Now I do, at least."

Helen's description of her strategy wheel, through the metaphor of a water wheel, illustrates how she utilizes formative assessment as a conceptual structure for her thoughts around the effective use of more discrete actions (e.g., questioning and multiple solution strategies). Additionally, it offers evidence that, by the end of the professional

development project, Helen viewed the discrete instructional actions explored by the

project in increasingly continuous and connected ways.

The results of my interview analysis yielded similar conclusions to those

suggested by Helen's description of her strategy wheel. The following quote summarizes

a very similar stance toward instructional actions. Helen made this statement during the

cumulative project impact interview in November 2007 when she encountered the list of

twelve instructional strategies for the second time. The research team used these actions

on a preliminary teacher survey for the project and I used them during the card-sort task

described above.

> I think I try and facilitate conceptual understandings by doing some of the other
> letters that are listed. Like when I walk around and I'm working with students --
> letter (C), thinking about what they know and then asking them questions based
> on how they respond to my questions, engaging whole class in productive
> conversation, letter (F), letter (G), asking to explain their reasoning, kind of all of
> those -- asking students to explain their concept, letter (H), helps with the
> conceptual understanding of mathematics. (interview, November 2007, lines 95-
> 108).

This quote further supports my claim that Helen had begun to cluster instructional actions

under the umbrella of formative assessment several years ago. A related quote that

occurred during an interview earlier in the project also suggests that Helen began making

connections between formative assessment and questioning strategies prior to the end of

the project. She stated:

> People [teachers in her district] seem to get their heads really around the whole
> idea of not to put a lot of grade on paper, but they are forgetting about all the
> formative assessment that can happen in their classrooms, the questions. Like
> asking me to paraphrase, like asking me to restate. Or, engaging me in the lesson
> itself (individual project impact interview, June 2006, lines 142-145).

Together these quotes indicate where Helen' thinking was towards the end and after the

initial professional development project ended. However, they do not tell the story of

why or how this change might have evolved over the course of several years. To unpack and retell the process that Helen went through professionally, including the ways in which took up and used tools to scaffold her preparation for and enactment of instruction, I focus on the three critical events along her journey that I outlined earlier in this chapter.

I embed findings regarding Helen's use of instructional actions within my analysis of these three critical events. I report findings in this way because the critical events appear to elicit an *opportunity to scaffold transfer* from professional development to classroom practice or from classroom practice to leadership practice through the take up of specific instructional actions suggested by the tools. Through my analysis of the three critical events along Helen's professional trajectory, I describe the ways in which the tools of this project, the MTF, TTLP, and TTSP served as mediating agents to facilitate such transfer to both Helen's classroom practice and her leadership practice.

Confirmation of Critical Events

In addition to the three critical events that I outlined earlier in this chapter, (1) the Case of Catherine Evans and David Young, (2) Natalie debriefs her enactment of a lesson that she and Helen began to plan together, and (3) Helen consciously connects classroom practice to leadership practice during a TTSP interview, Helen suggested that I consider two additional moments that were memorable to her. Helen's first suggestion for consideration was of a session during the first year of the project in which the lead investigator asked her whether something about doing the mathematics at this session felt different from how she has previously experienced mathematics teaching and learning. Her next recollection was of a Veteran's session when another teacher-leader had shared their district-based session with the whole group. In this instance, Helen noticed Nicole's

(a fellow teacher-leader from another district) inclusion of the TTLP as part of her

district-based session. Helen had not included the TTLP in her district-based session.

Although these were pivotal moments for Helen, they did not meet my criteria for a

critical even as they did not appear to instigate Helen's reconsideration of her own

practice. However, these moments do support the story that unfolds within two of the

critical events that emerged from my original analysis of her interviews and, as such

provide additional insight into my analysis of the related critical events.

Analysis of Critical Event 1: The Case of Catherine Evans and David Young

> And one student could answer it, and I would expect, that if one student answered it and the rest of the class was nodding, or if I had choral response, I would expect that the class really understood it. Where now I know deeper understanding and better assessment of a student comes from open-ended questions, engaging whole class in productive discussion, explaining your concepts to your peers, alternate solution paths, multiple representations, all of those would contribute…(project impact interview, November 2007, lines 120-132).

The quote above summarizes Helen's shift in thinking regarding instruction

designed to build conceptual understanding. It serves as a piece of evidence that Helen's

thinking about her practice evolved. That is, she learned things about practice she did

not know prior to her participation in the project and subsequent use of the tools. In this

quote she described what she took as student understanding prior to participating in the

professional development project that is the context for this study and in what ways that

has changed since her involvement in the project. I decided to begin with this quote

because it concisely tells the story of where Helen's thinking was at the beginning of the

project and where it was a year and a half after the end of the project. I purposefully

made the decision to place this quote at the beginning of my analysis of critical events

along Helen's professional trajectory. My intent in doing so is to "give away" a large

piece of the story of Helen so that the reader can focus on the story of tools to scaffold

transfer of instructional actions from one context to another related context.   The

question to consider as you read the analysis that follows is not: Where did Helen end up

in her professional trajectory? Rather, the question to reflect upon is: How did tools help

her to get there?

Why the Case of Catherine Evans and David Young?

Helen referred to cases seventeen times in the project impact interviews that I

included in the first phase of my analysis. Seven of those times, she explicitly mentioned

the Case of Catherine Evans and David Young. She did not mention any other case with

the same level of frequency. In fact, seven of the remaining ten references she made

were to case studies in general, not a titled case. Additionally, in one of the excerpts in

which Helen referenced Catherine and David, she used an *expression of notable change*.

This occurred in June 2006, when Helen noted:

> And, there were *moments of epiphany* [in the project], because like, in Catherine
> and David we were looking for what specifically the students understand. And
> then, I couldn't say that Holly understood it, because she wasn't involved in the
> conversation and made me think critically about my own practice. (lines 375-379)

The regularity with which Helen referenced this case, paired with her emotional

connection to this case, as exemplified by the fact that she identified a "moment of

epiphany" within it, led me to characterize Helen's engagement with the Case of

Catherine Evans and David Young as a critical moment worthy of further analysis.

Along with exemplifying Helen's emotional connection to this case, the previous

quote also points to Helen's developing understanding of what it means for her to assess

what a student does and does not understand during a lesson. In several informal

conversations I have had with Helen since the enactment of this professional

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development session, she references Catherine's, the case teacher, use of choral response as an indicator of whole class understanding.   Not only did Helen recall using a similar practice in her own classroom, she also recalled walking the halls and hearing similar interactions in the classrooms of her colleagues.

Helen's Case Notes

At the inaugural session of the professional development project in May 2003, teachers read and discussed the Case of Catherine Evans and David Young, this included doing and discussing a prominent mathematical task from the case.   My review of field notes and video from the whole group discussion of this case yielded no written or oral evidence that Helen actively participated in this case discussion. Although there was no objective evidence (e.g., written reflections or verbal participation) in these data suggesting Helen was engaged in this session, her body language offered some indication otherwise. For example, in the video, one can see Helen writing in and looking through her copy of the narrative case several times throughout the case discussion. Helen's use of her copy of the case, as seen in the video, suggests that she was engaged in the conversation though she did not contribute to the whole group discussion.

Upon reviewing Helen's copy of the case, I found it contained notes that Helen took as she read the case and listened to the case discussion. At this point, I made the decision to include Helen's case notes in my analysis to gain access to more data regarding what might have provoked or supported Helen's uptake and use of the tools embedded in the professional development project that is the context for this study.

Helen's case notes document a portion of her thinking during the reading and discussion of the case. Though her notations clearly do not allow access to all of what

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she was thinking, they offer some entry into her thoughts. Additionally, these notations grant access to Helen's thinking beyond what is apparent by solely watching or listening to video of the session. Helen's notations consist of underlined phrases, as well as written notes adjacent to sections of text. The notes are a compilation of comments and questions that occurred to Helen as she was reading the case and/or listening to the case discussion. Helen's written notes, combined with the portions of the case she underlined, serve as the primary window into her thinking at the first session.

During preliminary data analysis of Helen's case notations, I applied the original codes that the research team developed. I experienced similar complexities using these codes to analyze Helen's notations as I did when coding the interview data. Therefore, upon secondary analysis I opted to refrain from using excessively discrete codes for two reasons. First, data analyzed during the initial phase of investigation suggested that instructional strategies converged for Helen over her time in the project. Since the purpose of this study is not to understand Helen's use of instructional actions but rather how she was prompted to use such actions in her classroom and leadership practices (specifically, how and in what ways the TTLP, a tool of action, scaffolded transfer of instructional actions from professional development to practice and from classroom practice to instructional practice), distinguishing among instructional actions beyond those identified during interview analysis could be counterproductive.

Second, although much of the text Helen underlined reflected instructional actions that suggested by the MTF and TTLP, such as the raising or lowering of the cognitive demand of a task, I could not discern whether Helen's decisions to underline text indicated that she had connected the actions in the case to the actions suggested by the

tools. To avoid over-interpretation of Helen's notation and protect against researcher bias, I opted to refrain from using the tool codes in situations where Helen had underlined text without any elaboration of why she had done so. The following are my findings from my analysis of Helen's case notes.

Throughout the first portion of the case, Catherine Evans' classroom enactment of the Square and Hexagon Train tasks (see Appendix D), Catherine underlined twenty-eight excerpts of text. Of the twenty-eight underlined excerpts, she identified sixteen teacher moves grounded in questioning, or nearly sixty percent. Helen identified four additional teacher moves that were not question-based. In addition to teacher moves, Helen underlined five reflections on student thinking and two general teacher reflections.

Sentences in the following passage exemplify both types of Helen's notations with respect to teacher moves.

> I wanted to see if students understood so I asked how many squares would be in the middle of train 50 with this system. Nick said that there would be 48. I then added that there would be 48 two's, referring to the number of side that would be counted in the perimeter, and three on each end. (lines 206-209)[23]

In the first sentence, Catherine posed a question to her students, "How many squares would be in the middle of train 50 with this system? Thus, this represents a question-based teacher move. In the third sentence, Catherine made a very different move. This time she opted to insert her way of thinking about the task. In addition to the fact that Catherine's statement, "I then added that there would be 48 two's." does not represent a question-based teacher move, one could also argue that it potentially lowers the cognitive demand of the task.

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[23] The underlined text matches Helen's notations.

As I described previously, some of the underlined text reflected instances in which the case teacher acted to maintain the original demand of the task, other selections reflected instances in which the case teacher acted to undermine the original demand of the task. This mixture of excerpts, without clarifying notes by Helen, obscures how Helen was thinking about the case teachers instructional actions. Because Helen only underlined excerpts, there is no way to know precisely why she opted to underline the text she did. Thus, I cannot determine what Helen thought of these excerpts, only that these words resonated with her in some way.

Although one cannot know with certainty what Helen was thinking as she underlined text, the evidence makes visible that Helen was attentive to narrative that identified how and in what ways the task was enacted with students (one of the phases of the MTF), especially through the lens of the instruction action *questioning strategies*. Developing an awareness of what Helen was attentive to is important to understanding what might have provoked her use of a particular tool. Recall, Vergragt defined critical events as "events within or outside research that are *perceived* by relevant actors as critical, and compel them to take a decision about the course to be taken" (p.490). Knowing what Helen was attentive to offers insight into what was relevant to her. Thus, it suggests a reason why the Case of Catherine and David appears to have acted as a stimulus for her take up and eventual use of the conceptual ideas embedded within the Mathematical Tasks Framework and the instructional actions suggested by the Thinking Through a Lesson Protocol in her classroom and leadership practices.

I achieved additional clarity regarding Helen's thinking by considering the written notes that Helen included in her copy of the narrative case. Helen's written notes often

appear to be advice to Catherine, the case teacher. For example, Catherine solicits and receives a response from Angela regarding Angela's thinking about perimeter with respect to the Square Train task (lines 140-147). After receiving a response from Angela, Catherine continues to question Angela about what exactly she means by "on the third train there are three on the top and three on the bottom, which makes six, and one on each end." It is at this point where Helen wrote notes suggesting that Catherine "maybe ask someone else" to explain Angela's thinking.   Later in the case, Catherine asks Angela if her method will work for a larger square train; Helen wrote, "here too." These notes imply that Helen is uncomfortable with Catherine's focus solely on Angela's thinking. It appears that Helen would like to include more students in the conversation, though I do not know why Helen believes this might be an effective instructional action at this point.

A similar exchange between Helen and the text appears in lines one hundred fifty-five through one hundred seventy. In this portion of the case, there is an excerpt of dialogue from Catherine's classroom. Helen noted in the margin of the dialogue that Catherine's questions are "very guided."   Helen also included advice to Catherine regarding strategies for making this exchange with students less guided, and thus more aligned to the original demand of the task. In the text that follows, there is the excerpt from the case. I have included Helen's notes parenthetically in italics.

(very guided)

Catherine:	Using your system, do you think you could do any number I say? What would you do for 10? *(stop here, talk with a partner)* How many on the top and bottom?
Angela:	10
Catherine:	How many on the ends?
Angela:	2
Catherine:	How many all together?
Angela:	22.

Catherine:	Let's do another one. Listen to what she's saying and see if you can do it also. Angela, in train 12, how many will there be on the top and bottom?
Angela:	12.
Catherine:	And how many will there be on the ends?
Angela:	2.
Catherine:	How many will there be all together?
Angela:	26.
Catherine:	Tamika, what's she doing? *(ask someone else to generalize)*
Tamika:	She's taking the train number on the top and bottom and adding two.

This dialogue from the case illustrates the way in which Helen "talks" to the text through her notes. In the first set of parentheses, Helen appears to be judging Catherine's line of questioning by stating that it is "very guided." Helen does not explicitly include whether she believes the guided nature of Catherine's questioning to be a flaw or a feature of her instructional decisions. However, in Helen's later notes she suggests that Catherine stop her questioning and give students an opportunity to work with a partner. This suggestion by Helen, paired with her earlier comment about the guided nature of the questioning, indicates that Helen is attempting to consider how Catherine might open up the task to engage more students and reduce the amount of teacher direction. Additionally, Helens suggestions could serve to make more student thinking visible. Interpreting the evidence in this way aligns with Helen's earlier notations in which she suggested that Catherine attempt to engage more students by asking others to comment on Angela's thinking. Additional data supports this interpretation of the evidence in Helen's final comment in the dialogue above. Helen wrote, "ask someone else to generalize." Upon reading this phrase, it may appear that Helen is offering advice to Catherine once again. However, given that Catherine is clearly asking another student,

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Tamika, to generalize, this suggests Helen's note is, in actuality, marking an instructional action that she supports.

My analysis of the second portion of the Case of Catherine and David, David's classroom enactment, tells a similar story. Helen underlined forty sections of text, twenty-one of which I identified as question-based teacher moves, just over fifty percent. In addition to the question-based teacher moves, Helen underlined three teacher moves that were not question-based, six general teacher reflections, five teacher reflections on student thinking, and five student moves. Although my findings with regard to the two vignettes are compatible, there is a notable difference between Helen's notations in the text she underlined in David's vignette, as opposed to Catherine's vignette.

The difference is that the text Helen underlined in David's vignette represents instructional moves and reflections focused on what many might agree have the potential to maintain or raise the cognitive demand of a task. In Catherine's vignette, Helen underlined teacher moves that might lower, as well as moves that might maintain or raise the level of cognitive demand for students. Related to the type of move Helen underlined was her way of responding to the moves through her annotations. Helen did not appear to offer advice to David as she did with Catherine. Instead, Helen appears to be characterizing the type of instructional move David used. This could suggest that Helen was attempting to synthesize David's moves for later use in her own classroom practice.

Helen used the words *clarify, extend, stretch, diversify students and differentiate* to characterize David's moves. She used the word "clarify" to name a move when David asks for more information from a student regarding his thinking or conjecture. For example, when a student states, "well each square has 4 sides, so in the tenth train there

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would be 4 x 10 or 40 sides. But some of these are in the inside, so you have to subtract."

David asks, "How did you know how many would be on the inside?" Helen's label of

clarify indicates that this is and instance where David is asking for more information to

make sense of or "clarify" the student's thinking, a sort of formative assessment strategy.

Though Helen did not label all of the instructional moves in the case that she might

characterize as "clarification" moves, she repeatedly underlined examples of similar

strategies used by David. For example, Helen underlined an exchange where David asks

a student what the numbers next to his drawing represent and later, what that student

means by his use of the word "unit." Throughout the case Helen underlined eight

excerpts of text that I recorded as clarification moves based on the example she identified

by her notations. There were, however, times when clarification moves appeared to

overlap with diversification moves. To understand why this overlap might have occurred

it is important to consider what Helen meant by "diversify students."

Helen recognized David's instructional move as a form of diversification when he

acted to involve several students in the explanation of a task. Helen could have used the

term diversify in this way because David diversified the classroom dialogue by removing

himself as the primary questioner or explainer. By removing himself in this way and

inviting several students to explain, respond to, and question one another's ideas he acted

to "diversify" the conversation. As a result, there was a diversification of voices, as well

as thoughts, which entered the classroom dialogue.

Helen first branded the "diversify students" move when David asked one student,

James, to build and describe the pattern for the fourth train. He then asked another

student, Katie, to share what she found for the perimeter of the fourth train. Next to this

exchange in the case Helen noted, "diversify students with a task, not all parts to one student." "Not all parts to one student" could refer to "parts" that explicitly separate a task, as well as "parts" that implicitly separate a task (e.g., explanation of an answer). Using this reasoning to guide my analysis on Helen's notes, I found nine instances in which Helen underlined text where David invited students to enter the conversation. The overlap between diversification moves and clarification moves occurred when David invited a new student to add to or question a peer's ideas. For example, Helen underlined a section where David asks the class if others have questions for Jamal. Instead of David asking the question, he positions his students to interrogate one another respectfully. This enables a change in or diversification of voice, as well as a formative assessment opportunity for David. He has the ability at this point to learn what the class does and does not understand about a student's idea, as well as the student's ability to elaborate his thoughts.

Another of Helen's characterizations of an instructional move that David made is that of "differentiate." Although Helen's notes on differentiation appear focused on time management, the collective data suggests an alternative interpretation. There were two sections of text that Helen considered moves to differentiate. The first was when David asked students to "take a few minutes and think about what the tenth train would look like," a sort of question in disguise. Helen noted David's focus on wait time to give students time to think about the mathematical ideas. While wait time certainly is part of time management, it is also considered to be a discourse strategy in that it offers students time to think to be better prepared to share their ideas with classmates (Chapin, O'Connor, & Anderson, 2003). Later in the case, Helen underlined another instance in

which David gave his students time think about the mathematics. Although time is central to these teacher moves, both appear focused on time for students to formulate mathematical ideas. Thus, instead of considering these moves as time management, the data suggests they are moves to elicit student thinking.

Another strategy Helen identified was a "stretch" move. This occurred when David attempted to increase access to the mathematics of the task, without modifying the mathematics students engaged in during the lesson. For example, when students in David's class relied upon building the tenth train to find its perimeter, David asked questions and prompted students to look for patterns. He also suggested they might look for a relationship between the figure number and the perimeter. Helen's use of the word "stretch" to describe these moves indicates that Helen saw David stretching his student's mathematical ability. Others in educational literature have called similar moves focusing moves (Herbel-Eisenmann & Breyfogle, 2005). Use of such moves enables a teacher to increase access to the mathematics for students by focusing student thinking, while maintaining the cognitive demand of a task. Again, this type of move is one that mathematics educators accept as part of a larger family of discourse or questioning strategies.

Helen labeled one additional type of instructional move, "extend." Helen noted that David extended students' thinking in this task when he asked for the perimeter of the tenth train, and later when he asked for the perimeter of the one-hundredth train. Based on this data, it appears that Helen used the word "extend" when David asked his students to move beyond concrete representations and begin to consider more generalizable strategies for solving the task. "Extend" moves appear to differ from "stretch" moves in

that "extend" moves seem to advance students' thinking about the mathematics while "stretch" moves seem to open access to the mathematics. Helen identified two excerpts of text that I coded as "extend" moves given the example she gave in her notations.

In the preceding text, I have summarized what Helen appears to be attentive to as she read the Case of Catherine and David. I have suggested that Helen's annotations are a first step in her take up of instructional actions suggested by the TTLP (and implicitly by the MTF), her characterizations of the actions serving as a way for her to make sense of (i.e., begin to generalize) and later transfer these actions to her own practice. However, it is important to note that just because Helen appears to find David's actions relevant and useful for her own practice, it does not mean that she was able to transfer these actions in usable ways to her own classroom practice, merely that she is developing an image of what she wants her future practice to look like.

Another prominent finding of my analysis of Helen's notes regarding David's classroom vignette is that the teacher moves that Helen identified cluster under the larger action of instructional discourse or questioning strategies. Each of the separate moves (i.e.,clarify, diversify, differentiate, stretch, and extend) served as unique ways to engage students in the mathematical task. Clarification moves asked students to elaborate their thinking. Diversification moves asked students to share their strategies with others. Differentiation moves gave students time to think and develop ideas. Stretch moves served to increase access to the task. Finally, extend moves prompted students to move beyond concrete representations or the particulars of the task at hand. Together these moves seemingly functioned to support the overall classroom discourse which involved asking questions, sharing strategies, and making judgments regarding student

understanding (i.e., formative assessment)—the three instructional actions I originally identified through the interview analysis. This serves as further evidence of what appears to be relevant to Helen, but does not indicate that the case enabled transfer of these actions to Helen's practice.

While the authors designed the COMET cases, such as the Case of Catherine and David, for use in professional development settings to give teachers opportunities to learn to take an analytic stance toward practice and to take up some of the ideas embedded within them, they recognize that this is challenging to do. In *Implementing Standards-Based Mathematics Instruction: A Casebook for Professional Development* (2009), the authors write that, "In order to 'grab hold' of classroom events, to learn from examples, and to transfer what has been learned in one event to learning in similar events, teacher must learn to recognize events as instances of something larger and more generalizable. Only then can knowledge accumulate; only then will lessons learned in one setting suggest appropriate avenues in another," (p.24). Although Helen may be moving toward making such connections, the data does not suggest she has done so directly following her engagement in the Case of Catherine and David.

The Case as an Impetus for the Take-up of Tools

Helen' interest in and connection to the Case of Catherine and David is visible in a variety of data across the project including interviews, end of day reflections, and her work with colleagues. It is through these other sources that I am able to illustrate the ways in which this case, and more specifically Helen's disenchantment with choral response as an indicator of students understanding, served to provoke Helen's take-up of

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the Mathematical Tasks Framework (MTF) and the Thinking Through a Lesson Protocol (TTLP) and use them in her classroom and leadership practices.

Helen's realization that choral response, which she associated with lack of questioning strategies to elicit student thinking, may not be a productive instructional strategy is visible in the following quote taken from the November 2007 interview. She recalled:

> I can still remember, and this is what I presented at CMP last year, I can remember Catherine and David, where Catherine is talking about how she was getting these choral responses and she thought it was really worthwhile. And then, she did the reflection afterwards and she was realizing that she wasn't really getting an understanding for individual students (lines 376-386).

This excerpt points to two prominent findings (1) the case of Catherine a David caused some cognitive dissonance for Helen with respect to her own questioning strategies and (2) Helen associated choral response with obscuring her interpretation of individual student thinking. The former is visible through Helen's recall of this particular case four years after she first interacted with it and by her use of this case to create a similar case study for her presentation at the CMP conference. The latter is highlighted by Helen's reflection on Catherine's reflection.

Given Helen's admiration for this case in particular, some might say it was the case study, not the TTLP or MTF, which served to scaffold the transfer of instructional actions from the professional development to Helen's practice. The data points to a different conclusion. The data suggests the case served to provoke take-up of the TTLP to enable Helen to apply what she had learned in the professional development to her classroom practice. Below Helen expressed how the case paired with the TTLP led to changes in her practice. She reflected:

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And so, the case study, for me, helped me think deeper about the instructional practices. But then the thing that -- probably the thing that nailed it home was then connecting it to my own practice. Which, to me, even means taking it back into my own classroom or reflecting with other teachers and helping them bring it back into their own classroom, coaching level (lines 388-397).

Data suggests that Helen used the TTLP to do the things she described above in her classroom and leadership practices. Helen accomplished this by planning lessons using the TTLP in the sessions and later reflecting on these lessons individually and with colleagues. It is through this process of planning and reflecting that the data shows a shift in Helen's thinking regarding what she needs to consider in order to change her questioning strategies to more intentionally make individual student thinking visible.

To analyze how and in what ways actions from the tools moved into Helen's practice, I traced the instructional actions (i.e., questioning and assessment, with multiple solutions in the background) Helen identified in the Catherine and David case throughout data collected the first year of the project. In this portion of my analysis, I mainly focus on Helen's classroom practice. This is because Helen appeared to work on her classroom practice more intentionally than her leadership practice the first year of the project. With this said, there are some points with regard to Helen's leadership practice that are noteworthy the first year of the project and I will share my analysis of these events as they occurred given the timeline of the project (see Figure 3.6). Helen's attention appeared to shift more towards leadership practice in years two and three of the project. Changes in Helen's job description or in her perception of where she needed to improve her practice (i.e., teaching kids or teaching teachers) may have prompted this shift in focus.

In the section that follows, I share findings from the project retreat that took place the summer between the project launch and the first official year of the project. The purpose of including Helen's reflections from this session is to indicate to what degree Helen appeared prepared to move instructional actions suggested in the professional development to her own practice, as well as to make visible how she was thinking about her dual roles—teacher and teacher-leader. Following this introduction, I describe Helen's evolving classroom practice over the course of the first year of the project focusing on the ideas that appear relevant to Helen given my analysis of the Case of Catherine and David.

Project Retreat – June 2003

Helen first mentioned the MTF explicitly in her reflections during the June 2003 retreat. She wrote, "The framework [MTF] and cognitive demand were new to me (in May). I really liked the pattern block activity and think we can use it after 5.3 in Bit & Pieces." This reflection suggests that while Helen recalled the MTF and cognitive demand, she was not prepared to apply the conceptual ideas or instructional actions they suggest to her own practice, classroom or leadership. Instead, her reflection focused on the pattern block task that she liked. Something about this task apparently resonated with her and she readily connected the task to her work as a teacher and as a teacher-leader. As such, she was prepared to take the task back to her classroom practice (i.e., use it with her own students), as well as to her leadership practice (i.e., share the task with colleagues to use with their students).

There is some indication that Helen might have interest in taking back ideas, not just interesting activities (i.e., the pattern block task) when she is asked about what

questions she has. Helen wrote "As a math specialist in Devingston, my big question is how I can take this knowledge back to my building/district and share it (really implement it) with colleagues. Next to this statement Helen listed, "reflection, collaboration, case studies." It seems as if Helen may realize that there is more to shifting her colleagues' classroom practice than bringing them resources to use directly in their classrooms. However, she does not appear to have strategies within her leadership practice to help her accomplish such a shift in her colleagues practice. In fact, she explicitly states that her "big question" is how to take back knowledge and "really implement it with colleagues". Her notes off to the side may be an attempt to create a list of strategies and potential resources for her to use with colleagues. This suggests that Helen is hungry for strategies to support her leadership practice, but lacks methods for transferring such strategies from the professional development sessions to her work with colleagues.

After stating what she believed she needed as a mathematics specialist, Helen wrote, "As a teacher, my focus is on scaffolding. I am looking for content specific ideas." Two aspects of this quote are significant. The first is that again, Helen appears to be grappling with the idea of whether she wants (or needs) strategies to interact with students through scaffolding or whether she wants tasks to immediately enact in her classroom. I am making this claim assuming that when Helen referred to a need to "content specific ideas," she meant mathematical tasks. Such a struggle is significant to this study because it suggests that Helen was not prepared at this point in the project to take ideas/tools/frameworks into her practice. On the contrary, it seems she was prepared to take very concrete things, mathematical tasks or cases, and try to use them with students and teachers.

The second significant aspect of this quote is that Helen clearly separates her work as a teacher from her work as a teacher-leader. She specifically stated, "As a math specialist…" and "As a teacher…" This distinction among roles implies that Helen has not connected her two professional identities in any meaningful way. This disconnect could serve to be an obstacle for her to transfer ideas from her classroom practice to her leadership practice. As such, it is unlikely that at this point in the project that she would be able to use what she learns as a teacher and apply these experiences to her leadership practice. This concludes my analysis of her reflection the first day of the retreat.

At the end of the second day of the retreat, Helen seems more focused on learning strategies to improve her practice, as opposed to simply collecting tasks. She wrote:

> Scaffolding is probably the biggest area to consider/reflect on/improve. Continual reflection in this area will be beneficial. I also think classroom management is an important area for me to work on as very often rich discussion and discovery were inhibited.

In this reflection, Helen mentioned scaffolding strategies and classroom discussions, both of which are related to the instructional actions on which she eventually focused for the remainder of the project. However, even with some indication that Helen's thinking regarding ways to shift her practice is changing, there is evidence that her thinking about what she needs in order to be able to accomplish this goal is still scattered. She mentioned a little of everything from the day, but nothing in any depth. The most significant and focused point that Helen made in her final reflection at this session was, "I think the big thing is how much student learning is affected by teacher interaction." This suggests that although Helen was not necessarily prepared to know what to do to shift her practice, she recognized that the instructional choices she makes impact students' opportunities to learn mathematics— the central feature of the MTF.

The MTF and TTLP in *Classroom* Practice

In this section, I highlight evidence from sessions throughout the first year of the project that points to Helen's take up and use of the instructional actions suggested by the conceptual ideas of the MTF and actionable prompts in the TTLP. To do this, I traced Helen's evolving thinking with respect to the instructional actions (i.e., use of questioning strategies, identification and use of mathematical goals, and facilitation of multiple representations and/or solution strategies) that she first identified through her initial engagement in the Case of Catherine Evans and David Young.

September 2003

Evidence from this session reveals how Helen was thinking differently about her classroom practice with respect to questioning strategies focused on making student thinking visible to the teacher. Such evidence appears in Helen's lesson plan reflection, her annotations next to the task, and in her end of day reflections. Prior to discussing this session, it is significant to note that this is the first session in which Helen shared a lesson that she planned using the TTLP. It is also the first session in which Helen appears to have made suggestions to herself about what she might change, indicating that the TTLP served as both a lesson preparation and reflection tool. In the text that follows, I include excerpts from the evidence that suggest ways in which the TTLP scaffolded the transfer of instructional actions, specifically the selection of mathematical goals and use of questioning strategies to make student thinking visible, from professional development to Helen's practice.

In Helen's end of day reflection at the September 2003 session, it is apparent that she reconsidered the goals she had selected for the lesson she had enacted with students.

I think something I could do better is to highlight mathematics goals of a lesson with students (Prior to the lesson if it doesn't undermine the cognitive demand.) For example, in my lesson from September, my students should have focused on infinity, negative infinity, and the calculator instead of rational operations. I think it's important to remember long term goals as well as short term.

Although, for some, mathematical goals may not immediately resonate with questioning strategies, it seems this is the case for Helen. In her notebook, this connection is evident through the questions Helen practiced writing using a lesson she recently taught and wanted to revise. In addition to considering goal-oriented questions to ask students regarding the lesson she recently planned and enacted, Helen wrote notes regarding the task from the Randy Harris case (see figure 3.5) that the participants explored at the September session.

The following is the list of notes that Helen wrote next to the mathematical task from the Randy Harris case:

- Resist the urge to do an algorithm.
- Think about what's the mathematics involved.
- What do students need to know?

Upon reflecting on this session in an interview nearly three years later Helen commented,

I knew how to do the percent algorithm, but when we did that Randy Harris task, I was struggling a little bit, which is funny because it was a percent problem. I think I should know percent, but I haven't thought about it this way [visually]" (interview, June 13, 2003, lines 296-299).

Helen's notes indicate that she was thinking about potential goals of the lesson (i.e., the mathematics involved in the task and what students need to know). In addition, given reminders to herself , she seemed to be training herself to interact with tasks and students differently by "resisting" use of the algorithm. Thus, this quote provides evidence that Helen was learning from the project. In this instance, she was learning to avoid only the use of an algorithm to solve a mathematical task. Without the ability to solve tasks using

multiple representations, it would be nearly impossible for her to use multiple

representations with students in the ways she claimed she hoped she might and that she

described doing as the project progressed.

Thinking about mathematics through a pictorial representation (i.e., visually) was

a main feature of the task from the Randy Harris case; it was also a skill that Helen

claimed was new to her. After the project had ended, she remarked, "I was very

algorithmic in my background" (interview, November 13, 2007, lines 230-231). Helen

added that she felt her "algorithmic background" inhibited her from seeing students'

thinking stating, "…I saw one solution path, and because that's what I knew, I wouldn't

even think about the students doing anything differently (interview, November 13, 2007,

lines 237-241). Helen's self-proclaimed inability to see alternative representations and

solution strategies that were not algorithmic likely constrained Helen from using

questioning strategies to assess and to create opportunities for students to learn

mathematics. Furthermore, it is also probable that her algorithmic thinking guided the

mathematical goals she selected for lessons that she taught prior to her participation in the

professional development project.

In addition to writing notes about what to do in preparation for a lesson using this

task, and potentially other tasks, as noted above, Helen wrote sample questions that she

could ask students if she were to use this task in a future lesson. The following questions

were written next to her work from the task. She appears to be practicing writing

questions to assess student thinking.

- Can you find more ways to think about it?
- What part is missing? Find this, instead of what is shaded.

Helen also wrote notes regarding the value of having her students solve a task visually

rather than algorithmically or procedurally. She wrote:

- Connections between fractions and decimals ¼ = 25%
- Task visually represents understanding—teacher can observe and make inferences
- Non-standard nature of the problems—not just out of 100
- Number sense—it's easier to take rows in part 3 because you're taking halves of 1/8
- Proportional reasoning is evident here that isn't [in the procedure]
- Algorithms—loose track of connections between numbers

These notes may have been influenced by an exchange Helen had with the lead

investigator of the project at this session. Below is an excerpt from the session when

Helen first experienced this case and the corresponding task.

Investigator: What is or is there value in thinking about these non-numerically?

Helen: [The teacher] can see if a kid really understands percent.

Investigator: How can I tell if you understand?

Helen: Look for 25% = ¼.

Investigator: Why this task rather than ¼ = x%? Wouldn't that be easier?

Helen recalled this exchange when the investigator interviewed her on June 13, 2006,

approximately three years after it occurred. She recalled this situation being a bit

uncomfortable for her. However, she also used it to exemplify something positive that

she believes she attained by participating in the project. Helen commented, "And I

couldn't really at that point put my head all the way around why the mathematics felt

different, and what about it in particular. But, now I think I can do a very good job

articulating it. But it's about students creating meaning" (lines 30-35). Giving students

opportunities to make connections to mathematical meaning is foundational to the MTF,

and is implied through the suggested instructional actions on the TTLP. Thus, this

vignette illustrates a way in which the facilitation of the mathematical tasks from the cases supported Helen's understanding of and take up of the tool, the TTLP.

Through Helen's participation in the project, she saw alternative instructional actions modeled by the facilitator, the case teachers, and her colleagues. She was also given time to think about how she might use multiple solution strategies in the sessions. Finally, the research team provided her a tool, the TTLP, to start to take those strategies into her classroom practice.

In this session, there is preliminary evidence to suggest that transfer of instructional actions from the professional development session to Helen's practice began. It seems that there was an interaction between Helen's doing of the mathematical task, her participation in the case discussion specifically with respect to instructional goals, and her reflection on her own lesson using the TTLP. It is possible that it was the first question on the TTLP, "What are your mathematical goals for the lesson (i.e., what is it you want student to know and understand about the mathematics as a result of this lesson?)" that might have scaffolded this transition. Helen's original answer to this question on the TTLP that she completed for the September 2003 session was, "review fractions, decimals, and order of operations," "introduce 'attractors' and recursive procedures, infinity and negative infinity" (lesson plan, September 2003). You might recall that this section began with Helen's end of day reflection after she had debriefed this lesson with colleagues. In it she explicitly stated that she believed she could learn to identify more appropriate and meaningful mathematical goals. She also suggested revised goals for this lesson. Although her revised goals do not make explicit how Helen might include some type of visual representation, it does suggest a move away from

rational operations and more towards some level of mathematical meaning. This suggests that although Helen exhibits a desire to work on questioning strategies, she appears to realize that to improve her questioning strategies she must also be clearer about her intended outcomes for students. Ongoing evidence points to Helen's growing attentiveness to lesson goals throughout the rest of the year. However, there is also evidence that I discuss later that she struggled with instructional goals again as she worked on her leadership practice later in the project.

October 2003

Helen's end of day reflection from this session suggests that her primary instructional concern appears to live at the intersection of questioning, assessment, and goals. She wrote:

> We constantly need to look for evidence of student learning. If I don't know exactly what the students know, I need to ask questions or have them do another activity to demonstrate it. I think students can sometimes mask misunderstanding by following routines and other's examples.

These reflections appear linked to the Case of Catherine and David in that Helen expressed a need to "unmask" students' understandings and misunderstandings through questioning. These reflections also seem correlated to Helen's thinking about how she might prepare for and enact the percent task from the Randy Harris with her students. However, Helen's initial thoughts about her selection and use of instructional goals to create opportunities for student learning may have also been pushed further during an exchange that Helen had with a facilitator in October 2003.

Prior to examining the conversation Helen had with the facilitator, it is pertinent to see a glimpse of Helen's thinking coming into the session. According to Helen's lesson reflection notes, the mathematical goals she set for this lesson were the following

Short term:
- measurement metric and English
- ratio as a decimal
- develop the concept of ratio
- how to use ratios as a scale or conversion factor
- dimensional analysis

Long term:
- unit conversions
- applying scale factors [to] real situations

This list demonstrates a mixture of procedural and conceptual goals, indicating that Helen thought about some mathematical ideas she could actually explore with students (e.g., the concept of a ration). This is a shift from her September lesson plan in which she stated less refined goals: "review fraction, decimals, and order of operations;" "introduce 'attractors' and recursive procedures;" "infinity and negative infinity." Even with this noticeable shift, next to her October goals, Helen wrote, "I think I still focused on the process of the investigation in predicting misconceptions more than conceptualization." Although it is not clear what point Helen added this note on her lesson reflection, it seems she felt a need to move toward more conceptually based goals.

This finding is consistent with the conversation she and the facilitator had during the session. Evidence from this conversation suggests that, although Helen attempted to make instructional decisions focused on maintaining the cognitive demand of the original task (e.g., by writing students findings in their own words during the investigation and not using cross products to solve the questions), she seems to have realized that she missed an opportunity to unpack student thinking during her enactment of the task with students.

This possible missed opportunity began when on student "flip-flopped" his data when entering it into the list on the calculator. As a result, his solution represented a

conversion from inches to centimeters, instead of centimeters to inches. Although Helen did not correct the students' error, she shared that she was pleased that another student chimed into the conversation announcing, "Well you switched them. Your measurements were just switched." The facilitator pushed Helen on this classroom occurrence and the following exchange unfolded.

Facilitator: There might have been an opportunity then to push their thinking.

Helen: Right. Another thing that the book pointed out was the students don't recognize 2.54 as a ratio written in decimal form. I didn't get a whole lot of time to talk about that but they understood right away. Like, they asked me to tell then what the 2.5ish numbers represented. And all the kids could say, well not all of them, but a lot of them could say, that if you take this column and multiply it by that number you get the other column. So I think the columns, having the table in front of them helped.

Facilitator: Did they connect that?

In this portion of the exchange, it appears that Helen realized she knew what some of her students could do, but not all. This is reminiscent of Catherine's use of choral response. Helen might have realized her over confidence in student understanding when she inserted the phrase "well not all of them." What emerges from the rest of the exchange points to a potential shift in Helen's practice made possible by her use of the TTLP.

At this point Helen described more about the task, including some specific questions from her textbook. After a few minutes, the facilitator attempted to refocus the conversation by asking whether Helen could think of some way to help her students connect scale factor to proportional reasoning. Below is the rest of their exchange.

Helen: The link between proportions and the…Well, there was one student, he said, there was one question in here: "How did the relationship between centimeters and inches compare to the unit of measurement?" And a lot of them were just writing numbers, the average number. And he said, I know that when I go from this column to this one I multiply by that ratio

and when I go from this column to this one I divide by that ratio. He knew, like he was thinking this but still fell back [on previously developed procedures]. So I'm not sure…

Facilitator: (inaudible)

Helen: We've been using this strategy to multiply *x* over three, you'd multiply by three. Then this side up here is the scale factor.

Facilitator: Right. So you know where in the proportion is the scale factor?

Helen: Right.

Facilitator: Build it up a little bit more. Or, maybe even…

Helen: I think, yeah. And that one step where they had to actually do the conversion, I think that's an important thing right there. And I could just ask them if there another way you could do that? And like when I was talking with Jeremy and Jeremy said, "I just multiply to get this column and divide to get this column," the rest of them didn't hear it, it was just in a group. You know what I mean? So it wasn't…

Another teacher: Shared. So it wasn't shared.

Helen: Right.

By the end of the exchange, Helen began to consider questions to ask and moves to make to unpack student thinking and to engage more students in the conversation. These moves paralleled David's instructional decisions that Helen identified as *stretch* and *diversification* moves. In the excerpt above, Helen proposed to stretch student's thinking by asking for another way to think about the solution to the task. She proposed a diversification move my suggesting she should have found a way to make Jeremy's strategy public.

Even with evidence pointing to connections to the Catherine and David case, it is not explicitly clear that the TTLP or MTF supported transfer of instructional actions to Helen's classroom practice. However, implicitly, it appears that it was Helen's

attentiveness to goals, something she seemingly was making progress toward refining through her use of the TTLP (and supported by other activities throughout the professional development sessions) that enabled Helen to suggest questions and prompts to assess individual student thinking. Without her attentiveness to more developed goals, again, an attentiveness likely supported by her use of the TTLP to prepare lessons, it is probable that Helen would not have been able to pinpoint the step where students had to convert centimeters to inches as a pivotal mathematical idea worthy of further exploration. This also might be why, on Helen's lesson reflection document, she annotated her original goals and suggested a greater focus on conceptual ideas.

February 2003

Helen did not attend November and January sessions during the first year of the project. She returned in February. Again, Helen's case notations show that she focused on questioning moves the teacher made to elicit student thinking. Throughout the case, Helen underlined thirty-seven pieces of text. Twenty-one, or approximately fifty-seven percent, of the excerpts were questions that the teacher asked to unmask student thinking. Eleven of the underlined excerpts captured the student thinking prompted by the teacher's questions. Thus, approximately eighty-six percent of the text Helen underlined represented questioning strategies to assess and engage students in mathematical thinking.

At this session, following the discussion of the mathematical task and the case, teachers once again engaged in collaborative planning using the TTLP. Helen and her colleague Natalie, sat together to begin planning a lesson they would both teach prior to the next session. Time to plan was limited this day, as the discussion of the mathematical

task took more time than the project planning team suspected it would. Therefore, shortly after selecting a task to use and identifying the mathematical goals, it was time for Helen to complete the end of day reflections (annotated agenda, February 2003). Helen's reflections on the day remained focused on questioning strategies to encourage participation. She wrote, "Push myself to plan for content, not time" and "Encourage participating, what strategies encourage this?" These reflections indicate that Helen's focus on mathematical goals and questioning continued.

March 2003

The majority of this session revolved around teachers debriefing the lessons that they began to plan collaboratively in February. During the session, Helen and Natalie shared their very different enactments of a common task. This debriefing is the second critical event I identified in Helen's professional trajectory. As such, I will share my analysis of this session in more detail later in this chapter.

For now, it is just important to note an excerpt from Helen's end of day reflection. She wrote, "I'm afraid that I planned this month's lesson as an activity rather than for student learning." This is important because it suggests that Helen wants to refine not only the goals and corresponding questions to assess student thinking, but also other aspects of her planning—something that she might be able to employ the TTLP to help her accomplish. The November 2007 interview provides a corroborating quote to substantiate my claim that Helen may have used the TTLP in this way. Helen commented:

> Thinking through lesson protocol. One of the things that we had to always do was identify what the mathematical goals of the lesson were. Then when we had to think about what were the students' understandings or misunderstandings coming into the task and how might we scaffold. I think that's big, thinking

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through lesson protocol, those questions that we were asked to reflect or use in our planning.

The MTF and TTLP in *Leadership* Practice

In this section, I highlight evidence from sessions, both county-based and district-based, across all three years of the project that points to Helen's take up and use of the instructional actions suggested by the conceptual ideas of the MTF and actionable prompts in the TTLP. Again, I did this by tracing Helen's evolving thinking with respect to the instructional actions (i.e., use of questioning strategies, identification and use of mathematical goals, and facilitation of multiple representations and/or solution strategies) that she first identified through her initial engagement in the Case of Catherine Evans and David Young.

Helen's Summer 2003 District-Based Professional Development

Following the June 2003 project retreat and a summer training for the Connected Mathematics Project instructional materials, Helen and two colleagues planned and enacted a district-based session. The participants who attended this session included general education and special education teachers representing grades six through twelve. At this session, Helen used several resources she collected from the two summer professional development activities. These resources consisted of: the Hexagon Train Task from the Case of Catherine and David; the Case of Catherine and David; three solution strategies to the Hexagon Train Task with focus questions; a list of mathematics web sites; a document titled, Management and Grading Ideas: Suggestions and Ideas from CMP Teachers; and an article, *Never Say Anything a Kid Can Say* by Steven Reinhart. These items were a conglomeration of resources that Helen and her colleagues collected at their two prior professional development experiences. This potpourri of

resources supports a claim that I made earlier based on Helen's reflections in June 2003. That is, Helen appears to be prepared to collect and share things with her colleagues, but less prepared to facilitate activities focused on supporting colleagues to make substantive shifts in practice. With this said, the data also points to Helen trying to move her leadership practice into a more analytic and practice-based space.

Although Helen's collection may appear to be chaotic given the variety of resources, the theme of questioning to engage students and to assess their thinking seems to be the focus of the session—a theme that was prompted by her own engagement in the Catherine and David case a few months earlier. My reasons for this claim is that (1) Helen selected the Catherine and David case to launch her first professional development session, and (2) the primary tasks of the session are reading and discussing the case, using the Hexagon Train task to explore ways to write questions based on individual student strategies and, reading and discussing *Never Say Anything a Kid Can Say*. Helen's selection of these resources indicate that she is trying to take some of the instructional issues that are relevant to her and use them in her work with other teachers.

In reflecting on this session several years later Helen commented, "I think I learned so much after this point and yet I was so fired up at this point to share with others" (personal communication, November 25, 2009). The data indicates that Helen was engaged in what she was learning and had a desire to share this with colleagues. However, she still seems to be grappling with sharing activities, as opposed to facilitating change. The dissonance that appears to be present at this point in Helen's professional trajectory is not likely because Helen does not want to shift her classroom or leadership

practice, but rather because she does not have a strategy or set of strategies to accomplish such change.

Year 2 (September 2004 to June 2005) - District-based Sessions

Two of the three district-based sessions the Devingston team planned and enacted exhibit connections to Helen's interaction with the Case of Catherine and David. These two sessions, October 6 and April 20, are also the sessions Helen had an integral role in planning with her colleagues. She was on maternity leave for the other session that occurred in December 2004. In the analysis that follows, I describe in what ways Helen's initial engagement in the Catherine and David case appears to have a critical influence on her leadership practice.

Prior to the first district-based session, Helen, and the majority of the grade six through twelve mathematics staff in her district, attended a countywide session in September 2004. After working with her colleagues at this session, Helen reflected:

> I think we (as a department) are still not holding students accountable or thinking about lesson planning and how teaching decisions affect student outcomes. So, I continually reflect on my role in bringing teachers on board. Many students can currently hide in classrooms (no accountability).

This reflection, in light of others from Helen's first year in the project, further illuminates Helen's consistent interest in unveiling and using student thinking. Helen took hold of this issue during the Catherine and David case when Catherine used choral response as a valid indicator of individual student understanding. In this reflection, Helen also implicitly referred to the MTF. Helen did this through mentioning that lesson planning and teaching decisions affect student outcomes. These activities correlate to phases described in the MTF. Additionally, her comment appears to emphasize the potential impact teachers and their decisions have on students' opportunities to learn.

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Based on an analysis of field notes from the October district-based session, it appears that Helen used her interaction with colleagues at the September countywide session to inform her planning. It is as if she subconsciously used the September session as an indication of where her colleagues' thinking was and used this prepare their next learning experience. This type of instructional move aligns with the second set of questions on the TTLP. I have listed the set of questions from the TTLP below and included annotations in parentheses to adjust for leadership practice instead of classroom practice.

- In what ways does the task (what Helen chooses to do with colleagues at the October session) build on students' (teachers') previous knowledge?
- What definitions, concepts, or ideas do students (teachers) need to know in order to begin work on the task?
- What questions will you ask to help students access their prior knowledge?

Helen's attentiveness to these questions is evident in the activities with which she and her colleagues engaged other teachers from their district at this session. For instance, prior to asking teachers to read an article with an embedded case, a co-facilitator of the session briefly reviewed the Levels of Cognitive Demand and the Mathematical Tasks Framework. Reviewing the vocabulary and important concepts explored in the article could have been a way to address the second question listed above. The Devingston team then asked the mathematics staff to read the article and identify examples from the case in which the teacher shifted the cognitive demand of the task. Asking the teachers to engage in this task could have served to build on teacher's prior experiences from the September countywide session prior to asking them to do a similar task with respect to a lesson they planned and enacted using the TTLP.

The facilitation team also asked questions, seemingly to access teacher prior knowledge. This included a series of questions that the project planning team used with another case study at the countywide session. The Devingston teacher-leaders asked their colleagues to locate examples for their own lesson in which they: maintained or raised the cognitive demand of the task; undermined the cognitive demand of the task; and assessed student understanding of the task. The final prompt, regarding assessment of student understanding, directly relates to Helen's concern that too often students hide in classrooms and, that choral response is a major contributing factor that enables individual thinking to be masked. The following points are ideas the teachers at the session contributed as ways to assess individual student thinking.

1. Follow-up worksheet (Can they solve it?)
2. Actually listening to what each student says
3. Follow another group's procedure
4. Can you (student) create a situation (problem) that would use the mathematics?
5. Tell me more about…
6. Listening to the questions students ask
7. Look at their work—ask questions about it

Although not all of these points may be what Helen intended the teachers to consider, it appears that at least four of these ideas (items 2, 5, 6, and 7) are strategies that might help teachers move away from choral response toward more enlightening conversations that involved several student voices.

Helen made connections that are more explicit to the Catherine and David case during her planning and enactment of the April 2005 session. Additionally, she made a direct connection between the TTLP and her leadership practice. Helen did this by using the TTLP to plan one of the two lessons she videotaped for this session; she was attentive to her use of questioning strategies to unveil student thinking. When she planned the

other lesson, Helen intentionally attempted to ignore instructional ideas represented on the TTLP. She then used these videotaped lessons as her own dual case. Below is Helen's description of how she used these lessons in practice.

> I think it was with Catherine and David, when we were looking at assessment in the classroom. And then, when we were back to our site-based sessions and we watched the video of me teaching like two lessons that were about the questioning strategies. One, for two hours I did my old traditional questioning strategies, full of responses and calling on two or three kids and assuming the whole class got it. And then, the last two hours of the day, some of the more restating, paraphrase, why does this make sense (Inverview, June 13, 2006, lines 273-280)?

Here it is visible that Helen focused on questioning strategies to illustrate a formative assessment practice. Additionally, it shows her use of the TTLP to support leadership practice. She did not use the TTLP to design the session, but she used it to create an activity for the session.

My analysis of the field notes from this session reveal that during "episode one," the lesson that Helen planned attempting to ignore the instructional strategies represented on the TTLP and as such undermine the cognitive demand of the mathematical task, contained several leading or closed questions. In "episode two," Helen asked more open questions. The Table 4.3 below lists several of the questions Helen asked throughout the two enactments of the "same" mathematical task.

Table 4.3
Summary of Questions Asked by Helen during Her Dual Case

Episode One	Episode Two
Are you with me?	Does that make sense?
Everybody got the same?	Why does it make sense to have 4000?
Did you see what Jacob did?	Did anyone do it differently?
Any questions for Jacob?	What was square?
What was the equation?	How do I know for sure?
To the "what" power?	Do you agree?
Do you follow that?	So, you're saying for the 3rd one…"?
Can you see how we got the equation?	Can you convince me that's right?
Drawing connections? I am.	Did anyone else write it in another way?

Out of context it is challenging to know the impact of these questions on students opportunities to learn. However, this list does illustrate that when using the TTLP to plan a lesson, Helen asked more questions focused on mathematical meaning. For example, she asked, "Why does it make sense to have 4000?" This is an intrinsically different question than something like "Everybody got the same?" The later provides opportunities to see what sense students are making of a solution. The former focuses on confirmation that all students got the same answer. As such, the April 2005 session demonstrates both Helen's use of the TTLP to inform her plans for professional development as well as, Helen's evolving use of questioning strategies to elicit and assess student thinking.

In Year 3, the evidence suggests that Helen's focus on assessing student thinking persisted. However, during this year Helen placed the emphasis more solidly on written assessment data. There was a corresponding shift in the project into assessment for learning. It is not that assessment was absent from the past years of the project, rather that assessment was explored from the perspective of the teachers' enactment of lessons, not from written tests. During Year 3 teachers used student assessment (from written tests) data to make follow-up instructional decisions (Year 3 Agendas).

The first district-based session of the 2005-2006 school year took place in December. In preparation for this session, Helen asked teachers in her district to review their students' responses to selected items from a common assessment. In a memo one of Helen's colleagues sent to 8th grade teachers regarding their task in preparation for the session stated, "A note about grading…Helen is very interested in how students found their answers in problems 4, 5, 6, and 7. Please include this information when you give your results to Helen." This suggests that although the Helen (and the project) began to focus on written assessments, Helen still was situated making sense of and using students' to inform instructional decisions.

As such, at both district-based sessions Helen and Natalie, a fellow teacher-leader in her district planned activities modeled after the countywide sessions. When Helen participated in a session-planning interview before her March district-based session she replied:

> This session is actually easy for us in a way because we are modeling it right after what we did at the countywide session. Our goal is for teachers to look critically at the MEAP data and uh grade level above. And then, use the results of the test

to inform instruction that they will do next year and create activities that they will use this year.

Although planning seems to have been straightforward for Helen and Natalie, Helen raised a frustration with her work this year in the project. She grounded her frustration in teachers not seeing formative assessment in ways that she did. On June 13, 2006 Helen explained:

> We looked at the Stiggins' article and I felt like I was almost, like I had to put on the evaluator's hat and it was hard not to interject and say, "Well, this is not what he meant by formative assessment." They had these visions that they were doing a lot of things in their classrooms, that really aren't that formative in nature. People seem to get their heads really around the whole idea of not to put a lot of grade on paper, but they are forgetting about all the formative assessment that can happen in their classrooms, the questions. Like asking me to paraphrase, like asking me to restate. Or, engaging me in the lesson itself (lines 136-145).

Clearly, Helen saw formative assessment in multiple ways, like those first unveiled when she made a connection to Catherine's choral response. However, she felt her colleagues were not in the same place and she was struggling with how to proceed.

Helen's struggle is highlighted in the quote above when she said, "…it was hard not to interject and say 'Well, this is not what he meant by formative assessment'." Her cognitive disequilibrium around this issue indicates that ideas of the MTF appear to have transferred into her leadership practice. Helen seems to want to keep her colleagues engaged in ideas about formative assessment, but resisted telling them they are thinking about formative assessment incorrectly. Instead, she described trying to help her colleagues move forward through suggesting other ways they might consider assessment to be formative in nature. She described doing this during a session debriefing at the April 2006 Veteran's session. At this session, she recalled suggesting to her colleagues that formative assessment could be something small "like questioning techniques that you

use in your classroom (Session Transcript)." The data does not indicate any further

closure around the Devingston teachers' use of formative assessment.

Summary of the Case of Catherine and David as a Critical Event

At the first professional development, Helen connected her classroom practice to

Catherine's. She saw a similarity between Catherine's use of choral response and her

own use of the same technique. The data suggests this realization propelled Helen to

critique and refine her own classroom questioning techniques throughout the first year of

the project. In doing so, Helen seemed to develop an understanding of how instructional

goals inform a teacher's use of questioning in the classroom. Overtime, this connection

between questioning and assessment became so intertwined in Helen's mind that she

began to use the words nearly interchangeably. Although a myriad of experiences

merged to support shifts in Helen's classroom practice (e.g., mathematical tasks, cases,

and facilitator moves), I contend that it was the TTLP and supporting notions of the MTF

that served to scaffold transfer of the conceptual ideas and instructional actions into

Helen's classroom practice. An illustration of the role the TTLP played in facilitating

such transfer from the professional development to Helen's practice is shown in Figure

4.2 below. I am not suggesting that ideas and actions from the professional development

sessions would not have entered Helen's practice at all without the TTLP and MTF.

Rather, I am suggesting that this complementary set of tools scaffolded transfer and thus,

promoted a more efficient and possibly more enduring impact on classroom practice by

mediating the exchange of ideas from professional development to classroom practice.
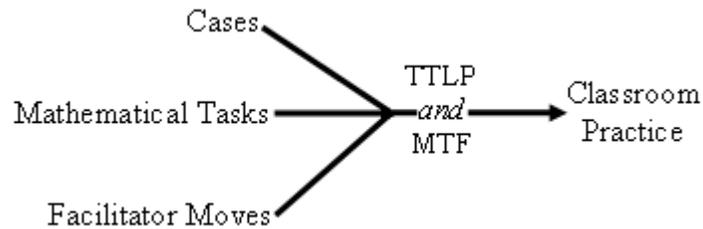

Figure 4.2. TTLP as a Scaffold for Classroom Practice

A related story unfolded with respect to Helen's leadership practice. The tools seemingly acted to scaffold Helen's leadership practice in similar ways. Helen incorporated the MTF and TTLP into her work with teachers not unlike she had with students. She planned lessons using the TTLP and MTF and enacted them with students, but she used the lessons in work with teachers. She focused activities for teachers around the phases of the MTF and student learning by designing and facilitating practice-based activities modeled after the countywide sessions. Moreover, she grappled with what to tell and what to enable teachers to create their own meaning of over time, as she had with students. Just like with Helen's classroom practice, I am not suggesting that these actions might not have occurred without the TTLP and MTF. For instance, Helen certainly could have planned a lesson that mimicked what she saw in David's lesson and what she saw in Catherine's lesson without the TTLP and MTF to guide her planning. However, the data suggests that the TTLP and MTF scaffolded this work and Helen's transfer of conceptual ideas and instructional actions from her classroom practice to her leadership practice. Figure 4.3 depicts how the ideas and actions suggested by the tools transferred from professional development and Helen's classroom practice (via the TTLP) to leadership practice.
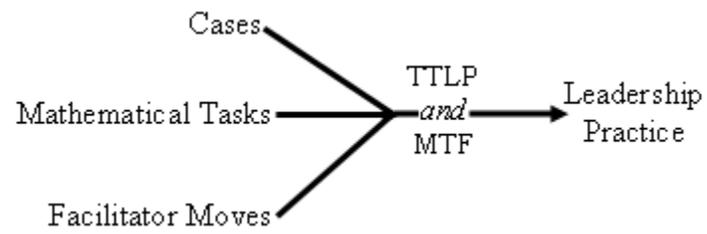
Figure 4.3. TTLP as a Scaffold for Leadership Practice

CHAPTER 5

SUPPORTING CRITICAL EVENTS IN HELEN'S
PROFESSIONAL TRAJECTORY

My analysis of the data suggests that the Case of Catherine Evans and David

Young was the primary critical event for Helen in terms of both her classroom practice

and her leadership practice. I made this determination because Helen referenced this

particular case more than any other case in interviews and because she used it as a model

for two "cases" she created of her own practice that she used with colleagues. Although

this case seems to be the primary stimulus for Helen's take up of the MTF and TTLP,

there were two additional supporting events that data suggests perpetuated Helen's use of

these tools and the TTSP.   This chapter contains my findings with respect to the two

supporting critical moments: (1) Natalie's debriefing of the Oak Tree task and (2) a

particular exchange between Helen and the interviewer during her first TTSP interview in

December 2005.

Natalie's Debriefing as an Impetus for Take-up of Tools

> …Like the whole sticky notes, Valerie modeled it with Marie Hanson[24] and
> Natalie took it into her classroom and Helen didn't. And I wish I would have.
> You know, why didn't you do that? It was not until the next lesson that I thought,
> okay, I'm going to do it this time. But I just needed to see it. Obviously, I needed
> to see it more than Natalie needed to see it (lines 256-265).

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[24] Marie Hanson is the name of a teacher in one of the COMET Cases. To read the COMET cases see
Smith, Silver, & Stein, 2005a, 2005b, and 2005c).

The opening quote transpired from a focus group interview on June 14, 2006.

Helen is reflecting on a moment in time when she realized that Natalie had enacted the

same lesson from CMP, one that they had begun planning collaboratively at a

professional development session, very differently than she had. The original moment of

dissonance occurred for Helen toward the end of the first year of the project at the March

2004 professional development session when she listened to Natalie's debriefing of her

enactment of the Oak Tree task (see Appendix E for a copy of the task how it appeared in

the instructional materials). I identified this particular moment as a critical event in

Helen's professional trajectory for three reasons. The first is because of the frequency

and point in time in which Helen referred to this event; Helen mentioned Natalie's

facilitation of the Oak Tree task several times throughout the interviews and she still

recalled this moment over two years after it originally occurred. The second reason I

included this moment is Helen's apparent emotional connection to this event, as

evidenced in the opening quote. Helen seems upset with her facilitation of the task as she

reflects upon Natalie's debriefing of her lesson enactment. The third reason is that this

event draws attention to Helen's use of multiple solution strategies, one of the

instructional strategies I identified through my primary analysis of the interview data.

Helen first talked about this event in the project-impact interview that the research

team conducted toward the end of the first year of the project in May 2004. Although

there is not a full interview transcript available for this session, there are notes from the

interview that included some direct quotes. The notes from this interview state that

Helen discussed that Natalie had had her students make posters of their solution strategies

to the Oak Tree task. In referring to Natalie's use of her students' posters Helen said, "I

now look at the way students solve problems and then choose specific students to present their solutions. Helen's description sounds very much like what Natalie shared doing with her students at the professional development session earlier that year.

Helen later mentioned Natalie's use of multiple solution strategies, or made another explicit reference to this event, six times throughout the June 2006 interviews (focus group and individual). Thus, three years after this relatively ordinary event occurred, a sharing of a lesson by another colleague, Helen vividly remembered the day and still connected emotion to this moment. Her emotion is visible in the opening quote when Helen said, "And I wish I would have [ordered multiple solution strategies]. You know, why didn't you do that" (lines 259-260)? Then, Helen added, "Obviously I needed to see it more than Natalie" (lines 264-265). I could hear the frustration in Helen's voice listening to the actual recording.

The third reason for including Natalie's debriefing as a critical event is that it illustrates another facet of Helen's interest in questioning strategies, an interest that first emerged after Helen interacted with The Case of Catherine Evans and David Young. That is, multiple solution strategies became a way for Helen to further articulate and refine her use of questioning strategies, as well as the questioning strategies of her colleagues. Although Helen often referred to multiple solution strategies and questioning strategies as separately throughout the data, the data still supports the notion that these ideas converged for Helen over time. Below is an example of one way in which Helen connected formative assessment, multiple solutions strategies, and questioning. In the November 2007 interview, Helen explained:

> But then also, back to the multiple solution strategies, I began to think about how the students' understanding coming into the task might lead them to a different

solution path. And so it goes back to, I think the second part of your question, that if I think about what a student's understanding is coming in, and I ask them a question…(lines 298-306).

This convergence of instructional strategies is something that I discussed when I described my methodological choices in Chapter 3. It is also something that emerged naturally during the card sort task that I inserted into the member check when I met with Helen to confirm my identification of critical events and instructional strategies within and along Helen's professional trajectory as a teacher-leader.   In the text that follows, I use Natalie's debriefing to illustrate the ways in which the MTF and TTLP scaffolded transfer of specific instructional actions from Helen's professional development experiences to her classroom practice.

The MTF and TTLP in *Classroom* Practice

Using the project version of the TTLP at the February 2004 session, Helen and Natalie began to plan a lesson from the recently revised Connected Mathematics Project 2 (CMP2) materials; neither teacher had taught this lesson in the past. Listed below are selected questions from the version of the TTLP that they used to plan the lesson that they later debriefed at the March 2004 session. I included these questions because they specifically address teachers' orchestration of multiple solution strategies, the topic central to this critical moment.

    A. Which solution paths do you want to have shared during the class discussion in order to accomplish the goals for the lesson?
        1. Which will be shared first, second, etc. Why?
        2. In what ways will the order to solution paths help students make connections between the strategies and mathematical ideas?
    B. What will you see of hear that lets you know that students in the class understand the mathematical ideas or problem-solving strategies that are being shared?

During the February 2004 session, teachers had approximately forty-five minutes to select a lesson and begin to plan it. Because time to plan was relatively short, most teachers continued to plan their lessons individually prior to enacting the lesson. In March 2004, Helen and Natalie returned to discuss their enactments of their lessons. Their lesson enactments were quite different. Below is a brief description of each task enactment.

Natalie's Lesson Enactment

The task, as it appeared in the CMP2 pilot materials, was composed of Parts A through D (see Appendix E). Part A consisted of four separate mathematical comparisons. The instructional materials presented data in a table for students to use to make these comparisons. The table included measurement data (i.e., circumference, height, and spread/diameter) for five types of trees. Natalie focused her lesson on Parts A.1 through A.4 of a problem set, a relatively small portion of the entire task. She began the lesson by having her students work in small groups to create posters that illustrated their solution strategies for Part A.1. During her lesson, debriefing Natalie described that she walked around and asked students questions while they worked to learn about their thinking (Session Video, March 2003). Natalie shared that she labeled students' posters with sticky notes numbered one through four as she traveled from group to group. To Natalie, the numbering represented an order from "most simple to most complicated" strategies. She did not tell the students what the numbers meant to her. The following is an exchange between Natalie and the lead facilitator at the March 2003 session that illustrates Natalie's decision making process.

Natalie: … I had them just present the first one [A.1] and then all together we talked
            about 2, 3 and 4. Because those hadn't—the different one there was no other

way to think about it—it was just a subtraction problem. And then the other two, this was if it's doubled, that one was simple, yeah. And we did together talk about 4 because that was one where I said, "Is it accurate? Is 23.5 close enough to 23?" So we talked about that one together.

Facilitator: So you really made some careful decisions about what to discuss and what not to discuss out of this whole time.

Natalie: Yes

Facilitator: So you sort of focused on part A, which meant you dropped those [parts B, C, and D], how did you feel about that?

Nicole: I was impressed. It seems that you have totally set that up.

Natalie: It wasn't hard--the only hard part was deciding, I knew this was a 1 because of the simple picture of it, but then it was, hey, which is 2, which is 3, it was deciding which was the most complicated way to solve it and then the simple way was easy to find. But it was after that. How to do it? But the kids did see and then they questioned number 3 where you just divide the 2 and get the same answer, so we talked about that.

Later in session, the facilitator asked Natalie whether she felt orchestrating the discussion in this manner made a difference in her students' learning. Natalie replied:

Yes, it definitely did, especially to the 1's, it made a difference with the 1's, because they were able to see a shortcut way to do it and they did not have to draw the dots especially if the numbers were to get bigger. It definitely helped out the 1's. I am not sure if the 2's would have gone, graduated to the way the 3's did it. But I think that that's Ok, they don't have to--they did it using the scale factor, which is exactly what we want them to do. So I think it was definitely beneficial to the 1's.

In her reply, Natalie expressed that this facilitation method made a difference for some of her students, especially those that used the least sophisticated method originally. She also demonstrated attentiveness to mathematical goals when she expressed her content around students' use of scale factor as a solution strategy.

Helen's Lesson Enactment

The research team did not capture Helen's lesson debriefing on video, but I located artifacts from Helen's lesson in her notebook. These artifacts consisted of the task as it appeared in the instructional materials with Helen's annotations regarding enactment and overhead copies of the task and table for the purpose of whole group presentation.

Helen had students complete the entire task, Parts A through D. She did not plan for or enact a whole group discussion in which students shared solution strategies as Natalie had (interview, November 2007). Instead, it appears that Helen focused on student access to the task. Her annotations on the original task seem to highlight potential misconceptions or obstacles for student engagement in the task. For example, the task asks students which statements "accurately" compare the largest trees. Next to the word "accurately," Helen wrote "accurate versus effective—defined back with Bolda Cola." This note suggests that Helen might have planned to have a class discussion regarding the definition of "accurately." Additionally, Part B of the task, students are asked to compare the height of the tallest person in history (8 ft. 11.1 inches) to the tree data. Helen noted, "consider rounding to nine feet" suggesting that she perceived the original value, which included a decimal, as too challenging for some students.

Because Helen's lesson debriefing and TTLP for this task are not available for analysis, I cannot make claims regarding what Helen actually did during her lesson enactment beyond what is available in interview data. However, for the purposes of this study, what Helen did is less important than what she did not do; she explicitly stated that she did not orchestrate a whole group discussion using multiple solution strategies prior

to April 2003. In the text that follows, I use interview data to illustrate Helen's perception of her use of multiple solution strategies, as well as ways in which the use of multiple solution strategies, an instructional action suggested by the TTLP, appears to have transferred into her classroom and leadership practice.

In November 2007, Helen described her knowledge of ways to use multiple solutions strategies with students as an exponential relationship dependent on her time in the professional development project. She stated, "…part of the thing was for me to think deeply about what are the different solution paths that students could use to think mathematically about a certain task. (interview, November 2007, lines 256-300). In an interview in June 2006, Helen expressed a similar sentiment. However, this time she implicitly referenced the TTLP. Helen commented:

> But seeing it in other people's classrooms and then trying it in my classroom, like I now see why those things are important because I tried it and it's not just something that I read about or something that, you know, the textbook suggests that I do, I did it and I developed my own value system on certain aspects. But because it was ongoing, I was able to do that. I don't think I would have been able to do that so well after one or two sessions.

Helen implicitly referenced the TTLP when she explained trying to use multiple solutions strategies in her own classroom. Yet, it was Natalie's debriefing that prompted Helen's awareness as to how and why she might use multiple solution strategies more deliberately. Worth noting is that, even though questions to prompt facilitation in ways consistent with what Natalie described were always part of the TTLP that Helen and Natalie used (both versions), Helen claimed that she did not attempt to use such a deliberate method for organizing a classroom discussion until after she saw it modeled by Natalie. With this said, Helen still discussed at multiple points in interviews that it was through planning, using the TTLP, that she actually incorporated such strategies into her

practice. Without the TTLP Helen very well might have tried to apply what Natalie described to her own classroom. However, the TTLP, provided a structure for facilitation through the questions it prompted Helen to consider with respect to this instructional action. Thus, it appears that the TTLP that situated Helen to prepare lessons that would scaffold her to make a shift in her practice over time.

There is evidence in Helen's November 2004 lesson plan, eight months after the critical event occurred that she used the TTLP in this way. In this plan, Helen wrote that she wanted to have students share methods they used to solve equations using tables, graphs, and equations. She numbered these strategies one through three, respectively. She also wrote that she would look for accurate graphs to assess student understanding while student share their strategies. Additionally, one of the goals Helen set was to have students work among tables, graphs, and equations. The word "among" is significant in this instance because it suggests that Helen was interested in students making connections from one representation to another, not simply finding a strategy that "works" for them. Making connections among strategies is an instructional move that the TTLP explicitly prompts.

In conclusion, although it does not appear that the TTLP prompted Helen to orchestrate a discussion using students' solution strategies as Natalie did, it does appear that once Helen was prompted by Natalie's uptake of this type of instructional action, the TTLP scaffolded her to move this instructional action into her practice. Once again, this conclusion emphasizes that tools have limitations. That is, outside of a larger context in which teachers and teacher-leaders learn to use the tools in ways that are consistent with the authors' intentions, tools are likely to have well more limited affects on practice.

The MTF and TTLP in *Leadership* Practice

There are three ways in which the TTLP appears to materialize in Helen's leadership practice over time. The first avenue is through Helen's use of the TTLP with colleagues. In June 2006, Helen described an exchange she had when working with high school teachers in her district using the TTLP. She recalled:

> We were doing some lesson planning [using the TTLP] and there was a question as to why did it matter the order that we present our multiple solution strategies. Now, I have it at the back of my head, I think of the activity that Natalie did where she had them [the students] present them[solution strategies] in a particular order and she helped them draw the connections between them and moved students from a very concrete level to a little bit more abstract level. One thing is that it's given me a tool that I can use in communicating with other teachers and principals…(lines14-21).

This quote illustrates a way in which Helen used the TTLP to prompt the consideration of novel instructional actions. In this manner, the TTLP served as an outside expert prompting change. Helen's words also highlight her belief that her experience using multiple solution strategies in her own practice, along with seeing her colleague explore the same strategy, has enabled her to communicate why using the ideas in the TTLP might influence students' opportunities to learn mathematics.

The second way in which Helen's capacity regarding the use of multiple solution strategies materializes is through her ability to recognize effective use of this instructional action. Just as Helen noted connections among strategies as an important mathematical goal in her own practice, she also has demonstrated her ability to recognize the use of multiple solution strategies as a complex aspect of practice when debriefing and observing others' lessons. For instance, in November 2007 Helen described the following scenario:

But I think the best part of the whole lesson -- I didn't get to see the lesson, but we debriefed about the lesson after, and it was so awesome to me because what she did, was she showed students who were very algorithmic, Y2 minus Y1 divided by X2 minus X1, how that connected to what Ms. Yeager did on the graph, and how that connected to what Ms. Unger did on a table. And so, it wasn't the show-and-tell of multiple representations, it was once they were shown how does building a connection increase the level of understanding, conceptual understanding for students in a classroom. (interview, lines 174-193).

This description suggests that Helen debriefed lessons with colleagues and, in doing so, she was attentive to ideas embedded with the TTLP, such as multiple solution strategies. Furthermore, it demonstrates Helens understanding that multiple solution strategies are not about variety, validation of ideas, or "show-and-tell." Rather, the use of multiple solution strategies is grounded within a larger goal of building students' conceptual understanding through mathematical connections to meaning. Again, these are all notions implicitly and explicitly developed in the MTF and TTLP.

The third way in which multiple solution strategies is visible in Helen's leadership practice is through her facilitation of teacher responses to professional learning tasks. Below is an excerpt from a session-planning interview in which the interviewer asked how Helen planned to have teachers share their thinking following a practice-based learning task. Helen replied:

We might even be able to draw connections like if we start presenting with 6th grade and like Sam comes up with a lesson. We could say something like, "Sarita, how might you use this in 7th grade or how could you use his strategy?" Do you know what I mean? Or, if we come up with a topic that is identified in 6th grade, like order of operations, then in 7th grade we might say, "Is there a spot in your curriculum that we can also address it in 7th grade." Kind of pull the whole group together with strategies (March 2006, lines 151-156).

Here Helen suggested connecting teacher "solutions" much like she might ask students to do using a mathematical task. She does not appear to want sharing if ideas simply for the

sake of sharing, but so that teachers make connections across grades. This indicates that

Helen has begun to make connections between her classroom and leadership practices in

more explicit ways than she had up to this point. A significant aspect of Helen's

suggestion to make connections among teachers' ideas is that she did so without being

prompted by the interviewer to make connections. The interviewer simply asked how she

would have teachers share ideas. I will explore the significance of this moment, as well

as similar moments of time more fully in my analysis of the third critical event—Helen's

meta-reflection during a session-planning interview.

Bridging Instructional Actions: MTF and TTLP to MTF and TTSP

In the following text, I explain ways in which Helen's developing conceptual

understanding of the MTF and the instructional actions suggested by the TTLP scaffolded

conscious (as opposed to subconscious) transfer of instructional actions from her

classroom practice to her leadership practice. Figure 5.1 below illustrates the role of the

TTLP, TTSP, and MTF in scaffolding transfer of instructional actions and conceptual

ideas from the professional development to Helen's leadership practice. The illustration

depicts that there are multiple influences on Helen's leadership practice including, but not

limited to, case studies explorations, discussions of mathematical tasks, as well as her

observations of facilitator instructional moves. The figure also shows the TTLP and

MTF serving as the primary pairing of tools to scaffold transfer to instructional practice

with the TTSP and MTF serving as a secondary set of tools to make connections between

classroom and leadership practice more explicit to the potential teacher-leaders.
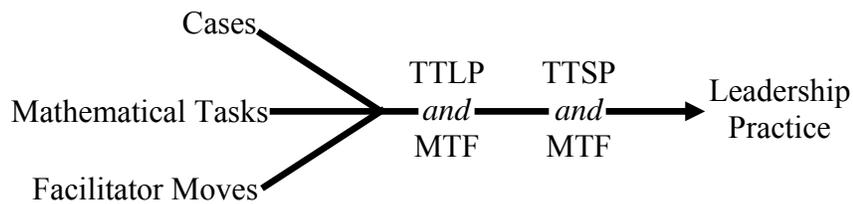
Figure 5.1. TTLP and TTSP as Scaffolds for Leadership Practice.

Helen's Reflection on Practice as an Impetus for Take-up of Tools

The project team began using the TTSP as a pre-session interview during the 2005-2006 school year, the third year of the project. A member of the project team interviewed Helen in this manner twice that school year, once prior to her December 2005 district-based session and once prior to her March 2006 district-based session. Clearly, the project team did not use the TTSP nearly as often or as directly as they had used the TTLP throughout the entire series. It was during the December interview when the following exchange occurred.

Interviewer: What will you see or hear that lets you know how to choose their thinking about the mathematical idea or aspects of practice?

Helen: I think one of the things…These are hard questions. Are they hard for everyone or just me? These are good though because we don't think about that. I think about it for kids, but I don't always think about it for professional development.

This event was critical for Helen in that is appears to be the moment in time in which she consciously connected her classroom practice and her leadership practice. Up to this point, there was preliminary evidence to suggest that Helen had begun to transfer ideas from the TTLP and MTF to her leadership practice but not that Helen actually viewed her two professional identities, teacher and teach-leader as complementary. Additionally, it

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was not clear whether Helen viewed her professional expertise with respect to classroom practice as a resource for her developing leadership practice.

Prior to the exchange above, Helen mainly had incorporated the TTLP and MTF as a resources or activities to complete in the professional development sessions she planned. For example, on several occasions, Helen asked her colleagues to use the TTLP in similar ways that she had during her participation in the project as a classroom teacher. That is, she had them use the TTLP to collaboratively plan lessons (field notes, October 2003; field notes, April 2005; field notes, March 2006; interview, November 2007). Similarly, Helen used the MTF as she had seen it used by the project team. One way in which she did this was by having teacher colleagues read the Case of Ron Castleman (Smith, Silver, & Stein, 2005a) and note evidence that suggested the case teacher lowered or maintained the cognitive demand of the task (field notes, October 2004). Helen implemented a related task with colleagues at the April 2005 district-based session she co-planned, this time using her own teaching as a dual case. Although the TTLP and MTF were present in the professional development sessions she planned, it did not appear that she consciously applied ideas from the TTLP and MTF when planning sessions for colleagues—she did not seem to use them as planning tools for sessions with teachers as she had used them when planning lessons for students.

The excerpt below describes one occasion in which Helen used the TTLP and the MTF in the manner suggested above, as resources for her colleagues to reconsider their classroom practice but not to scaffold Helen's leadership practice. The session when this occurred was during the 2005-2006 school year in Helen's work with high school

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teachers. Upon reflecting on this session, Helen expressed her pleasure with using the

TTLP and MTF in this manner.

> But, its just gonna take them [high school teachers] a little bit more shifting than it took us at the middle-school level. Because they really can't present all the lessons the way they are presented in the textbook. They have to set up the math task differently than it is set up in the curriculum, in some cases, so that it can be more like high-level cognitive dense, more student-centered. And then, we used the lesson template. They actually had to do this, since we ran out of time, as usual. So, they had to come back together on their own, and plan a lesson. And, Lisa Gallagher said that the lesson they planned for Algebra II on projectile motion was one of the best lessons of the whole year because they really thought about it differently (interview, June 13, 2006, lines 108-117).

This example illustrates one way in which Helen incorporated the MTF and TTLP as

activities or resources, but not as conceptually based or actionable tools to inform her

leadership practice. With respect to Helen's leadership practice, she used the MTF as a

resource in that it was something she could use to help her colleagues reconsider their

classroom practices. Though the MTF and TTLP served as resources to Helen, much like

an unplanned mathematics task might be to a teacher, she seemingly had her colleagues

use them as tools to reconsider their classroom practice.

Helen appears to have used the TTLP in much the same way that she used the

MTF in this case. She used the TTLP as a resource to create an activity for her

colleagues to complete and as a tool for her colleagues to transfer "new" ideas from the

professional development session into their classroom practices. The TTLP does not

seem to have served as a tool for Helen in this scenario. That is, there is not evidence to

suggest that Helen was able to use her expertise regarding facilitation of mathematical

tasks, as scaffolded by her use of the TTLP to prepare lessons for students, to prepare

sessions for her colleagues. Thus, in this particular instance, it does not appear that Helen

used the TTLP or MTF to inform her evolving leadership practice in substantive ways.[25]

However, there are several additional instances in the data to suggest that Helen had

begun to move toward more substantive uses of the TTLP and MTF to inform her

leadership practice following her exchange with the interviewer during the December

2005 TTSP session-planning interview. These data suggest that Helen was progressing

toward transfer and it appears that the exchange noted above from the TTSP interview

was the impetus for this change.

MTF and TTLP: More than Resources for Leadership Practice

To report findings regarding Helen's professional evolution I begin by reviewing

points from the December 2005 TTSP session-planning interview in which Helen

experienced the second order metacognitive move that I shared earlier in this chapter in

which she reflected on her thinking about practice. Then, I compare these points to

related exchanges during her March 2006 TTSP session-planning interview. Together,

these two interviews provide evidence for a shift in Helen's thinking away from

separated instructional practices (i.e., classroom practice as something separate from and,

to some extent, unrelated to leadership practice) to parallel, and to some extent,

intertwined practices. Based on this evidence my assertion is that the TTSP, via the

TTSP interview protocol acted to explicitly scaffold Helen's ability to make connections

between her two practices.

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[25] Although I do not view Helen's use of the MTF and TTLP in this instance to be substantive with respect
to her evolving leadership practice, I do not wish to convey in any way that her use of the TTLP and MTF
as resources for professional development is unimportant. Helen's use of the TTLP and MTF as resources
for colleagues to consider when analyzing and planning lessons is significant. It indicates that she saw
these tools as relevant and purposeful to her leadership practice and to her colleagues' classroom practices.

TTSP Session-Planning Interview—December 2005

The December 2005 TTSP interview began with what appears to have been a jarring moment for Helen. The interviewer began the review of her session plan by asking her to talk about the goals of the session to which Helen replied, "I've thought about everything that we are doing, but [the goal] for teachers to think loosely about assessment" (lines 10-11). Following Helen's realization that she had not explicitly considered a goal for the session, Helen asked if she could write herself a note and said, "I want to be clear about it all" (lines 25-26). Next, Helen began to articulate what she noticed by reviewing the student work teachers submitted for this session. She described the types of student errors she saw in the work and what she would like the teachers to discuss after they analyzed the same data. Helen stated:

> Students were able to do it with arithmetic but couldn't write an equation. So I was looking at it and a student would say something like 46*6+35, 35 was like the signing bonus and then we had like the hourly wage, but they couldn't write the equation. So if teachers could look at that and say well there able to do this so maybe if they make a table…(lines 36-41).

In this excerpt, Helen attempted to state a goal for the session by reflecting on her analysis of the student work. This suggests that Helen knew, given a specific context, what she wanted teachers to accomplish, but had not explicitly considered a more general goal for this work.

There are two important features of Helen's attempt to articulate a goal. First, although Helen had not explicitly planned a specific instructional goal, it was clear that she had thought carefully about what she might see or hear to let her know that teachers understood the task—one of the questions on the TTLP. Additionally, this is evidence that Helen did the task she intended for teachers to do prior to the TTSP interview and, as

such, prior to the actual session with teachers. Again, doing the task and considering

solutions is one of the prompts in the TTLP.

Ironically, instead of recognizing her "doing of the task" as a process similar to

what she might so with students, Helen described her preparation as an "advantage," as

something she saw a project team member model. She commented:

> See I think I have an advantage here because I went through the quizzes for the
> intense reading, the common assessments like to do an evaluation like what
> Lawrence [a project team member] did.   So I thought about what I would do to
> help a student go from A to B so I can ask things about a scaffolding strategy like
> how can we organize this information to help students (pause). Those kinds of
> questions. I guess that's where I'm kind of stuck.   My mind set is stuck in the
> scaffolding stage and the kinds of questions that I should ask.   I'm not sure if
> there are any misconceptions content-wise with the teachers so I that's where I
> would probably go.   I would try to get them back into the scaffolding strategy
> (lines 79-87).

By describing her "doing of the task" as an "advantage," it suggests that Helen has not

yet begun to connect this process to what she does when she considers potential ways in

which students might solve a mathematical task prior to using it in her classroom.

Although there still appears to be a disconnect for Helen, it seems that subconsciously

she had begun to make connections between her classroom and leadership instructional

practices. The scaffolding questions that Helen considered for teachers in the interview

excerpt above are also indicative of a parallel question on the TTLP. The parallel TTLP

question asks the teacher what questions she will ask if students begin to struggle or have

misconceptions. Here, Helen has considered questions to ask if teachers struggle with the

task.

Not long after the previous quote occurred in the session-planning interview the

third critical moment emerged. Below I have repeated this exchange to remind the

reader.

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Interviewer: What will you see or hear that lets you know how to choose their thinking about the mathematical idea or aspects of practice?

Helen: I think one of the things…These are hard questions. Are they hard for everyone or just me? These are good though because we don't think about that. I think about it for kids, but I don't always think about it for professional development.

After this exchange, the interview continued but no other questions appeared to evoke such emotion as the first question did when the interviewer first asked about goals. In fact, at the conclusion of the interview Helen again professed her discontent with respect to not planning explicit goals for the session. She commented:

> It [the TTSP session-planning interview] was very helpful. I can't believe we didn't articulate a goal" (lines 336-337). Helen further stated, "When we planned it [the session] we were so involved with the tasks that we had to accomplish that we didn't actually think about the behind the scene important things" (lines 344-346).

Given the evidence referenced above, one might wonder why I consider Helen's response regarding the difficult nature of the questions on the TTSP and their connections to questions she claims to use when preparing for students to be the pivotal moment in Helen's leadership practice. Another moment that some might argue was more pivotal for Helen was when she realized she did not have explicit goals for the session. My reasoning to identify the former as a critical moment in Helen's leadership practice was based upon identifying this particular exchange as a second order metacognitive move unlike any other reflection in all of the interview data. That is, it was not until Helen realized that the questions she had been using to prepare lessons for students paralleled the questions the TTSP interviewer asked of her when preparing for teachers. This moment was when Helen appeared to connect *consciously* her classroom and leadership instructional practices. Thus, I identified it as the critical moment.

The March 2006 session-planning interview unfolded differently. This time, when asked about goals for the session Helen was prepared to articulate her plans. She stated, "Our goal is for teachers to look critically at the MEAP data at the grade level above. And then, use the results of the test to inform instruction that they will do next year and create activities that they will use this year" (lines 9-11). As the interview continued, Helen appeared to make several connections between questions on the TTLP to questions the interviewer asked using the TTSP. For instance, when asked about what questions she might ask to access prior knowledge Helen responded first by referencing a series of questions she and Natalie (her colleague) prepared to focus teachers' thinking on analyzing their students' work on an assessment task. However, without prompting she added:

> …we might also ask questions that are specific to content. Like, I might refer to a book. If we are at a graph that is distance versus time I might say, "well remember what we did in *Variables and Patterns*" Kind of have them recall activities that we have already done so that they can plan some more. I guess we could ask questions…just when I think I have thought of everything. We could ask questions to refer back to our professional development to referring to cognitive demand or referring to the scaffolding strategies or the lesson planning template. As they are planning an activity we might ask: what is the goal? What is the mathematical goal of this activity (lines 40-52)?

Helen's ongoing list of questions appears to parallel what she might consider when working with students. That is, just as she might have students refer to a previous mathematical task to access their prior knowledge, Helen listed the different reference points that might be available to teachers given their past teaching and professional development experiences. Referring teachers to a book they teach, is similar to referring students to a mathematical task they explored. Additionally, referring teachers to past

professional development experiences is much like referring students to past classroom experiences.

Just as Helen appeared prepared to articulate a goal for the March 2006 session during this TTSP interview, she also appeared to make more connections, more explicitly, between leadership and classroom practices. This pattern continued as the interview progressed. When the interviewer asked Helen what expectations she had for teachers as they worked on the task, Helen immediately offered probable teacher misconceptions, along with what she wanted teachers to do. Again, such thinking, although not explicitly requested on the TTSP, was something Helen was prepared to share. This may have been scaffolded by her prior experiences using the TTLP to plan for students.

In addition to seeming prepared to make connections between leadership and classroom practices, Helen also appeared to be clearer about her goals with regard to potential artifacts the teachers might produce. She stated, "Our goal is to examine the data to use it to inform our practice. I need to see the product. Activities that they can use next year when they are doing that content again or activities they can use this year to bring students up…" (lines 72-75). Related to Helen's perceived need to see a product teachers could use in their classrooms, a way for them to make connections between the professional development session and their classroom practices, she appeared to adjust this session based on the December session. To this end, she discussed how she planned to monitor teachers' engagement in the task by asking questions to prompt mathematical connections for them.

In addition to Helen's proposed monitoring of teacher engagement serving as a form of formative assessment, it also makes visible her attentiveness to mathematical connections. In the interview, she referenced mathematical connections at two levels: (1) connections to more complex content, such as calculus and (2) connections across grade levels. She elaborated how she might structure teachers' sharing of ideas, in the following excerpt (*note: this is in addition to her colleague's offering that each grade level group would report out their findings and potential plans for instruction based on these findings*):

> We might even be able to draw connections like if we start presenting with 6th grade and like Sam comes up with a lesson. We could say something like, "Sarah, how might you use this in 7th grade or how could you use his strategy?" Do you know what I mean? Or, if we come up with a topic that is identified in 6th grade, like order of operations, then in 7th grade we might say, "Is there a spot in your curriculum that we can also address it in 7th grade." Kind of pull the whole group together with strategies (lines 151-156).

Especially interesting about Helen's proposal to structure connections for the teachers across grade levels through questioning is that making connections among teachers' strategies is not a question explicitly asked in the version of the TTSP used for the session-planning interviews. Instead, prompting students to make connections among strategies in this manner was a question that was on the version of the TTLP Helen used to prepare lessons for students. One might also recall that use of multiple solution strategies was an instructional action that appeared relevant to Helen based on my preliminary analysis of the interview data. Finally, making connections among strategies was the central instructional issue embedded within the second critical event, Natalie's debriefing of the Oak Tree task. Each of these instances mentioned throughout this section provides further evidence that Helen's interaction with the TTSP in December

2005 may have prompted her to be more prepared to learn. In this case, "more prepared to learn" means that she was potentially more prepared to transfer ideas from her instructional practice to her leadership practice.

CHAPTER 6

COMPLEMENTARY TOOLS AS INSTRUMENTS TO
PREPARE USERS FOR FUTURE LEARNING

"In a word, we live from birth to death in a world of persons and things which in large measure is what it is because of what has been done and transmitted from previous human activities." -- Dewey, 1938, p.39

The quote above from John Dewey embodies what is at the heart of this study, the transference of ideas through past experiences (research) to develop tools (instruments of change) to scaffold change in what we do (practice). Thus, I analyzed how a set of complementary tools functioned to support ongoing learning in a teacher's practice. To do so, I built an analytical frame based on the work of psychologists who study learning such as Bransford, Cole, Engeström, Schwartz, Star, and Tuomi-Gröhn. Simply stated, the resulting analytical framework was: (1) tools exist to assist someone in accomplishing a task or carrying out an activity; (2) critical events (i.e., boundary encounters) potentially provoke the take up of a tool; and (3) tools have the potential to convey knowledge beyond that readily available to the user, possibly connecting separate social worlds as is the case with boundary objects. Thus, tools might have the capacity, when used by knowledgeable actors to serve as instruments for future learning that scaffold both one's teaching practice and her leadership practice.

In addition to this analytical frame, I grounded my work in a conceptual frame that grew out of my literature review of relevant past attempts at education reform and a trend toward teacher leadership as a relatively recent methodology for supporting ongoing and future reform efforts. In this review, I pointed to an over emphasis on communication of ideas by a variety of stakeholders and an under emphasis on opportunities for teachers to interact with and engage in the ideas that are communicated, to greater of lesser extent, through a variety of pathways.

In this literature review, I was also attentive to an oversimplification of the construct of teacher leadership.   An overwhelming amount of literature is available that discusses different conceptions of teacher leadership. Unfortunately, there are several other aspects of teacher leadership that research and theory do not address. For instance, there is not research that addresses administrators' needs in supporting the practice of teacher leadership as opposed to the role of teacher-leader. Also missing from this body of research is content-focused work to support the practice of teacher leadership within mathematics. While some mathematics educators have designed professional development to scaffold the practice of teacher leadership (Carroll & Mumme, 2007), there is not research to speak to what might be effective. Additionally, theory in this area is very limited (NCSM, 2008). A key feature of this study is that it begins to address this elusive aspect of educational research. It does this primarily by focusing on the evolution of a teacher's leadership practice grounded in her evolving classroom practice, both within the context of the teaching and learning of mathematics.

Using my conceptual framework to inform a need for this study and my analytical framework to analyze data, I sought to build a generalizable theory that suggests the use

of complementary tools, composed of conceptually based tools and tools of action, in practice-based mathematics professional development to scaffold the transfer of instructional actions from professional development to practice, both classroom and leadership instructional practices.

Discussion of Findings

As I stated in an earlier chapter, my study is not about proving transfer but rather about using a developmental conception of transfer as a way to analyze the manner in which a set of complementary tools served to prepare a teacher for future learning. My analysis of what surrounding critical events appeared to provoke a teacher to take up specific instructional actions suggested by the tools revealed insights into how teacher educators could use common problems of practice, in this case a teacher's overuse of choral response to assess student thinking, to prompt teachers to take up research-based instructional actions. Furthermore, my study suggests that complementary sets of tools, composed of conceptually based tools and tools of action, afford a synergy that supports ongoing learning by first providing a conceptual understanding or way for teachers to make sense of an aspect of their practice. Later, the tools provide a structure to scaffold the transfer of the instructional actions they suggest to a teacher's practice. To elaborate the possibilities of practice-based tools as instruments of change (i.e., mediating objects that bridge research and practice) I discuss the findings of this study in two parts. I begin by focusing on the impications of this study and then discus the potential to use this study to inform future research.

Within my discussion of the findings, I focus on two themes: (1) the power of tools to serve as both conceptual and actionable structures of practice and (2) tools to

scaffold the take up of instructional actions explored in professional development to a teacher's practices.   As part of my argument on the power of tools as conceptual and actionable structures, I revisit the instructional actions that this particular set of tools appeared to make visible to Helen and elaborate the ways in which the tools scaffolded the transfer of these actions from professional development to practice. Next, I turn to the notion that tools are representations of ideas to enable someone to accomplish something in his or her practice. Within this notion lies the work of Wertsch with respect to possible affordances and constraints of tools. Therefore, I articulate ways the tools in this study appeared to constrain or support Helen's ability to reconsider her practices.   I also discuss how Helen, as part of a larger activity system, acted to filter instructional actions into and out of her practices.

Power of Tools as Conceptual and Actionable Structures

The Oxford English Dictionary (2010) defines conceptual as "That is conceived or taken into the mind." It is with this definition that I view the tools of this project, the MTF, TTLP, and TTSP, to have conceptual properties embedded within their design structures. While each of the tools function in some way to hold together ideas or concepts, the research team used the MTF as the primary conceptually based tool for the teachers in this project. The research team opted to use the MTF, with corresponding levels of cognitive demand, in this manner because it provided a structure and language for teachers to characterize mathematical tasks and to consider how their implementation offers different opportunities for student learning.

Helen used the MTF with corresponding levels of cognitive demand as a conceptual tool repeatedly throughout the project when she considered and selected

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mathematical (or pedagogical) tasks to use with students or teachers. The MTF appeared to enable Helen to think about her selection of tasks from a new perspective. Thus, the MTF did not supply Helen with "good" tasks; it provided her a framework with which she could evaluate students', or teachers', opportunities to learn given a particular task. In this way, the MTF supported a movement of ideas from the professional development to Helen's practice by serving as a bridge from one context to the next.

Prior to implementing the MTF and other tools in her practices, Helen noticed aspects of her practice that she wanted to change (e.g., her use of choral response). Once Helen appeared to achieve some level of cognitive disequilibrium around a specific aspect of practice relevant to her, it appeared that she became poised to take action to facilitate change in her practice. With regard to Helen's uptake of the MTF, and later the TTLP, the Case of Catherine Evans and David Young (i.e., Critical Event 1) seemingly provoked her aspiration to make changes in her planning for classroom instruction. While the MTF supported Helen's understanding of the phases through which tasks move throughout a lesson and her role in maintaining the cognitive demand of a rich task, it was the TTLP that appeared to prepare Helen to move the actions that she read about and discussed in the case into her own practice. In this way, the TTLP was a tool of action for Helen. The TTLP did not simply provide ideas about what Helen's practice could look like; it provided a structure to prompt Helen to move the actions she read about and was beginning to understand into her practice. The TTLP appeared to do this by prompting Helen to plan for instruction in an increasingly deliberate manner that focused on student thinking rather than structural components of the lesson.

Evidence of Helen being attentive to issues associated with the MTF, including cognitive demand, materialized as early as the June 2003 project retreat when Helen noted the importance of the role of the teacher in student learning. At this point in the project, the MTF appeared to serve primarily as a conceptual tool to Helen. Later, however, the data indicated that although Helen continued to use the MTF as a conceptual tool, she also began to use it to reflect on her practice. I saw evidence of this type of use primarily in interview and session transcripts when she reflected on her enactment of lessons and sessions. During interviews, she reported questioning whether something she did lowered the cognitive demand of the task. For example, when sharing about her work with other teachers in an interview in November 2007 Helen stated:

> …teachers, like students, come to us with such diverse mathematical ability and knowledge. So one of the things I think about is whether or not a particular activity got a deeper understanding, what it was about my instruction that either facilitated deeper understanding or undermined it (lines 2229-2239).

In a related quote, Helen did not report concern over what she might have done to undermine a task; however, she appears to grapple openly with issues of cognitive demand with regard to teacher learning. She commented:

> We looked at the Stiggins' article and I felt like I was almost like I had to put on the evaluator's hat and it was hard not to interject and say, "Well, this is not what he meant by formative assessment." They had these visions that they were doing a lot of things in their classrooms, that really aren't that formative in nature (June 13, 2006, lines 136-139).

Thus, the tools became a way for Helen to reflect on her work. They focused her attention on her role in supporting or undermining learning giving Helen another avenue by which she could reconsider her practices and connect what she had been learning in professional development to those practices. Furthermore, they acted to focus her

reflection on specific instructional actions embedded implicitly in the MTF and explicitly in the TTLP, thus constraining her work.

Tools to Scaffold Instructional Actions

My analysis of the interview data yielded three related instructional actions that appeared to be relevant to Helen: questioning; use of multiple solution strategies/representations; and formative assessment. Although I initially identified these strategies as separate, my hypothesis was that these individual strategies converged for Helen over time in the project. I later confirmed this hypothesis through additional data analysis and a semi-structured interaction with Helen in which she reviewed and commented on the strategies I had identified. During this interaction, Helen elaborated her belief that the three strategies listed above became intertwined within her practice over time. I further corroborated her belief regarding these strategies by having Helen complete a card-sorting task in which she organized a set of instructional strategies related to assessment, questioning, and multiple solution strategies/ representations. Helen's creation of her lesson "strategy wheel" provided additional supporting evidence of the merging of these ideas within her practice.

Of particular interest to this study is understanding from where these strategies emerged. Although I do not, and would not, claim that these instructional strategies emerged solely from Helen's interactions with the tools; I do believe that the tools, and in particular, the TTLP, supported Helen's interest in continually reflecting on and reconsidering her use of these actions in her practices. Therefore, my claim is that the tools raised Helen's attentiveness to these strategies through the questions they prompted her to consider *and*, more importantly, by providing a structure by which Helen could

incorporate them into her practices via lesson preparation and reflection using them in conceptual and actionable ways.

Within my analysis of the three critical events, I pointed to instances that support this claim. For example, when Helen prepared lessons to develop her own dual case modeled after the Case of Catherine Evans and David Young (i.e., Critical Event 1) she used the TTLP to guide her planning. In the first lesson, she attempted to unpack student thinking and provide opportunities for multiple solution strategies to emerge, both are instructional actions suggested by the TTLP. In the second lesson, she acted to stifle such practices through her questions and responses to students. By doing this, we see evidence of how Helen took up and used the TTLP and MTF for purposes of lesson and session preparation.

A similar situation unfolded when analyzing Helen's practices through the lens of Natalie's lesson debriefing (i.e., Critical Event 2). In this scenario, Helen realized that she was not attentive to the "sharing and discussing" portion of the TTLP in which the purpose is to prepare for students to discuss their strategies with their peers through a classroom discussion. As a result of realizing her inattentiveness to this aspect of her practice, Helen's attention seemed to refocus. Though Helen's attention appeared to refocus, it did not distract her from her ongoing interest in developing questioning strategies to assess student thinking. Instead, it refined her focus toward improving the ways in which she prepared for and implemented the use of multiple solution strategies within her practice. Thus, Helen's use of multiple solution strategies became a particular aspect of questioning to consider when preparing for and reflecting on lessons.

Explicit Connections between Practices

Extending from Helen's work within her classroom practice was the emergence of parallel strategies in her leadership practice. Evidence of Helen making connections between her classroom and leadership practice as it pertains to multiple solution strategies was visible in her second TTSP session-planning interview when she mentioned her intent to scaffold the sharing of teachers' summaries of their tasks by asking questions to prompt teachers to think about possible connections between grade levels. Such an instructional move was not one that the interviewer prompted Helen to consider explicitly. Instead, it was a move that Helen transferred into her practice over time culminating from her use of the TTLP and MTF within her classroom practice and likely prompted by at least two of the supporting critical events, Natalie's lesson debriefing and Helen's noticing of the similarities that exist between her two practices.

Tools as Part of an Activity System

Although I argue the tools of this project play a role unlike other resources of the project to scaffold the transfer of ideas from professional development to practice, they do not act alone. There are other experiences (e.g., cases, discussions of mathematical tasks, and observations of colleagues' lessons or sessions), within and outside of the professional development, that also were likely influences on Helen's reconsiderations of her practice. Furthermore, the tools do not act in the absence of a user, in this case Helen.

In this study, Helen participated in two activity systems. The first activity system, as shown in Figure 2.3, represented Helen's classroom practice. The second activity system, as shown in Figure 2.4, represented Helen's leadership practice. Within these

systems, a set of complementary conceptually based tools and tools of action served as the instruments mediating potential shifts in Helen's practices. Although the tools were the mediating agents, Helen was the funnel by which the tools and strategies embedded within the tools passed. As such, she served as a filter deciding what strategies entered, exited, and were blocked from her practices.

The data discussed in Chapters 4 and 5 provide a window into what Helen perceived to be relevant to her practices and, as such, allowed to enter her practices. In addition, data suggest that Helen became an increasingly "knowledgeable" user of the tools, through her successive interactions with her colleagues, and other supporting activities at the professional development sessions. Having said this, Helen came to the project knowing things about mathematics, mathematics teaching, and mathematics learning that informed her use of the tools. Thus, her incoming knowledge likely influenced what Helen was able to accomplish in her practices with the help of the tools. As such, it is important to note that while the tools appear to have functioned particularly well for Helen, for some the tools may not offer enough scaffolding or appropriate scaffolding to be the impetus for similar shifts in practice.

While the tools of the project appeared to support shifts in Helen's thinking about her practice, they also constrained Helen's focus. That is, researchers designed the tools for a purpose and structured them to address this purpose by prompting teachers to consider specific instructional actions while preparing lessons (or sessions). In this way, the tools of this project focused Helen's attention to selecting and enacting cognitively demanding tasks. Therefore, I do not believe that it was by chance that Helen focused on the three instructional strategies discussed throughout this paper. Instead, my assertion is

that it was the constraints of the tools and the other activities embedded in the series that

prompted Helen to reconsider her practice through these instructional actions. Having

said this, Helen probably would not have taken up the tools or the strategies that she did

had she not perceived them as relevant and productive to her practices.

While some might perceive the constraints discussed above as flaws, in this case,

I believe the constraints served as features to advance and transform Helen's thinking

about her practice in ways that are consistent with reform efforts. Thus suggesting that

tools, like those used in this project, could become what Ball and Cohen (1999), in

Developing Practice, Developing Practitioners, a pivotal paper discussing a practice-

based theory of professional education, refer to as a "key element in a curriculum of

professional development"(p.6), an element that could provide structure and focus

teachers' attention on specific instructional strategies.

Implications for Professional Development

Earlier in this chapter, I asserted that although some teacher educators have

published resources to support the development of teacher leadership practices, little is

understood about how and in what ways mathematics teacher(-leaders) interact with and

take up the ideas and instructional actions among which they engage in professional

development settings. The findings of this study begin to shed light on this particular

question. As such, the findings have implications for both the design of evaluation of

future professional development projects.

In *Designing Professional Development for Teachers of Science and Mathematics*

(2010), Susan Loucks-Horsley and her colleagues suggest a framework for the design and

evaluation of professional development that they ground in years of educational research.

In the introduction to this recognized resource for professional developer's in mathematics and science education, the author team writes, "There is widespread consensus regarding what constitutes effective professional learning: It is directly aligned with student learning needs; is intensive, ongoing, and connected to practice; focuses on the teaching and learning of specific academic content; is connected to other school initiatives; provides time and opportunities for teachers to collaborate and build strong working relationships; and is continuously monitored and evaluated (p.5)." Given that effective professional development is composed of the characteristics listed above, the author team developed a design framework for professional development that includes six phases connected by ongoing reflection and revision. In addition to the six phases, the authors discuss four inputs into the design framework: *Knowledge and Beliefs*; *Context*; *Critical Issues*; and *Strategies*. The findings of my study have implications for at least two of these inputs, *Knowledge and Beliefs* and *Strategies*, with regards to how these inputs influence the take up of instructional ideas and action experienced by teacher(-leaders) as part of ongoing professional development.

The input *Knowledge and Beliefs* draws attention to professional developers' knowledge of and use of research and practical experiences to inform their work with teachers. It is composed of five domains, each of which is connected to learning. Of the five domains, the domain most relevant to my study is, "The Change Process." Loucks-Horsley and her colleagues write:

> Understanding this domain helps designers think about professional development as a process of individual and organizational change through which teachers transform their knowledge and apply new ideas to changes in practice. An understanding of the change process enables designers to anticipate and plan for how teachers will be supported to move from awareness to implementation to sustainability of new practices (p.23).

Notable in this quote is the authors' attention to transfer of learning from awareness or understanding of new ideas or strategies to implementing them, and finally, to sustaining new instructional actions.

Related to the input *Knowledge and Beliefs* is that of *Strategies*. The input *Strategies* outlines sixteen options professional developers have by which to engage teachers in explorations of content, students, and pedagogy. Loucks-Horsley and her colleagues divided the *Strategies* input into four clusters. Of particular interest to my study is the cluster, "Examining Teaching and Learning." It is within this cluster that both lesson study and case discussions reside; these are the two primary strategies that were used by the project that was the context for my study. As shown in Figures 2.3 and 2.4, I identified these strategies as the "rules" within Helen's activity systems. In the text that follows, I explain how the findings of my study suggest refinements to the Loucks-Horsley framework by unpacking aspects of two of the existing inputs, *Knowledge and Beliefs* and *Strategies*.

In my study, I used activity theory to consider a teacher's change process by focusing on how the MTF and TTLP, a set of complementary tools, used as mediating agents, scaffolded transfer of instructional actions from professional development to practice. Using activity theory as an analytic frame enabled me to identify how and in what ways the MTF, a conceptual tool, paired with the TTLP, a tool of action, appeared to function to support shifts in Helen's thinking with regards to her classroom and leadership practices. Furthermore, it allowed me to notice that these shifts in Helen's practices, while supported by the tools, were not solely the effects of the tools. This is evident in the fact that the tools did not appear to provoke Helen to think about her

practices differently. Rather, other supporting critical events (e.g., a case discussion) appeared to provoke Helen to take up the ideas and actions suggested by the tools. By using activity theory to consider the overall context of the professional development, I was able to document the roles and influence of the tools, as well as other aspects of the activity system.

To summarize, out of this analytic approach emerged three key findings. First, the tools used in the professional development project were not what appeared to provoke Helen to reconsider her practice. Instead, it was other activities, represented in the "rules" of the activity systems, which appeared to act as stimuli for her take up of instructional actions suggested by the tools. Second, the complementary nature of the tools appeared to support an evolution in Helen's thinking regarding her classroom and leadership practices that suggests that the tools scaffolded her ability to move beyond awareness of the ideas and actions in relation to her classroom instructional practice to actual implementation of the ideas and actions in her leadership instructional practice. Third, Helen's leadership practice emerged as an extension of her classroom practice. Thus, this suggests that working with potential teacher-leaders initially within their own practice appears to be a productive strategy to support teachers as they learn to engage with their colleagues around related instructional issues. However, Helen appeared to benefit from experiences that helped her make connections between her roles as teacher and teacher-leader.

Primarily, these findings suggest that professional developers should consider the system when designing, planning, and evaluating professional development. That is, instead of focusing on what strategies might enable professional developers to reach their

instructional goals, they should be attentive to how these strategies are likely to work together to support teacher(-leaders') reconsiderations of their practices. Evaluators, whether part of or separate from the planning and implementation team, should analyze how and in what ways specific strategies supported or undermined one another in action with teacher(-leaders).

Furthermore, this study points to a need to develop methods to scaffold transfer of ideas and actions from professional development to practice. In this study, it was the complementary set of tools (i.e., the MTF, TTLP, and TTSP) that appeared to serve this function in the teacher's practices. Within the existing Louks-Horsley et al. professional development framework, there is no suggestion that a supporting strategy, such as the inclusion of complementary tools, may be necessary to scaffold transfer of ideas and actions explored through these strategies to teacher(-leaders') practices. Evaluation of such methods should focus on assessing whether mediating agents were present and how and to what extent they appeared to scaffold the movement of instructional ideas and actions from professional development to practice.

Finally, professional development focused on supporting teacher leadership practice should be grounded in teachers' classroom practices and extended to their leadership practices through ongoing and structured experiences designed to help teachers create connections between their intertwined roles as teachers and teacher-leaders. I identified a need for such explicitness in learning experiences designed for teacher(-leaders) through my analysis of Helen's initial TTSP interview. Recall, this was the point at which Helen appeared to connect consciously her practices. Although it had appeared that the TTLP had begun to facilitate subconscious connections for Helen with

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respect to her classroom and leadership practices, it was not until the TTSP interview that Helen appeared aware of the intertwined nature of her roles. Evaluation of this type of professional development could consist of formative and summative assessments to determine how teachers are making connections between their practices and to what extent such connections are prevalent within a given group of teachers.

In short, the implications for the design and evaluation of professional development that I articulated above are refinements of currently existing frameworks and understandings of effective professional development. They seek not to replace what exists but rather, to suggest ways in which designers, facilitators, and evaluators of mathematics professional development can optimize what teacher(-leaders) take from professional development to their own practices.

Future Research on Tools

In this section, I articulate the ways in which the findings of this study could inform future research pertaining to how teacher educators use tools to support teacher learning with respect to instructional actions of classroom and leadership practice.   In the previous section, I highlighted three findings.   To begin, critical events that provoke the take up of a tool or set of tools may be prompted by a variety of experiences. Although the types of experiences differ, it appears that each critical event is an experience that makes visible to the teacher something that she wants to improve upon with respect to her practice or with respect to her ability to help others refine their practices. In this way, the critical events prompt cognitive dissonance that provokes the take up of a tool. The second finding that I discussed is that conceptually based tools and tools of action have the potential to work in synergistic ways to scaffold the take up of both implicit and

explicit instructional actions suggested by the tools—conceptually based tools providing understanding and tools of action providing appropriate scaffolding to do something differently within one's practice. The third finding I shared is a potential benefit of helping a teacher make explicit connections between her classroom and leadership instructional practices. Although the tools of this project provide implicit scaffolding for natural transfer of ideas from one context to the next (i.e., classroom to leadership instruction), this type of unsupported transfer appears to be slow and inconsistent. Therefore, teachers may benefit from deliberate experiences focused on helping them relate their two parallel practices that go beyond simply using the TTSP as an interview protocol. In the following text, I suggest lines of future investigation with respect to tools and tool usage in teacher education.

The findings of this study point to the benefits of using complementary sets of tools to scaffold the transfer of specific instructional actions from professional development to practice by describing the ways in which tools appeared to influence Helen's practice. However, there are still questions to be studied that could help teacher educators optimize teachers' opportunities to learn through the integration of tools within practice-based learning experiences. One avenue for future research is to seek understanding regarding the grain size of a tool. More specifically, research could explore how and in what ways grain size influences teacher learning. Another question that has emerged is whether teacher educators could create additional tools of action similar to the TTLP to scaffold the movement of instructional ideas that are suggested only implicitly by other research-based frameworks.

The earlier scenario, in which Helen attempted to refine her use of students' solution strategies after her interaction with Natalie, provides additional evidence of how and in what ways Helen used the TTLP. Furthermore, it sheds light on potential issues that teacher educators need to consider when using tools as part of teacher education. While this evidence might suggest that a feature of a relatively comprehensive tool of action, such as the TTLP, is that it enables teachers to focus on the particulars (i.e., more refined or complex actions) of an aspect of practice when they are prepared to do so, an alternative explanation is also possible.   This example could indicate that "smaller," more precise, tools are a way to affect change more efficiently or effectively by intentionally focusing teachers' attention on particular instructional actions. Although this study is inconclusive with regard to this dimension of tools, it offers two potential theories for future investigation.

The type of investigation described above is related to the work of Pamela Grossman and her colleagues around the notion that tools might be created to structure what Ericsson calls "deliberate practice." Deliberate practice is isolated and repeatable activities that focus on the most challenging aspects of practice. Grossman (2008) argues that articulating ways in which teachers might practice the most complex aspects of practice are necessary but missing from current work in teacher education. With this in mind, she suggests that the field move beyond "pedagogies of investigation" to "pedagogies of enactment." She grounds her assertion on the premise that many opportunities exist for pre-service and in-service teachers to investigate practice through resources like case studies of classroom enactments and samples of student work. However, she notices what is missing from teacher education, with the exception of

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student teaching experiences, is focused inquiry around what she calls "the interactive aspects of teaching." My belief is that properly and intentionally designed tools, like those used in this study might serve to scaffold such inquiry. Part of creating properly and intentionally designed tools is to understand the impact of grain size on teacher learning.

As I mentioned in a preceding chapter, the MTF with corresponding levels of cognitive demand is similar to other types of conceptually based tools that were originally developed as analytic tools for research. Like many of the other frameworks in educational research, the MTF offers its users a common language, the potential for shared understanding of a process, and a way to characterize or sort ideas. Two similar frameworks in mathematics education are those used within Cognitively Guided Instruction (CGI) and the Ongoing Assessment Project (OGAP). Unlike the MTF, CGI and OGAP frameworks do not have a complementary tool of action to support the implementation of the ideas and actions embedded within these frameworks in teachers' practices. In fact, CGI researchers have argued that the separation between these frameworks and particular instructional actions is a feature rather than a flaw because of the generalizability and potential generativity of the framework as it exists. Below I discuss why I believe teacher educators could create a complementary tool of action to help teachers and teacher-leaders implement the CGI frameworks, and other similar frameworks, in ways that would support fidelity and sustainability of instructional actions.

To begin, the ways in which teacher educators have used the CGI frameworks with teachers is similar to how they have used the MTF with teachers and teacher-

leaders. That is, teacher educators have embedded both tools within professional development in which teachers are participants within a reform community seeking to improve their practice. Another similarity is that both frameworks place an emphasis on creating opportunities for teachers to make visible and use student thinking to affect student learning of mathematics. Finally, both provide organizational structures for teachers to consider mathematics. In the case of CGI, teachers learn to sort students' computational strategies in an effort to build computational fluency. Using the MTF, teachers learn to sort mathematical tasks based on a shared understanding of cognitive demand. Even with these similarities, the CGI developers have clearly taken the stance that CGI does not train teachers to implement given practices. Instead, they state:

> …the interest is in having teachers come to see themselves as ongoing learners, seeking classroom practices that are responsive to the needs of the students and continually evaluating and adapting classroom practice. (Franke, Carpenter, Levi, & Fennema, 2001, p. 658).

The CGI team hopes that once teachers develop an understanding of CGI and the corresponding frameworks they will be able to "see how the analyses of children's thinking discussed at the workshops directly relates to the ways that students in their classroom think and learn" (Franke et al., 2001, p. 657).

I agree with the position that teachers need to see themselves as ongoing learners and that they need to be able to adjust instruction in ways that meet the needs of their students. However, I also believe that the expectation on the part of the CGI research team that teachers will transfer ideas from the professional development to practice naturally requires a substantial leap of faith. Therefore, it is my assertion that a tool of

action could be developed, similar to the TTLP, which is flexible enough to allow for the type of teacher autonomy the creators aspire to protect, while providing a structure by which teachers are better situated to move the instructional actions implicitly embedded within CGI to classroom practice. For example, such a tool could include prompts similar to the TTLP in which teachers are asked to consider ways in which students might solve a task and then prepare questions to ask students based upon probable solution strategies. Creating and using such a tool, given the findings of my study, might help teachers who have struggled to use CGI shift from viewing it as a set of procedures to something they understand *and* have a plan for implement in their classrooms in ways that are consistent with the developers' intent.

While I focused on CGI for this discussion, primarily because of its similarities to the ways in which the MTF has been used by its designers with teachers and teacher-leaders, I believe there are several similar types of frameworks in educational research that might consider adding a complementary tool of action to a pre-existing conceptually based tool. Research could build upon the findings of this study regarding the potential that tools have to support the transfer of ideas from professional development to a teacher's practices, to inform the development of and refinement of tools that might support ongoing reform efforts.

In addition to considering ways to refine existing tools and develop new tools, research could also take up studies that focus on elaborating techniques to strengthen teachers' perceived connections between classroom and leadership practice. In this particular study, the teacher's realization that her leadership and classroom practices are parallel happened by chance during a TTSP session-planning interview. Research could

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focus on unpacking ways to make this, and similar understandings, more explicit to teachers in hopes of supporting more efficient and lasting pathways from teacher to teacher-leader.

Potential Influence on Educational Policy

A fundamental obstacle with attempting to leverage practice-based professional development to support mathematics reform efforts is the number of knowledgeable mathematics teacher educators compared to number of mathematics teachers in the United States. Furthermore, the research community has only begun to spend time, energy, and funding on developing research-based practices to inform teacher education. With limited resources and limited methods to accomplish change teacher education is left in an uncoveted position. Having said this, Elmore and others have proposed theories which, when combined with tools like those used in this study, might support necessary and productive change within teacher education.

In a piece entitled, *Getting to Scale with Good Educational Practice* (1996), Elmore proposes four strategies to accomplish such an achievement by advancing the field's understanding of the problem of scale and suggesting structures that need to be developed so that educators might take on this issue in realistic and substantive ways. What is critical concerning Elmore's argument is that it is grounded in building capacity within a system over time. To Elmore, change is not about individuals but rather, about structures that researchers and practitioners can develop that will support teams of teachers to serve as change agents. As such, it has the potential to build capacity within a diminished system.

A second important aspect of Elmore's argument is his claim that educators are infatuated with the status quo concerning issues that are at the "core" of teaching and that this infatuation inhibits the community from taking "good" practice to scale. He writes, "by 'core of educational practice,' I mean how teachers understand the nature of knowledge and the student's role in learning, and how these ideas about knowledge and learning are manifested in teaching and classwork" (p. 1). He continues saying, "Schools, then, might be 'changing' all the time -- adopting this or that new structure or schedule or textbook series or tracking system -- and never change in any fundamental way what teachers and students actually do when they are together in classrooms" (p.2). These words communicate Elmore's recognition that practice-based professional development, working within the "core" of teaching and learning, is one aspect that educators must consider when attempting to take reform efforts to scale.

Elmore also reminds us of Larry Cuban's study of the late progressive movement in education. In Cuban's study, *How Teachers Taught: Constancy and Change in American Classrooms, 1890-1980*, he found that student-centered, as opposed to teacher-centered, forms of instruction "seldom appeared in more than one-fourth of the classrooms in any district that systematically tried to install these varied elements" (Cuban, 1984, p. 135). Elmore blames this low level of implementation on haphazard or non-existent plans for taking effective change beyond small pockets of success. Thus, together, the need for practice-based professional development as well as a conceptual plan to take good practice to scale is a pairing that must exist in order for best practices to move beyond classrooms, to schools, to districts, and eventually across the nation.

In an effort to sketch a conceptual framework for "getting to scale," Elmore outlines four strategies to reach scale. These strategies are:

- Develop Strong External Normative Structures for Practice

- Develop Organizational Structures That Intensify and Focus, Rather than Dissipate and Scatter, Intrinsic Motivation to Engage in Challenging Practice

- Create Intentional Processes for Reproduction of Successes

- Create Structures That Promote Learning of New Practices and Incentive Systems That support Them

Though Elmore explicitly unpacks each of these strategies, they are inherently intertwined by a common theme—to prevent overreliance or unrealistic expectations for what individuals know and can accomplish. A dangerous misconception anytime the expectation is transformative change within a system is the belief that effective change can be about individuals. Spillane (2006) warns about this very misconception is his book, *Distributed Leadership*. He explains that heroic leaders, those individuals that seem to be able to make change happen in the midst of chaos and a variety of unsupportive structures, do exist. However, the change that results from such leaders may not be sustainable over time. Additionally, focusing on such instances can obscure other leaders and followers that are acting beside the heroic individuals diminishing our ability to understand *how* change is occurring (Spillane, 2006). As a result, researchers are able to tell a story depicting *what* change happened, but only negligible ideas regarding *how* and *why* that change happened.

Elmore clearly recognizes the fragility of individuals, and change built upon individuals as each of his strategies are in some way structures to support and scaffold individuals' efforts within a system of reform. It is also interesting and important to

recognize that Elmore centers his strategies on teachers. Though other actors exist in the periphery of his strategies through the development of structures to support analytical practice or to build a system in which stakeholders can share information in productive ways, at the ground level his strategies are about teachers improving their own practices and then helping others to do the same. My interpretation of Elmore's work is that if the education community is not to repeat failures of the past, we must formulate a plan in which to build teachers' instructional practices and content knowledge over time that is at some level self-sustainable and at another level dependent upon ongoing influence from outside sources of expertise. Intentional development and use of tools in practice-based professional development, grounded in Elmore's principles, is one manner in which I assert that educators can achieve transformative and lasting change aligned with current reform efforts.

Appendix A

Thinking Through a Lesson Protocol (Smith et al., 2008)

Part 1: Selecting and Setting up a Mathematical Task

➢ What are your mathematical goals for the lesson (i.e., what do you want students to know and understand about mathematics as a result of this lesson)?

➢ In what ways does the task build on students' previous knowledge, life experiences, and culture? What definitions, concepts, or ideas do students need to know in order to begin to work on the task? What questions will you ask to help students access their prior knowledge and relevant life and cultural experiences?

➢ What are all the ways the task can be solved?
- o Which of these methods do you think your students will use?
- o What misconceptions might students have?
- o What errors might students make?

➢ What particular challenges might the task present to struggling students or students who are English Language Learners (ELL)? How will you address these challenges?

➢ What are your expectations for students as they work on and complete this task?
- o What resources or tools will students have to use in their work that will give them entry into, and help them reason through, the task?
- o How will the students work—independently, in small groups, or in pairs— to explore this task? How long will they work individually or in small groups or pairs? Will students be partnered in a specific way? If so in what way?
- o How will students record and report their work?

➢ How will you introduce students to the activity so as to provide access to *all* students while maintaining the cognitive demands of the task? How will you ensure that students understand the context of the problem? What will you hear that lets you know students understand what the task is asking them to do?

Part 2: Supporting Students' Exploration of the Task

➢ As students are working independently or in small groups, what questions will you ask to—
   o help a group get started or make progress on the task?
   o focus students' thinking on the key mathematical ideas in the task?
   o assess students' understanding of the key mathematical ideas, problem-solving strategies, or the representations?
   o advance students' understanding of the mathematical ideas?
   o encourage *all* students to share their thinking with others or to assess their understanding of their peer's ideas?

➢ How will you ensure that students remain engaged in the task?
   o What assistance will you give or what questions will you ask a student (or group) who becomes quickly frustrated and requests more direction and guidance in solving the task?
   o What will you do if a student (or group) finishes the task almost immediately? How will you extend the task so as to provide additional challenge?
   o What will you do if a student (or group) focus on non-mathematical aspects of the activity (e.g., spends most of his or her (their) time making a poster of their work)?

Part 3: Sharing and Discussing the Task

➢ How will you orchestrate the class discussion so that you accomplish your mathematical goals?
   o Which solution paths do you want to have shared during the class discussion? In what order will the solutions be presented? Why?
   o In what ways will the order in which solutions are presented help develop students' understanding of the mathematical ideas that are the focus of your lesson?
   o What specific questions will you ask so that students will—
      1. make sense of the mathematical ideas that you want them to learn?
      2. expand on, debate, and question the solutions being shared?
      3. make connections between the different strategies that are presented?
      4. look for patterns?
      5. begin to form generalizations?

➢ How will you ensure that, over time, each student has the opportunity to share his or her thinking and reasoning with peers?

➢ What will you see or hear that lets you know that *all* students in the class understand the mathematical ideas that you intended for them to learn?

➢ What will you do tomorrow that will build on this lesson?

Appendix B
Thinking Through a Lesson Protocol (Project Version)

1. Identify the mathematical goals of the lesson both short and long term.

2. Identify all the ways in which the task can be solved.
   - Which of these methods do you think your students will use?
   - What misconceptions might students have? How will you help students correct these misconceptions?
   - What errors might students make? How will you help students recognize and correct their errors?

3. Launch: How will you introduce students to the activity so as not to reduce the demand of the task? What will you hear that lets you know students understand the task?

4. As students are working independently or in small groups:
   - What questions will you ask to focus their thinking?
   - How will you help students who have trouble with the task in a way that does not undermine the cognitive challenge of the task?
   - What questions will you ask to assess students' understanding of key mathematical ideas, problem solving strategies, or the representations?
   - What questions will you ask to advance students' understanding of the mathematical ideas?

5. Which solution paths do you want to have shared during the class discussion in order to accomplish the goals for the lesson?
   - Which will be shared first, second, etc. Why?
   - In what ways will the order of the solution paths help students make connections between the strategies and mathematical ides?

6. What will you see or hear that lets your know that students in the class understand the mathematical ideas or problem-solving strategies that are being shared?

7. Any other comments or questions

Appendix C
Thinking Through a Session Protocol (Project Version)

Part 1: Setting up the Session

➢ What do you see as your role during this session?

➢ What are your goals for the session? (pedagogical and/or mathematical)
  o What is it that you want teachers to know and understand about math teaching and/or mathematics as a result of this session?

➢ In what ways does the task build on teachers' previous knowledge? What questions will you ask to help teachers access their prior knowledge?

➢ In what ways does the task/activity connect to the teachers' own practice?

➢ What are your expectations for teachers as they work on and complete this task/activity?
  o What resources or tools will teachers have to use in their work?
  o How will the teachers work -- independently, in small groups, or in pairs -- to explore this task/activity? How long will they work individually or in small groups/pairs? Will teachers be partnered in a specific way? If so in what way?
  o How will teachers record and report their work?

Part 2: Supporting Teachers' Exploration of the Task/Activity

➢ As teachers are working independently or in small groups:
  o What questions will you ask to focus their thinking?
  o What will you see or hear that lets you know how teachers are thinking about the mathematical ideas or aspects of practice?
  o What questions will you ask to assess teachers' understanding of key mathematical ideas, problem solving strategies, or the representations?
  o What questions will you ask to advance teachers' understanding of the mathematical ideas or aspects of practice?
  o What questions will you ask to encourage teachers to share their thinking with others or to assess their understanding of their peer's ideas?

Part 3: Sharing and Discussing the Task/Activity

- ➤ How will you orchestrate the discussion so that you accomplish your pedagogical and mathematical goals? Specifically:

    - o What specific questions will you ask so that teachers will:
        1. Make sense of the pedagogy and mathematical ideas that you want them to learn?
        2. Expand on, debate, and question the ideas being shared?

- ➤ What will you see or hear that lets you know that teachers in the session/school understand the pedagogical and mathematical ideas that you intended for them to learn?

- ➤ Based on the discussion today, what will the team/teachers further explore or continue to wonder about as they go back to their classrooms?
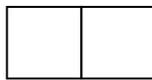
- ➤ What records of practice will you have teachers bring to the next session?

Appendix D
Square and Hexagon Train Tasks from
"The Case of Catherine Evans and David Young"[26]
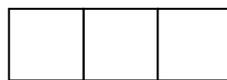
Square Train Task

train 1   train 2   train 3

Solve

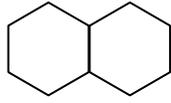Find the perimeters of the first three trains in the pattern shown above.

Find the perimeter of the 10th, 20th, and 100th trains in this pattern.

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[26] Smith, M.S., Silver, E.A., & Stein M.K. (2005b) *Improving Instruction in Algebra: Using Cases to Transform Mathematics Teaching and Learning.* Teachers College Press: New York.
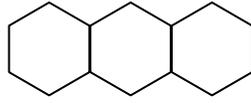
Hexagon Train Task
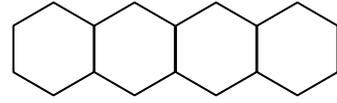

train 1   train 2   train 3   train 4

Solve

Trains 1, 2, 3, and 4 are the first 4 trains in the hexagon pattern. The first train in this pattern consists of one regular hexagon. For each subsequent train, one additional hexagon is added.

For the hexagon pattern:
- compute the perimeter for the first 4 trains;
- determine the perimeter for the tenth train without constructing it; and
- write a description that could be used to compute the perimeter of any train in the pattern. (Use the edge length of any pattern block as your unit of measure. If pattern blocks are not available, use the side of a hexagon as the unit of measure.)

Consider

Find as many ways as you can to compute (and justify) the perimeter.

Appendix E
Oak Tree Task from Connected Mathematics 2[27]

Tree Type (State)	Circumference	Height	Spread/Diameter
Giant Sequoia (CA)	83.2 feet	275 feet	107 feet
Coast Redwood (CA)	79.2 feet	321 feet	80 feet
Swamp Chestnut Oak (TN)	23.0 feet	105 feet	216 feet
Florida Crossopetalum (FL)	0.4 feet	11 feet	3 feet
White Oak (MD)	31.8 feet	96 feet	119 feet

[Source: Washington Post 12/25/2000 "Tree Lovers on a Crusade to Clone 'Champions'" by Rick Weiss, page A19.]

Problem 1.3

A. Which of the following statements accurately compare the largest trees to each other?

1. The spread of the largest white oak is the greater than that of the largest Coast Redwood by a *ratio* of about 3 to 2.

2. The *difference* between the heights of the largest Coast Redwood and the largest Giant Sequoia is 46 feet.

3. The spread of the largest Giant Sequoia is less than *50%* of the spread of the largest Swamp Chestnut Oak.

4. The circumference of the largest Swamp Chestnut Oak is about *three-quarters* the circumference of the largest White Oak.

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[27] Lappan, G., Fey, J.T., Fitzgerald, W.M., Friel, S.N., & Phillips, E.D. (2004). Comparing and scaling: Ratio, Proportion, and Percent (pilot ed.). *Connected Mathematics 2*, Boston, MA.

B. The tallest person in history, according to the Guinness Book of World Records, was Robert Wadlow who was 8 ft. 11.1 inches tall. Write two accurate statements comparing Wadlow to the world's tallest trees. In your statements, use ideas of fractions, ratios, percents, or differences.

C. Average waist, height, and arm span measurements for a small group of adult men are:

Waist = 32 inches   Height = 72 inches   Arm Span = 73 inches

Write two statements comparing the data on men to the world's tallest trees. Use ideas of fractions, ratios, percents, or differences.

D. When a problem requires a comparison of counts or measurements, how do you decide whether to use difference, ratio, fraction, or percent ideas?

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