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Despite reform efforts and calls to accept science as a primary subject in elementary school curriculum and instruction (NRC 2007, 2012), science is still often neglected, deprioritized, minimally taught, or taught through traditional methods where teachers and textbooks are the gatekeepers of knowledge (Banilower, 2019; Banilower et al., 2018; NSTA, 2002; NRC, 2007). In elementary school classrooms, research has found that many factors contribute to the obstacles faced when attempting to engage in science teaching and learning that can be categorized as either an internal or external barrier (Southerland et al., 2007). This study investigates the role of Science Teacher Leaders (STLs) in addressing these challenges within a large NGSS state. Specifically, the research examines how STLs at district and county levels utilize distributed leadership dimensions to navigate internal and external barriers to science reform. Through a comparative case study approach, the study delves into the experiences of STLs across different organizational levels. Using a distributed leadership framework, the study conducts a comparative analysis between county-level and district-level STLs. Findings reveal that organizational levels indeed influence how leadership is enacted. County-level STLs often adopt a broader perspective, engaging in systemic changes and policy alignment across multiple districts. In contrast, district-level STLs provide more hands-on support within their own districts, focusing on teacher development and curriculum management. Overall, the study underscores the critical role of STLs in elementary science reform efforts and highlights the importance of leveraging distributed leadership dimensions to address the complex challenges faced by educators in science teaching and learning.

"SCIENCE IS MORE THAN A REWARD": UNDERSTANDING SCIENCE TEACHER LEADERS' ROLES IN SUPPORTING ELEMENTARY SCIENCE REFORM

by

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Dr. Sara C. Porter
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DEDICATION

"The best teachers are those who show you where to look but don't tell you what to see." – Alexandra K. Trenfor

I dedicate this dissertation to Mertys Ward Bell (Maw Maw) and Caryl Cook Schunk (Granny Schunk)

Without the two of you, my love for learning would have never been explored. I am forever grateful for everything you two have shown me on this beautiful educational journey. Most importantly thank you for loving me and always believing in me.

APPROVAL PAGE

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Mom: “A mother is she who can take the place of all others but whose place no one else can take.” -Cardinal Mermillod

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CHAPTER I: INTRODUCTION

Statement of the Problem

Children are born with the ability to wonder, explore, observe, discover, and engage with natural phenomena and the world around them (National Research Council [NRC], 2012). For elementary school students, they deserve consistent and frequent opportunities to incorporate these skills into their educational experiences. Engaging in authentic, consistent, and intentional science instruction during elementary school provides an opportunity to create a solid science foundation where students can leverage their experiences and knowledge in middle school, high school, and beyond (Jirout, 2020; National Research Council [NRC], 2007). Unfortunately, science instruction at the elementary level is lacking or nonexistent in some cases. Limited science exposure complicates efforts to lay a solid science foundation to build upon. Science education is essential as it molds students, the future of our society, and provides opportunities to create critical thinkers who can compete with the growing demands of the global economic market (Bookbinder, 2022). However, if our students are not being introduced to science during their elementary years, students and their teachers will be left playing catch up.

Since the 1950s, the United States has increased its focus on the need for educational policy to promote science education through large-scale reform efforts mandated by the courts, backed by legislation, and sponsored by government agencies and other interested parties (Bookbinder, 2022; Smith & Southerland, 2007). Despite the necessity of promoting science education through reform efforts, elementary schools in particular face various barriers that prevent the implementation of effective science instruction. Researchers consistently identify the time spent on science content in comparison to high stakes testing and accountability subjects such as English language arts (ELA) and mathematics as a barrier to adequate science teaching and learning (Banilower et al., 2013; Diamond & Spillane, 2004; Smith & Southerland, 2007). However, time allocated to teaching science is not the only barrier limiting science instruction in elementary schools. For example, researchers continuously find elementary teachers are reluctant to teach science due to a lack of teacher preparation, discomfort with curriculum and standards, time, and resources (Brophy et. al., 2008; Fitzgerald & Snider, 2013).

With the recent focus on improving science education, The Framework and NGSS emphasize the three-dimensional approach to science education as the standards aim to deepen students' understanding of science by focusing on scientific inquiry, critical thinking, and application of knowledge beyond the school walls. Additionally, NGSS promotes equity and adequate opportunities for all students to engage in high-quality science instruction while promoting inclusivity as well as diverse learning environments (NASEM, 2015; NGSS, 2013). Given the increased focus on advancing science education, it becomes imperative to establish targeted support mechanisms aligned with the NGSS objectives. Thus, elementary science teacher leaders (STLs) emerge as pivotal figures, equipped with the experience, knowledge, and skills to provide tailored support and facilitate professional development initiatives that resonate with the current vision and trajectory of science reform efforts (Reiser, 2013; Stein & Nelson, 2003; Whitworth et al., 2021). Elementary STLs can serve as a resource to attend to barriers within science reform and serve as advocates for elementary science instruction. STLs' science content knowledge, science pedagogical knowledge paired with experiences and innovative efforts can be geared towards attending to the growing needs necessary to empower teaching and learning within science reform efforts (Campbell et al., 2019; Cobb et al, 2009; Hanuscin & Sinha, 2011; Howe & Stubbs, 2003; Whitworth et al., 2021).

In this study, I explored how various STLs in district and county-level positions in a large NGSS state understood their role in science reform efforts utilizing the four dimensions of distributed leadership (setting direction, developing people, redesigning the organization, and managing curriculum) to address internal and external barriers to science reform. To address the importance of elementary STLs and their role in science reform, I start by describing the literature on internal and external barriers experienced by elementary teachers when engaging in science teaching and learning. Specifically, honing in on how STLs leverage the dimensions of distributed leadership and why STLs are an important mechanism in addressing internal and external barriers to science reform in elementary settings.

Science Instruction at the Elementary Level

Despite reform efforts and calls to prioritize science as a primary subject in elementary school curriculum and instruction (NRC 2007, 2012), science is still often neglected, deprioritized, minimally taught, or taught through traditional methods where teachers and textbooks are the gatekeepers of knowledge (Banilower, 2019; Banilower et al., 2018; NSTA, 2002; NRC, 2007). In elementary school classrooms, research has found that many factors contribute to the obstacles faced when attempting to engage in science teaching and learning that can be categorized as either an internal or external barrier (Southerland et al., 2007). Internal barriers include the beliefs teachers have in regard to science and students, their understanding of the curriculum and content, and personal experiences and opportunities to engage in authentic science; whereas external barriers correlate directly to the availability of school resources and systemic obligations centered around learning and assessment (Southerland et al., 2007). For example, an elementary science teacher may not feel confident to teach science because they had a bad experience learning science in school. Another teacher may feel confident to teach science, however their schedule restricts how much time they teach science which results in more traditional direct instruction of science content. Understanding the internal and external barriers are important as STLs at varying levels must determine how to support elementary science teachers and schools to navigate science reform efforts.

Internal Barriers

Elementary science faces many internal barriers when it comes to science instruction. For example, internal barriers include teachers' confidence to effectively teach science, teacher preparation to understand pedagogical content knowledge, and overall teacher beliefs and experiences to engage with authentic science (Southerland et al., 2007). Teachers' confidence levels and knowledge have been found to hinder their ability to effectively teach science curriculum in their classrooms (Hsu et al., 2011). When elementary teachers do not feel confident and knowledgeable to engage students in science teaching and learning, this can lead to limited or nonexistent science instruction and in return creates a limited science foundation for students to build upon over time.

When elementary science teachers' overall beliefs and experiences to engage in authentic science serve as an internal barrier, they might tend to become dependent on their past experiences and learning with science. Lortie's apprenticeship of observation (1975), a psychology study found that teachers often rely on teaching practices and educational experiences that they remember engaging in. Due to this, research has found that elementary teachers often depend heavily on science textbooks and traditional ways of teaching science as they feel they do not have adequate science content knowledge to teach standards and curriculum appropriately (Carlsen, 1999; Gress-Newsome, 1999; Southerland et al., 2007). Despite elementary science teachers feeling like they lack confidence and content knowledge, with support and opportunities to practice, elementary teachers can find best practices to effectively implement science within their classrooms (Mutch-Jones et al., 2022). Therefore, elementary science teachers must have support to increase their confidence and shift their beliefs in order to provide adequate science instruction to their students. To help build confidence, content knowledge, and pedagogical knowledge, district, and country-level STLs can serve as a resource to support a vision for science education that further supports the development of science teaching and learning.

External Barriers

Elementary science also faces external barriers to science instruction. External barriers are factors that take place outside of the classroom and typically impact the political, institutional, and societal levels of education (Southerland et al., 2007). External barriers faced by STLs include but are not limited to (1) Time allocation for science instruction and professional learning, (2) lack of resources to teach science, (3) administrative priorities directed elsewhere, (4) teacher accountability measures, (5) and school, district, and state curriculum mandates and priorities (Lee & Houseal, 2003). Working within these constraints can impact the way elementary teachers approach teaching and learning within their classrooms as they navigate the political, institutional, and societal barriers while being expected to teach all core subjects (ELA, math, science, and social studies). However, a hyper-focus on state assessments that prioritize ELA and mathematics at multiple grade levels and science at only fifth grade leads to different allocations of resources to science instruction including time, money, and curriculum.

In elementary schools, science instructional time is either neglected, deprioritized, or minimally taught (Banilower, 2019; Banilower et al., 2018; NSTA, 2002; NRC, 2007). Banilower and colleagues (2018) found that primary grade classes (K-2) taught science approximately twenty minutes per day and grades third through fifth taught science approximately twenty-seven minutes per day. In comparison to the limited time spent on daily science teaching, only seventeen percent of kindergarten through third grade teachers reported teaching science most days in a school week, and thirty-five percent of fourth and fifth grade teachers (Banilower et al., 2018). The minutes and percentages of instructional time show that there is a significant gap that needs to be addressed when it comes to the time allotted to teach this core subject. Systemically, the demands and pressures placed on high-stakes reading and math testing reduces the time to teach science in elementary schools. Identifying and addressing barriers associated with conflicting goals in elementary education is crucial to ensure that students have ample opportunities to engage meaningfully in authentic science experiences. To address external barriers within elementary science education, the policymakers, administrators, district/county STLs and other stakeholders must work to coordinate schools, districts, and national reform efforts to align with the goals and needs of science education, specifically at the elementary level (Desmoine, 2009; Garet et al., 2001). Beginning with coherence and alignment, district/county level STLs must understand the organizations in which they serve and what is needed to promote science teaching and learning. District/county level STLs can serve as liaisons as they work to develop a vision for science education that seeks to develop people, manage and support the curriculum, and redesign the overall organization views in regards to elementary science education to align with the overall vision and mission to improve science education (Ball & Cohen, 1996; Borko, 2004; Garet et al., 2001; Miller, 2010; Whitworth et al., 2017).

Science Teacher Leaders

STLs are well-positioned to deal with these internal and external barriers to science education reform. An STL is, “A teacher of science, who influences others while developing their leadership identity, and who uses their social, cultural, and symbolic capital to advocate for science and promote student learning." (Whitworth et al., 2022, p.251). STLs are not just teachers within the school. STLs serve at the district/county level, collegiate level, and through science research-practice partnerships. Due to the varying nature in roles for STLs, Bae and colleagues (2014) recognize that district/county level STLs not only support teachers to effectively implement high-quality science practices, but they also have knowledge and a voice to advocate within the policies of science education and reform efforts. Therefore, in this dissertation, I focus on district science coordinators who are, "individuals tied to a district's effectiveness in improving teaching and learning and often plan an intermediary role between teacher needs and schools' division requirements" (Whitworth et al., 2017, p. 915). Research indicates that elementary science education benefits from the expertise of STLs and their endeavors to enhance the proficiency of those they assist (Miller, 2010). However, there is a call for more research to understand the varying roles, contexts, and backgrounds of STLs specifically at the district level (Bae et al., 2016; Miller, 2010; Whitworth et al., 2017).

STLs are essential in elementary schools because they not only enhance the quality of science instruction, but they also foster a culture of collaboration, support the development of colleagues, and advocate for a vision within science education (Wenner, 2017). STLs understand that elementary contexts are unique entities and leverage their practices, skills, and knowledge to respond to the internal and external barriers that their organizations and teachers face when it comes to science teaching and learning. STLs have specific content knowledge, pedagogical knowledge, experiences, and resource knowledge (Stein & Nelson, 2003) to plan instruction accordingly and manage the safety of science materials and equipment (Criswell et al., 2018a; Wenner, 2017; Whitworth et al., 2021). STLs lead and support others in the building(s) they serve to effectively plan and implement curriculum through collaborative planning efforts. When STLs have opportunities to plan science lessons with science-related personnel or others, they can provide support to locate and use adequate resources to ensure that students have the opportunity to engage in effective science instruction (Wenner, 2017). STLs also possess the ability to model best practices through co-teaching efforts or for others to observe. When STLs model best practices it sets the standard for the type of science instruction needed to support the organization's vision for science. Using STLs as a resource, will not only lead to school-wide change but also district/county-level change for science education where organizational members feel supported to focus on content-specific issues to actively teach science to the students that they serve (Curtis, 2013; Muijs & Harris, 2006). STLs are an asset to elementary education and science reform as they help create the vision for science education and implement the proper supports to attain success for their organization.

Introduction to Theoretical Framework

In this study, I seek to better understand the work of STLs as they attend to the various internal and external barriers to elementary science education within their localized contexts. To do so, I leverage constructs from distributed leadership to understand how STLs can help set the direction for science education, redesign the organization to prioritize science, develop people within their organization to teach science, and manage the curriculum to ensure that science education aligns with the mission, vision, and strategic goals within the organization to promote overall organizational success (Leithwood et al., 2007). Educational researchers promote the distribution of leadership roles and practices, departing from the concept of sole leadership responsibility, where every decision rests on one individual (Fullan, 2005). This shift acknowledges that a single individual, such as a school principal, cannot lead educational initiatives to success alone, as supported by various studies (Fullan, 2005; Bennett, 2003; Bolden, 2011; Gronn, 2000, 2002, 2008; Harris, 2008; Leithwood et al., 2004; Spillane, 2005, 2006; Spillane et al., 2004). Distributed leadership draws from work centered around activity theory, where multiple actors come together with a shared purpose or vision and work together collaboratively to leverage one another's strengths and expertise (Gronn, 2000, 2002). In elementary schools, most if not all teachers are required to teach science as a core subject, and therefore, they all have a vested interest to ensure best practices are being supported and implemented. STLs leverage their experience as classroom teachers to navigate both internal and external barriers by using effective teaching and learning strategies, drawing on their expertise in science education to address challenges, adapt instructional approaches, and collaborate with colleagues to overcome obstacles and enhance student learning experiences (NASEM, 2015). STLs insights into the landscape of science education within diverse elementary contexts present an opportunity to collectively shape a vision for elementary science. By capitalizing on STLs' science content knowledge, pedagogical skills, experiences, and relationships, there is potential for substantial improvement in elementary science education (Heredia et al., 2023; Lotter et al., 2020; NRC, 2010; Wenner, 2017). This collaborative effort has the power to cultivate a more informed and scientifically literate society (NASEM, 2015).

How is Distributed Leadership Operationalized?

Distributed leadership involves creating a collaborative structure and culture within an organization that fosters a sense of shared responsibility and collective decision-making (Devos et al., 2014; Liu et al., 2023). Distributed leadership is operationalized through a variety of practices that seek to influence and empower members within the organization to take part in leadership activities that lead to school and overall district improvement (Bennett et al., 2003;

Gronn, 2002; Spillane, 2006; Spillane et al., 2004). Distributed leadership provides four practice dimensions that organizations can implement: (1) setting direction, (2) redesigning the organization, (3) developing people, and (4) managing instruction (Firestone & Martinez, 2007; Leithwood et al., 2007). Specifically, these four practice dimensions help researchers to understand how their work is organized in hopes of sharing with other leaders an accurate vision for science education that promotes science education and supports students, teachers, administrators, and other stakeholders to understand the importance of effective science instruction. Once a vision is in place, STLs can explain how redesigning an organization with science in mind will allow them to effectively develop science teachers and manage the curriculum to ensure that the strategic goals of the organization are being met including that science is taught in the organization.

However, when implementing distributed leadership to support elementary STLs there are several supports and tensions to consider. For example, some supports for distributed leadership include opportunities for shared decision-making, innovation and creativity, improved communication across the organization, and increased accountability to move towards success (Gronn, 2002; Hargreaves, 2007; Harris, 2008; Muijs & Harris 2007). Tensions with implementing distributed leadership include role ambiguity, communication challenges, power dynamics, and keeping the clarity of the organizational vision (Devos et al., 2014; Storey, 2004; Timperley, 2005). Recognizing and addressing these supports and tensions is essential for STLs to use their relationships, practices, skills, and knowledge to promote science education that benefits students, teachers, administrators, and the science educational community.

Supports to Using Distributed Leadership

Using distributed leadership to support science education in elementary schools provides a space where there is a sense of shared responsibility that leads to improved decision-making while promoting innovation, professional growth, and leveraging the expertise of multiple if not all actors within an organization (Bolden, 2011; Gronn, 2002; Harris, 2008; Leithwood, 2004; Timperley, 2005). Involving multiple stakeholders in both formal and informal roles allow for more perspectives to be involved in the decision-making process. Specifically thinking about science education in elementary schools, STLs bring unique knowledge and when sharing how science can be integrated into other content areas, they provide insights for other leaders from different content areas to see how their disciplines are interpreted (Wenner & Campbell, 2017; York-Barr & Duke, 2004). Using distributed leadership as a framework supports organizations to practice the work of decentering the leader, providing space for multiple if not all actors to demonstrate qualities of leadership to enhance reform efforts (Bolden, 2011; Gronn, 2000; Leithwood et al., 2007; Spillane et al., 2004).

Tensions to Using Distributed Leadership

Distributed leadership as a framework can also cause tensions for STLs and their work within their organizations. For example, distributed leadership can be time-consuming, which could equate to coordination and organization challenges that potentially place more demands on STLs and other colleagues or frustrations as they may feel as if nothing is moving forward. Therefore, it is particularly important for an organization to recognize and navigate these potential tensions to ensure that distributed leadership is an effective leadership approach (Harris et al., 2022).

When organizations provide opportunities for individuals to participate in a distributed leadership model, formal leaders like the superintendent, district leaders, policymakers, and the principal must relinquish power to others (Harris, 2004), which also allows space for those who have competing agendas to come forward. Competing agendas could lead to ambiguity or even conflict due to varying perspectives. For example, an STL from the district/county level might be working with a team of third-grade teachers to provide rich, hands-on learning experiences for their students and request more time and resources to teach inquiry-based science. However, due to the demands from the state and district/county, the principal is faced with the dilemma of complying to mandates and providing proper resources for high-stakes tested subjects over providing these teachers what they need. These competing priorities within the organization can lead to tension, as the STL's emphasis on exploration and flexibility in science instruction may not always align with the state or district/county focus and in return forces the principal to make a decision on where their focus should lie, elementary science or standardized testing (Smith & Southerland, 2007). To address these competing agendas, leveraging the district/county STLs is necessary as they have opportunities to meet and collaborate with other district supports such as ELA, and math coordinators to discuss opportunities to potential find a balance across content areas that benefits both science education and the overall success of the district/county (Heredia et al., 2023). Inviting all actors of an organization to come together and collaborate can provide great insight and perspective, however, it is important to manage the clarity of the vision for shared decision making to ensure that there is a clear understanding of the responsibilities and risks involved when making decisions for elementary science reform efforts (Harris, 2004).

In general, employing a distributed leadership framework to aid STLs presents both advantages and disadvantages. The efficacy of this approach rests on well-organized structures, transparent communication, and the readiness of leaders across all levels to collaborate. When executed proficiently, distributed leadership can nurture collaboration, spur innovation, and facilitate professional growth among all participants, thereby positively impacting elementary science education overall.

Research Questions

Due to gaps in the literature regarding STLs and the varying roles they serve within science education and reform efforts, it is essential to understand their efforts and support (Whitworth et al., 2017). By understanding the background, roles, contexts, and how district/county level STLs respond to internal and external barriers serves as a guide to better understand how they support other educators to promote science teaching and learning. Therefore, as STLs work to create a vision for science education in hopes of redesigning organizations to develop strong science teaching and learning for the students that they serve they must assess strategic goals and curriculum to determine if it allows for organizations to implement effective change for science education. In this dissertation study, I asked the following questions to better understand how STLs make sense of their work within their localized contexts. Specifically, I asked:

Overarching Question: How do district/county-level elementary STLs who participated in this study understand their role in utilizing the four dimensions of distributed leadership to address internal and external barriers to science reform?

a) What are the commonalities and differences in the internal and external barriers attended to by district/county level elementary STLs within the four dimensions of distributed leadership?

b) What variations exist among district/county level elementary STLs in the enactment of distributed leadership specifically focusing on the four dimensions; setting direction, developing people, redesigning the organization, and managing curriculum to attend to elementary science reform efforts?

Introduction to Research Methodology and Design

In this dissertation, a case study methodology (Merriam & Tisdell, 2016) was employed to examine a diverse group of district/county (STLs) across different district and county contexts within a large state on the West Coast in the process of implementing NGSS. This case study aimed to unravel the organizational dynamics of elementary STLs' leadership, relationships, professional practices, skills, and knowledge in various contexts that differ geographically. The specific focus was seeking to understand how these distinct/county STLs understand their roles as science leaders to navigate the internal and external barriers inherent in science reform efforts.

This dissertation examines data collected from STLs who participated in a comprehensive design-based research study (Cobb et al., 2003) funded by a National Science Foundation (NSF) grant. The overarching design-based research aimed to comprehend the nuances of science teacher leadership across the state, with the goal of enhancing support for STLs and their initiatives. The larger study focused on describing the roles of STLs that work at various levels of the organization (classroom, school, district, county) that support science instruction in middle and high schools (Heredia et al., 2023). This dissertation aimed to gain a deeper understanding of the varying roles of district/county-level STLs who primarily support elementary science education.

Network Context

The case study of STLs in this dissertation study participated in a museum-based, statewide science teacher leadership network. The museum developed this network of science teacher leaders from across the state to provide professional support for local implementation of the Next Generation Science Standards [NGSS]. The museum recruited STLs from all over the state to create an equitable distribution of resources in an attempt to be representative of all regions as well as being inclusive to the variety of roles that formal and informal STLs encompass as defined by their context and experience.

Research Study Sample

To better understand the work of STLs in elementary schools, I sampled STLs from the network that focused on K-6 science teaching and learning. The sample of STLs included four district-level STLs and two county-level STLs who actively worked and supported elementary teachers and educators to implement science reform efforts in their district or county. This case study of district/county STLs included three men and three women who represented six larger districts (2 suburban and 4 urban) and held the titles of instructional coach/science specialist, program specialist, STEAM coordinator, or teacher on special assignment (TOSA).

Sources of Data

In the larger study, researchers collected a variety of data from the participants including their application to the professional learning program, semi-structured interviews, a representative sample of artifacts (resources and documents) used to support science teacher learning in their school and/or district as well as resources created within the professional learning program. Each of these data sources will be used in the analysis of the elementary STLs and their leadership practice. More details about these data sources can be found in chapter three.

Data Analysis

The application to the professional learning program helped me to identify the six research participants to analyze for this case study to better understand the variations in their work as STLs at the elementary level. Semi-structured interviews were used as the primary source of data to learn how the STLs described their roles as they worked to set a direction, develop people, redesign their organization, and manage curriculum for elementary science teaching and learning within their localized contexts. Four phases of data analysis took place to grasp an understanding of how STLs leveraged the four dimensions of distributed leadership to attend to internal and external barriers within their districts/counties. The first phase of data analysis included segmenting the data based on the four dimensions of distributed leadership: (1) setting direction, (2) developing people, (3) redesigning the organization, and (4) managing instruction (Firestone & Martinez, 2007; Leithwood et al., 2007). Following the segmentation of data, deductive coding was used to analyze the interviews, to better understand how STLs described their work through a distributed leadership lens and how they attended to the internal and external barriers they faced within elementary science reform efforts. Once the data was coded, I compared and contrasted across the case study to enhance understanding of how STLs strategically utilized and articulated their relationships, professional practices, skills, and knowledge to address internal and external barriers in diverse contexts, ultimately supporting elementary science education and reform. Other data sources such as the other artifacts from their professional learning as well as a monthly survey of their leadership practice were used to triangulate and validate emergent themes and findings. Chapter three details more in regard to the data analysis process and chapter four details the findings.

Significance of the Study

The prevalence of scientific phenomena in our daily lives provides opportunities for students to critically explore the world around them through a scientific lens. Despite this, there exists an inconsistency in the incorporation of science education at the elementary level. With the persistent call for improvements in science education, elementary schools have the opportunity to leverage STLs as invaluable assets to enhance initiatives for the improvement of science education for all students. Examining elementary STLs through the lens of distributed leadership yields valuable insights for the science education field where collaborative efforts can empower educators and foster improved teaching and learning outcomes in science education. This approach enriches our comprehension of STLs and district/county STLs' diverse roles and how they address internal and external barriers within their localized contexts. This research study contributes to the elementary science education field, offering a better understanding of how STLs' varied roles influence and shape their responses while addressing localized reform efforts.

Definitions of Key Abbreviations

STLs: Science Teacher Leader(s)

NGSS: Next Generation Science Standards

TOSA: Teacher on Special Assignment

ELA: English Language Arts

CHAPTER II: LITERATURE REVIEW

Introduction

Science is often not consistently taught in elementary schools due to various factors, including competing priorities, limited resources, and a lack of emphasis on science education. It is extremely important that elementary students receive daily science instruction. In order to support science reform efforts and elementary science instruction, I present the idea of science teacher leaders (STLs) as a solution. To better understand science teacher leadership in elementary schools, I use distributed leadership as my conceptual framework to better understand how STLs are supporting teachers within their organizations to implement science instruction. Leveraging the distributed leadership framework, this dissertation specifically explores how STLs seek to set the direction of their organizations, redesign their organizations, develop people, and manage curriculum. In this chapter, I will explain the reform initiatives of the Next Generation Science Standards (NGSS), shifts teachers need to make to attend to reform efforts, an overarching framework for comprehending Science Teacher Leadership (STL), and the rationale behind adopting distributed leadership as a conceptual framework. Using distributed leadership as a conceptual framework aids the education field in gaining a deeper understanding of STLs roles and their significance in addressing internal and external barriers to reform efforts within diverse elementary educational contexts.

NGSS Reform: What is it and Why do we Need it?

Over thirty years ago, *A Nation at Risk* was released by the National Commission on Excellence in Education (National Academies of Science, Engineering, and Medicine [NASEM], 2015). The National Commission on Excellence in Education (1983) warned that if the nation continued to move forward without improving the quality of teaching within its public schools that general and science education would continue to be at risk. Despite published reports, there has been little change to improving the quality of science education within public schools, and as a result, our nation has suffered economically and globally (National Academy of Sciences, 2007). Therefore, *The Next Generation Science Standards: For States, By States* (NGSS) were developed through a collaborative partnership of multiple states as well as The National Research Council, The National Science Teachers Association, The American Association for the Advancement of Science, and Achieve to respond to the nations needs to provide consistent, competitive science education that responds to 21st century needs (Next Generation Science Standards Lead States [NGSS], 2013). The NGSS standards seek to address the call for high-quality science education by providing a framework that emphasizes hands-on learning, critical thinking, and real-world application of scientific concepts for all students regardless of their background or ability with the aim to create scientific literate citizens who can competitively contribute to global scientific efforts. (NASEM, 2015; NGSS, 2013). It is important to recognize that while there are many risks to attend to within education, the NGSS standards are only focused on attending to ways of strengthening teaching and learning within K-12 science education (NASEM, 2015). Therefore, these standards are in place to support students to fundamentally master science concepts and enhance their capacity within the science field.

The NGSS standards are not new ideas. In fact, the Framework and NGSS built upon previous K-12 science documents created by parties such as *National Science Education Standards, Benchmarks for Science Literacy, Science Framework for the 2009 National Assessment of Educational Progress, and Science College Board Standards for College Success* (NASEM, 2015). NGSS standards were created in hopes of moving away from the memorization of science facts, prescribed inquiries/experiments, and the teacher being viewed as the gatekeeper of knowledge. The NGSS standards recognize and emphasize the importance of integration across multiple disciplines and core subjects to create scientifically literate students. Scientific literacy refers to the knowledge and understanding of scientific information that can be used in daily decision making and daily phenomena (Ashbrook, 2020).

In hopes of reaching scientific literacy, the NGSS standards include three dimensions of learning: scientific and engineering practices; crosscutting concepts, and disciplinary core ideas that are integrated within the standards, curriculum, instruction, and assessments within the classrooms (NASEM, 2015; NRC, 2011). These dimensions collectively form the foundation of the NGSS framework, aiming to cultivate a deeper understanding of science and engineering among students (NASEM, 2015; NGSS, 2013; NRC, 2011). The scientific and engineering practices focus on the skills and methods used by scientists and engineers, promoting hands-on inquiry, problem-solving, and evidence-based reasoning (NASEM, 2015; NGSS, 2013; NRC, 2011). Crosscutting concepts serve as the thread that connects the diverse domains across different scientific disciplines, emphasizing patterns, cause and effect relationships, and systems thinking (NASEM, 2015; NGSS, 2013; NRC, 2011). Lastly, disciplinary core ideas (Physical Sciences, Life Sciences, Earth and Space Science, Engineering, Technology, and Applications of Science) represent the foundational content knowledge in science and engineering, providing students with essential concepts and principles to comprehend the natural world (NASEM, 2015; NGSS, 2013; NRC, 2011). Through the integration of these dimensions, NGSS seeks to foster critical thinking, innovation, and scientific literacy among learners. Here is a brief example of what three-dimensional instruction might look like and sound like in an elementary science classroom according to NGSS (2013). The brief example focuses on the scientific phenomenon of photosynthesis.

In a three-dimensional NGSS classroom, the teacher would begin by taking the students on a walk around their school to observe, compare, and contrast the different plants. The teacher would facilitate a brief discussion to activate students' prior knowledge about plants and their growth. Then, the teacher guides the students in conducting an experiment to investigate the factors that affect plant growth, such as light and water.

During the investigation, the students will actively engage in the scientific practices outlined in the NGSS as they carefully observe and measure the growth of plants under different conditions, record their observations in their science journals, and collaboratively analyze the data they collect. Students will also be given opportunities to discuss their findings with their peers, make predictions, and draw conclusions based on evidence.

Throughout the lesson, the teacher will encourage inquiry-based learning and critical thinking by asking probing questions and providing guidance when needed. The students demonstrate their understanding of the scientific concepts related to photosynthesis by applying their knowledge to real-world scenarios and communicating their findings effectively. As a result, both teachers and students are actively participating in a dynamic learning experience that aligns with the three-dimensional approach of NGSS.

As the example demonstrated, the three-dimensional approach of NGSS builds upon numerous principles and leverages student's prior knowledge, ideas, and experiences as a foundation to build upon with a focus on developing core ideas and practices within science overtime (NRC, 2011). The framework highlights the importance of integrating both knowledge and practices, while also recognizing students' prior ideas and experiences, in the journey of constructing their understanding of science from kindergarten and beyond (NGSS, 2013). Overall, NGSS represents a comprehensive effort to enhance science education, promote critical thinking skills, and better prepare students for the demands of the modern world through learning progressions across the disciplinary core ideas in science (NGSS, 2013).

Learning progressions are tools that demonstrate how students' ideas and understanding evolve over time and provide a foundation where students leverage their experiences and learning to access curriculum (NASEM, 2015; NGSS, 2013; NRC, 2015). Learning progressions represent a sequence of difficult cognitive approaches to understand a specific concept over time (Corcoran et al., 2009; Duschl et al., 2007; Kaldaras et al., 2020). With appropriate standards, scaffolding, strategies, and performance expectations in place, students are able to deepen their understanding of concepts across grade levels and across time. NGSS were developed and assessed by performance expectations created for each grade level band (K-5, 6-8, and 9-12) (Fulmer et al., 2018; NGSS, 2013). The performance expectations summarize what students should be able to do by the end of the unit and encompass the three-dimensional approach to learning (scientific and engineering practices; crosscutting concepts, and disciplinary core ideas) and assess the development of students' scientific and engineering understanding (Fulmer et al., 2018; Kaldaras et al., 2020; Reiser et al., 2003). The performance expectations assess learning across the four content domains and detail in each grade level what students should be able to do by the end of each grade level and grade level band (Fulmer et al., 2018; NGSS, 2013). Due to the expectations of learning assessed through the performance expectations, it is imperative that students receive science instruction in all grade level bands (K-5, 6-8, and 9-12) as they build upon one another and become more abstract in high school (NGSS, 2013). Therefore, vertical planning kindergarten through fifth grade could support elementary educators to understand how science standards build upon one another over time. Without knowledge of elementary science concepts, it makes science teaching and learning exceptionally harder as students get older.

Elementary science creates the foundation for science teaching and learning through concrete concepts that are built upon in each grade level (NGSS, 2013). For example, photosynthesis is a learning progression that evolves throughout the grades. In kindergarten through second grade students understand and make sense of plants and their basic needs in order to survive (NGSS, 2013). Grades third through fifth take the concept of photosynthesis to the next level as students make sense of how matter and energy play a role in a plant's survival as plants make their own food and convert oxygen into carbon dioxide (NGSS, 2013). In middle school, students learn that photosynthesis is a chemical reaction, converting radiant energy from the sun into chemical energy that is used for food (NGSS, 2013). In high school, completing the photosynthesis learning progression, students learn that amino acids and proteins are created through cellular respiration where matter and energy flow through various ecosystems to support the survival of animals, humans, and plants (NGSS, 2013). Through this example, the learning progressions continuously build upon one another and become more abstract at each grade level band. Below in Table 1 are the NGSS standards that align with the photosynthesis learning progression detailed above.

Table 1: Photosynthesis NGSS Learning Progression

LS1.C Organization for Matter and Energy Flow in Organisms	
Photosynthesis Standards Across Grade Level Bands (K-5, 6-8, and 9-12)	
K-2nd	Animals obtain food they need from plants or other animals. Plants need water and light.
3rd-5th	Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.

6th-8th	Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.
9th-12th	The hydrocarbon backbones of sugars produced through photosynthesis are used to make amino acids and other molecules that can be assembled into proteins or DNA. Through cellular respiration, matter and energy flow through different organizational levels of an organism as elements are recombined to form different products and transfer energy.

(NGSS, 2013)

What Shifts in Practice, Knowledge and Skills Does NGSS Require of Teachers?

For this paradigm shift to materialize, educators must reassess their beliefs and practices concerning science, and strive to enhance their confidence and comprehension of both scientific content and pedagogical knowledge. Reiser and colleagues (2017) advocate for three specific modifications to science instruction for teachers: (1) adjustments and reduction in the number and types of science concepts covered, (2) how to assess student learning of chosen concepts, and (3) leverage curriculum that centers students' sensemaking using the science and engineering practices (Reiser et al., 2017).

New science standards bring substantial changes and require teachers to make shifts within their craft of teaching science. To effectively support the comprehensive endeavors aimed at enhancing science education, requires teachers to veer away from traditional methods of science teaching that historically dominated science teaching and learning in classrooms (Next Generation Science Standards Lead States, 2013; Windschitl et al., 2008). Traditional science teaching and learning prioritizes rote memorization of facts and vocabulary, lectures, teacher-lead demonstrations, reliance on outdated textbooks with abstract theories, limited hands-on inquiry/experimentation for students, and assessments that only test for recall (NRC, 2015). Due to this, NGSS reform efforts can cause frustration as these teaching shifts require a different mindset, where teachers are no longer gatekeepers of science knowledge and ideas, but rather provide a space for students to figure out science ideas through critical thinking, practice, and collaboration (Schwartz et al., 2017).

In response to NGSS, elementary science instruction is witnessing a paradigm shift away from traditional rote learning and memorization of science facts (Haverly et al., 2020). Due to the pressures of high-stakes testing, science education is often confined to textbook or passage reading where they respond to multiple choice questions, leaving little room for students to ask their own questions and engage in authentic scientific inquiry. NGSS recognizes that science learning is more than memorizing facts. Therefore, instead of students learning science from merely reading passages, NGSS seeks to have students actively engaged in hands-on, inquiry-based learning experiences (NGSS, 2013).

Shifting from merely reading and answering multiple choice questions, also requires teachers to provide space where students can ask, and answer questions based on their conceptual thinking. However, this type of discourse between teacher and students and peers to peers requires teachers to listen to their students' conceptual understanding and how they are making sense of the science concepts being taught. This type of discourse however poses challenges as it can be difficult to follow students' conceptual understanding without accurate use of scientific vocabulary. Therefore, this requires that teachers have strong science content knowledge and science pedagogical content knowledge to scaffold and support their students to understand the content through the three-dimensional approach while also incorporating lessons that promote scientific vocabulary.

While science seeks to be more than a reading passage, we also must move away from worksheets such as matching, labeling, true/false, or fill in the blank as they do not assess a student's whole conceptual understanding. Take, for instance, a lesson on animal adaptations.

Traditionally teaching methods might present students with images of animals and their habitats, where students are tasked with the simple exercise of matching and gluing. While this is not a reading passage, this activity fails to truly engage students in meaningful science experiences. Therefore, for teachers to assess the full conceptual knowledge of students, they must have a strong science content background and a plethora of science content pedagogical knowledge to provide opportunities for students to engage with science as called for by NGSS (NGSS, 2013). In order to do this, teachers must understand how standards and core disciplinary ideas build upon one another to ensure they are reaching the breadth and depth of the science content based on the revised standards (NGSS, 203). NGSS emphasizes a more dynamic approach, where students are led to delve deeper into the concept being explored. For example, working with animal adaptations. One way to begin a unit would be to engage students in a science talk (Gallas, 1995). A science talk begins with presenting students with puzzling phenomena that can be explored, discussed, explained, and investigated (Gallas, 1995). The phenomena can be presented through a picture, video, or simply a question. Posing the puzzling phenomena allows students to express what they notice, and what they wonder, while also providing a guide into what students know and what they are interested in learning more about (Gallas 1995). Leveraging the knowledge shared by students during the science talk, teachers can then plan hands-on exploration, experimentation, and critical thinking activities centered around students' interests. Therefore, moving away from worksheets and using science talks to plan investigations requires teachers to facilitate open discussions, encourage inquiry-based approaches, and foster collaborative exploration among students.

In order to attend to the shifts required to effectively teach NGSS, teachers need support in understanding science content, recognizing best practices for teaching and learning, have a keen understanding of science pedagogical content knowledge, and a solid recognition of how the standards build upon one another within the scaffolds of NGSS (NGSS, 2013; NRC, 2015). In elementary school, it is especially important for high-quality science instruction to be taught every day. Based on the way the NGSS designed its standards, the first two scaffolds of learning within the disciplinary core ideas (Physical Sciences, Life Sciences, Earth and Space Science, Engineering, Technology, and Applications of Science) take place in grades Kindergarten through fifth (NGSS, 2013). Therefore, it is imperative that teachers move away from historical science teaching practices and neglecting or minimally teaching science as a core subject to help students gain a solid science foundation early so they can leverage their learning and build upon it in middle school, high school, and beyond (Bookbinder, 2022).

As emphasized the biggest shift with NGSS entails moving away from the teacher giving students content to creating an environment where students take ownership of their learning and leverage their personal experiences to enhance their critical thinking skills to solve real-world problems (NRC, 2015). Therefore, to effectively implement NGSS elementary teachers need support as they work to gain confidence in their instructional practices, deepen their science content knowledge and science pedagogical skills, and have opportunities to engage in ongoing collaboration and professional learning to adequately equip students to excel in science and engineering (Bookbinder, 2022; Campbell et al., 2019; Cobb et al, 2009; Hanuscin & Sinha, 2011; Howe & Stubbs, 2003; Whitworth et al., 2021).

Anticipated Internal and External Barriers with Shifts in Practice

NGSS seeks to promote critical thinking skills and effectively prepare students to be science literate to contribute to global competitiveness in science through equitable opportunities (NASEM, 2015; NGSS, 2013; NRC, 2012). The Framework and NGSS calls for students to learn science through the three-dimensional approach and in return require teachers to shift their teaching practices from traditional ways of teaching science to practices that are student-centered. However, understanding these required shifts in practice, and previous research do not come without barriers to reform. As science education continues to transform, there are many internal and external barriers STLs must anticipate in order to provide proper support for the teachers and contexts they serve.

Internal Barriers

Elementary science faces many internal barriers when it comes to science instruction. Internal barriers commonly faced by elementary educators are science content knowledge, science PCK, and teacher confidence to teach science (Southerland et al., 2007). While these are not the only internal barriers that elementary educators face, they are however some of the most prevalent internal barriers and require specific support. As NGSS calls for teachers to shift their teaching craft from all teacher and textbook directed instruction to allowing students to investigate, teachers must have a sound understanding of science content knowledge (van Driel et al., 2001). Understanding the standards for the current grade level being taught, as well as previous and future standards, is crucial. It enables students to investigate phenomena continuously, builds their understanding while applying their learning to the real word. As students investigate, a teacher with sound science content knowledge knows when to provide support, when to push for additional thinking and understanding, and how to make the learning in their classroom applicable to the real world (Darling-Hammond et al., 2020; van Driel, 2021).

Once there is a solid understanding of science content knowledge and what is expected to build the science foundation in elementary schools, teachers can begin to tackle the best ways to implement science instruction by enhancing their science pedagogical knowledge. Sound science pedagogical content knowledge (PCK) is more than just knowing the content; it encompasses understanding how to effectively teach that content to students and planning for their misconceptions (Appleton, 2013). Truly understanding NGSS allows educators to plan and align their instruction to model the three-dimensional approach that is called for in science reform efforts (NGSS, 2013). Pedagogical content knowledge in regard to implementing the three-dimensional approach effectively includes inquiry-based learning, hands-on investigations, cooperative learning, and integration across other core subjects are necessary (Reiser et al., 2017). These pedagogical strategies used to teach elementary science must have the ability to be adapted to ensure objectives and the needs of students are being met. To ensure that students are effectively learning science, it's essential to have science pedagogical content knowledge focused on assessing student expectations. This knowledge ensures that assessments go beyond simple multiple-choice questions and instead evaluate critical thinking skills and the construction of knowledge, rather than just the memorization of facts (Smith & Banilower, 2015). Strong science pedagogical content knowledge provides opportunities for students to engage in effective science teaching approaches and enrich their learning experiences.

Teacher confidence to teach elementary science is an anticipated internal barrier that needs to be attended to within reform efforts. When teachers feel insecure in their science abilities and knowledge, it has been found that they might shy away from implementing hands-on explorations, inquiry-based instruction, or other science pedagogical strategies (Hsu et al., 2011; Mutch-Jones et al., 2022). One-way elementary STLs can support elementary science and anticipate educators' needs is by recognizing that the three-dimensional approach to teaching NGSS standards might be drastically different from the ways in which science used to be taught or the ways in which elementary teachers experienced science (NGSS, 2013). Therefore, elementary STLs can leverage their knowledge of science content to model best teaching practices, meet teachers where they are, and continuously provide ongoing support and feedback (Heredia et al., 2023b; Wenner, 2017). By strengthening teacher confidence, schools and districts can empower educators to deliver engaging and effective science instruction that inspires curiosity, critical thinking, and lifelong learning in students.

External Barriers

Elementary science also faces external barriers with science instruction. External barriers are factors that take place outside of the classroom and typically impact the political, institutional, and societal levels of education (Southerland et al., 2007). External barriers faced by STLs include but are not limited to: (1) administration and policy priorities, (2) time allocation, (3) standardized testing pressures (Lee & Houseal, 2003).

External barriers, such as administration and policy priorities, present significant challenges for elementary science education. The decisions at the administrative and policy levels have the ability to impact the allocation of resources, the emphasis placed on science instruction, and the overall support provided to teachers and students (Lee & Houseal, 2003; Southerland et al, 2007). For example, when administrators prioritize subjects like ELA and mathematics over science, it can result in limited instructional time and resources allocated to science education. Additionally, policies that emphasize high stakes standardized testing in ELA and math may inadvertently sideline science instruction, as educators feel pressured to focus primarily on tested subjects (Banilower et al., 2013; Diamond & Spillane, 2004; Smith & Southerland, 2007). Addressing these barriers requires collaboration between stakeholders, advocacy for science education, and a strategic approach to policy development that recognizes the importance of science (Desmoine, 2009; Garet et al., 2001).

Due to administration and policy priorities, an unintended consequence that science faces is adequate time to teach science in elementary schools. Time to teach science can range from zero minutes, to approximately twenty minutes in kindergarten through second grade, and approximately twenty-seven minutes in third through fifth grade (Banilower et al., 2018). With limited time in the daily schedule to teach science, teachers often find it very difficult to teach science with the three-dimensional approach that NGSS calls for (NGSS, 2013). Therefore, students are not able to engage in hands-on experiments, exploration, and inquiry-based learning activities, which are essential components of effective science instruction (Chowdhary et al., 2014; Lee & Houseal, 2003). Due to the constrained time allocated for science instruction each day leads to insufficient coverage of science topics and concepts (Bybee, 2002; Lee & Houseal, 2003).

High stakes standardized tests in ELA and mathematics create a significant external barrier for elementary educators. With school performance measures and standardized tests such as ELA and mathematics being the basis of determination for whether schools are successful or not, compel teachers and administrators to prioritize tested subjects over science, fearing repercussions if students perform poorly (Griffith & Scharmann, 2008). Due to this, science education may be marginalized, and students may not receive the comprehensive science instruction they need to develop critical thinking skills and scientific literacy. This challenge highlights the need for educational policies and practices that value and prioritize science education alongside other core subjects (NASEM, 2015; NGSS, 2013).

To support teachers to effectively implement science reform efforts in elementary schools, STLs play a crucial role in attending to both internal and external barriers. STLs lead science reform efforts by building teacher capacity, fostering collaboration, advocating for resources, addressing administration and policy constraints, and promoting data-informed decision-making (Wenner, 2017). Leveraging STLs' expertise and leadership skills can support teachers in making meaningful changes to improve science teaching and learning that supports the goals of elementary science reform. Specifically in elementary school, the first two scaffolds of NGSS build the foundation for middle school and science (NGSS, 2013). If science is not taught, then we only continue to widen the gap in students' science knowledge and skills. The Framework and NGSS represent a significant step forward, however there is significant work to be done. Therefore, leveraging the skill sets, knowledge, and experience of STLs can serve as a mechanism to effectively address and support elementary science reform efforts.

Science Teacher Leaders as a Mechanism of Support

Many have suggested and reported on the importance of STLs as a mechanism for supporting science education reform (Heredia et al., 2023b; Lotter et al., 2020; Wenner, 2017, Whitworth et al., 2022). To better understand the roles and ways in which STLs support science reform efforts research has been conducted with varying levels and contexts of STLs. For example, Wenner (2017) researched elementary STLs in high-achieving districts, Bae et al., (2016) researched STLs and their work in middle schools, and Heredia and colleagues (2023) researched diverse secondary STLs. While each study researched STLs in different school-level positions and contexts, they all uncovered the need for research to better understand the roles of STLs and how they can be leveraged as support mechanisms for science education.

STLs can be defined as: "A teacher of science, who influences others while developing their leadership identity, and who uses their social, cultural, and symbolic capital to advocate for science and promote student learning" (Whitworth et al. 2022, p.251). STLs are also individuals who are considered the "go to person" when it comes to science teaching and learning because they have a vision for science and actively lead others within their organizations to improve science practices (Wenner & Campbell, 2017; Heredia et al., 2023b). Typical roles of STLs include introducing and working with science standards (new and current), curriculum work (choosing, piloting, or understanding), mentoring and coaching teachers using science teaching practices, seeking, and providing resources, and working closely with administration to support science reform efforts within their contexts (Heredia et al., 2023a; NASEM, 2015; Davis & Zwiep, 2021; Smith and Southerland, 2007; Wenner & Campbell. 2017; York-Barr & Duke, 2004). Heredia and colleagues (2023b) also found that STLs also take on other various roles such as: activist, ambassador, collaborator, innovator, networker, organizer, and translator based on the priorities of their localized contexts. While these roles align with current literature this study supports the efforts in the various ways STLs define and prioritize their roles based on organizational needs.

In 2014, the National Science Teachers Association (NSTA) drafted a position statement calling for sound leadership teams to form that included administration (at school and district levels), STLs, and community members to collaboratively work together to create a science education reform that would lead *all* students to attain scientific literacy. This statement was released approximately a decade ago and science education today is still facing many internal and external barriers (Southerland et al., 2007; Wenner, 2017). STLs support the Framework and NGSS as they influence and advocate for effective science teaching and learning (Whitworth et al., 2022). Leveraging STLs as a support mechanism emphasizes the importance of science and engineering through collaborative efforts, critical thinking skills, and consistent opportunities for high-quality, hands-on learning and investigations that prepares students for the complex world of science and technology (NRC, 2015; NGSS 2013).

Elementary science often faces ongoing challenges in securing sufficient instructional time, especially when compared to ELA and Mathematics. This ongoing struggle persists because school performance measures primarily rely on standardized tests in ELA and mathematics. Due to high-stakes testing, science time is often traded out for an extra high-stakes tested subject to review, or due to teachers' beliefs, knowledge, and confidence to teach science it is skipped over (Banilower et al., 2013; Diamond & Spillane, 2004; Southerland et al., 2007). STLs have the ability to help address these internal and external barriers as they have specific experiences and instructional knowledge to support educators in engaging in science instruction.

STLs have adequate experience with science education and play a crucial role in implementing positive change and improvement within science education (Whitworth et al., 2022). Elementary STLs are individuals who have the ability to lead state-wide, district-wide, and school-wide change based on their knowledge of how elementary schools function. Through a variety of practices and specific goals, STLs can collaboratively work with others in their organization at varying levels to understand the science standards and curriculum work necessary for their contexts (Whitworth et al., 2022). It is especially crucial for elementary STLs to work closely with administration and other leaders to ensure that the vision for science is supported and communicated amongst the organization (Wenner, 2017). With the specific science content and pedagogical knowledge that STLs have, they can mentor, and coach teachers and administrators based on their individualized and contextual needs when it comes to science teaching and learning.

Elementary STLs take part in a variety of practices to enhance science education because elementary needs vary across organizations and STLs have the knowledge necessary to successfully implement reform efforts (Haverly et al., 2022; Wenner, 2017). For example, elementary STLs have experiences with creatively integrating specific science content knowledge into other disciplines as means for science instruction to be taught. When planning for science instruction, elementary STLs have the science content knowledge and science pedagogical knowledge to take science standards and creatively find ways to use the limited science time to potentially engage in hands-on learning, due to their ability to integrate the content through other core subjects. One way science integration occurs is when teachers pose phenomena, provide time for investigation, and then use ELA time to read non-fiction text to support students to scientifically explain the phenomena and potential solutions. This specific knowledge of how to integrate science into other core subjects enriches the learning experience for students and provides opportunities for students and teachers to engage in a more holistic learning approach (NASEM, 2022).

While this type of science content and pedagogical content knowledge takes time to acquire, STLs must first create a foundation of trust within their organization. Trust is important as it lays the foundation for multiple leaders to feel safe to share their ideas and shortcomings with others and allows for collective activity, mutual assistance, and joint accountability to transpire (Coleman, 1988). Tschannen-Moran (2004), described trust as the glue and lubricant to the life of an organization, she states, "As glue, "trust binds organizational participants to one another," and as a lubricant, "trust greases the machinery of an organization. . . . [It] contributes to greater efficiency when people can have confidence in other people's words and deeds" (p. 16). Thinking about elementary STLs, specifically district/county STLs, it is imperative they build a sense of trust with the contexts they support in order to support true learning and growth to happen. Oftentimes, district/county leaders can be viewed as evaluative and not helpful, therefore, it is imperative for elementary STLs to partner with their teachers to truly foster a level of collaboration and communication that leads to a successful outcome for science education and students.

Many theoretical and conceptual frameworks have been used to research and operationalize teacher leadership within various subjects and capacities, but over the last few decades, researchers have found that as a field, we lack a coherent conceptual framework for teacher leadership (Wenner & Campbell, 2017; York-Barr & Duke, 2004). Therefore, I propose distributed leadership as a framework for STLs and other leaders to build relationships and involve themselves in collaborative efforts and shared decisions. In return, these efforts help teachers feel more empowered, valued, motivated, and committed to the work of their organization (Muijs & Harris, 2007; Taylor et al., 2019). When STLs establish close relationships with other members of the organization and foster a community centered around trust, mutual respect, mutual learning, and collaboration this leads to shared decision making which ultimately leads to organizational improvement (Coleman, 1988; Harris, 2003; MacBeath, 2005; Smylie et al., 2007; Tschannen-Moran; 2004). For this dissertation I use distributed leadership as a framework to better understand the work of STLs as they attend to the various internal and external barriers of elementary science education within their localized contexts. To do so, I leverage constructs from distributed leadership to understand how STLs can help set the direction for science education, redesign the organization to prioritize science, develop people within their organization to teach science, and manage curriculum to ensure that science education aligns with the mission, vision, and strategic goals within the organization to promote overall organizational success (Leithwood et al., 2007).

What is Distributed Leadership?

Distributed leadership can be characterized as multiple actors (leaders and followers) within a network interacting around a shared purpose or vision with the intent to benefit their organization (Elmore, 2000, 2002; Gronn, 2000, 2002; Spillane, 2006). In elementary schools, a distributed leadership team can include individuals from various grade levels, individuals passionate about particular content areas, specialists (art, PE, Music, Computer, and Media), administrators, district/county leaders, and other stakeholders. These individuals come together to create a shared purpose or vision and work together collaboratively to leverage one another's strengths and expertise (Gronn, 2000, 2002). In particular, elementary science teacher leaders (STLs) need to lead the vision for science due to their teaching experiences and ideas to enhance science instruction and creatively coordinate with others to see science being taught consistently. Specifically focusing on science reform efforts, STLs are supports for the Framework and NGSS standards as they call for classrooms to emphasize the importance of science and engineering through collaborative efforts, critical thinking skills, and consistent opportunities for high-quality hands-on learning and investigation that prepare students for the complex world of science and technology (NRC, 2015; NGSS 2013). Attending to this call for action in science education, distributed leadership is best defined as a "leader-plus" (Spillane, 2005 p. 144) aspect which allows for a multitude of individuals and stakeholders to be involved in leadership practice and decision-making (Devos et al., 2010; Spillane & Healey, 2010) to benefit the overall being of their organization and the ability to attend to the need within science education.

An important quality of distributed leadership is the ability for individuals to fluidly step in and out of leadership depending on the problem of practice at hand (Spillane et al., 2004; Spillane & Healey, 2010). The ability to move in and out of leadership allows for multiple members to be heard and share their expertise which supports elementary contexts to potentially create a vision for cross-cutting disciplinary curriculum and support. For example, STLs can provide ideas and suggestions to the ELA and mathematics leaders in the building of how to creatively integrate science into their core content which is a noted gap between science education and the vision of NGSS (NASEM, 2015).

It is important to understand that distributed leadership only works when there is an inclusive approach to leadership which encourages leaders and followers to work together to problem solve, collaborate, share knowledge, and adapt in response to educational reform efforts (Gronn, 2000, 2002; Spillane, 2005, 2006; Spillane et al., 2004). In particular for elementary schools, contexts are especially important because they are responsible for laying a strong foundation for life-long learning in every content area. Specific to science, distributed leadership supports STLs in assessing the most important factors to address when it comes to science teaching and learning based on their organization's needs. Considering the role of a district/county level STL their expertise is especially important as they work to support multiple contexts with a variety of needs. Wenner (2017), found that elementary STLs in an urban context leveraged the needs of their context and planned effectively in order to close achievement gaps. These STLs were successful in their efforts. Leveraging these findings from Wenner (2017), elementary STLs know the science needs of their schools, but to create traction toward success, support is needed from other members within the organization to work together. Specifically, leveraging district/county STLs can be beneficial as they plan an important role in supporting science instruction, act as liaisons between district leaders and teachers, and understand the structures and backgrounds of the districts and schools they support (Whitworth et al., 2017).

Leveraging Distributed Leadership as a Conceptual Framework

The purpose for leveraging distributed leadership in this dissertation conceptualizes science teacher leadership (STL) and their ability to understand and support the unique nature of science improvement in elementary schools. Distributed leadership as a conceptual framework does not provide a prescriptive or directed approach when organizing leadership, but rather distributed leadership provides an analytical framework to better understand how leadership is distributed throughout an organization to reach overall success (Bookbinder, 2022). Distributed leadership most importantly focuses on the how and why of leadership practices. Specifically in elementary science reform efforts, how leadership is distributed supports researchers to better understand the roles of STLs, specifically how and why they address the varying internal and external barriers across contexts (Bae et al., 2016; Taylor et al., 2018). STLs recognize and understand the inner workings of their organizations, and they can leverage their experiences to support science within their localized contexts. For example, STLs can support teachers to creatively integrate other core subjects such as ELA and science to introduce science concepts at the elementary level. Science and Math can also be integrated as a way to represent, analyze, and discuss data. STLs with their knowledge and experience bring value to elementary science and through a distributed leadership lens, find ways to leverage their expertise to share with others in hopes of moving science reform forward (Gronn, 2000; Spillane, 2005, 2006).

Educational researchers believe in the value of distributing leadership across multiple actors within an organization and moving away from the "heroics of leadership” (Spillane, 2005 p.143) where one person knows best (Spillane, 2005). In elementary contexts, there are six grade levels represented and four core content areas that are expected to be taught. It is especially hard for administrators to know all the specifics of each content amongst the many other managerial needs and functions of an organization. Therefore, STLs can support administration, curriculum facilitators, and teachers with elementary science as STLs obtain the specific and unique knowledge required for science teaching and learning (Whitworth et al., 2021) that most individuals, even the administrator, do not have. STLs can leverage their specific content and pedagogical knowledge and lead others within their organization.

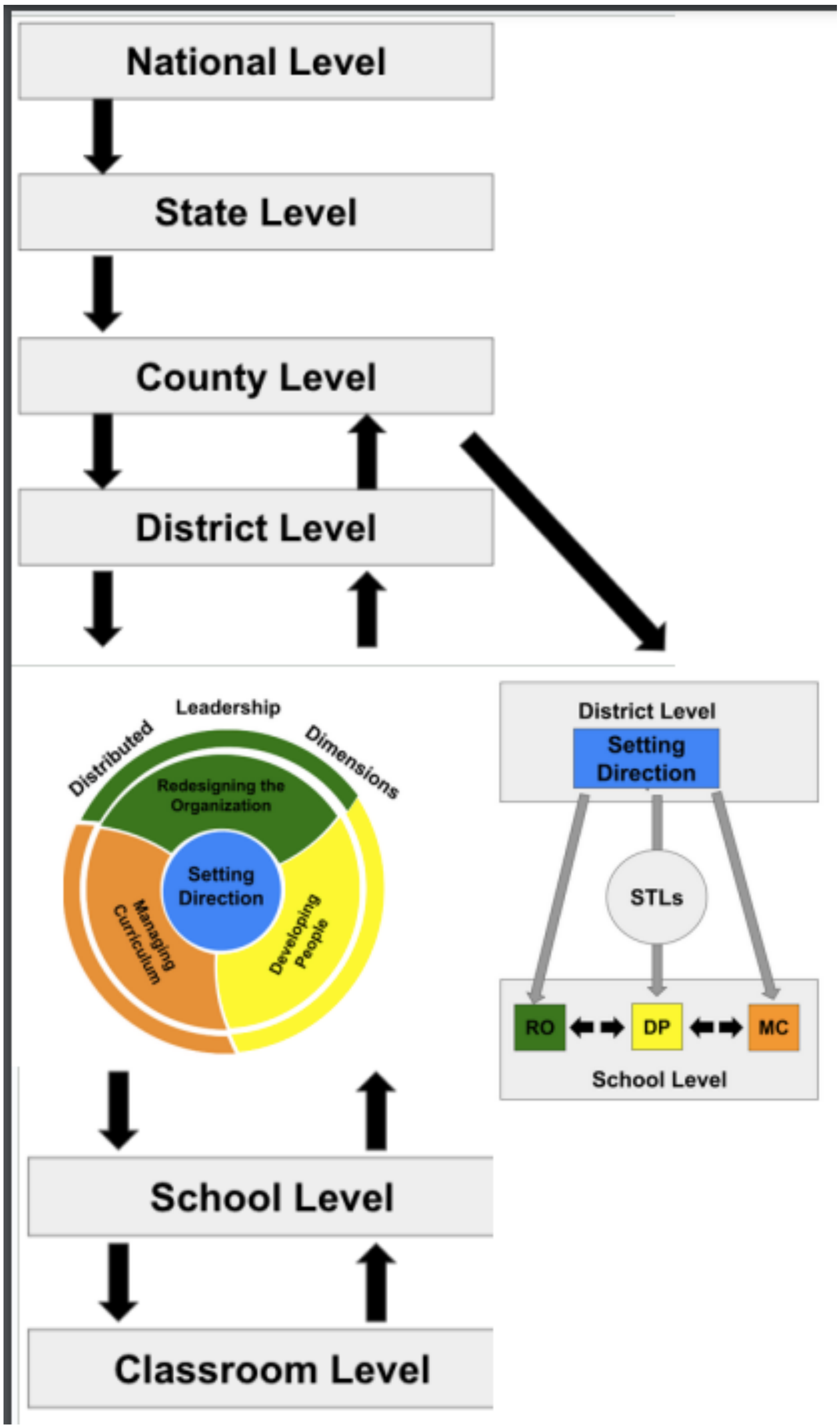
The unfolding of distributed leadership as a concept was launched as researchers recognized the limitations of the individual hero (Fullan 2005), and the overload that many individual leaders and principals faced (Hartley 2010; Mifsud, 2023). Principals are not only responsible for the instructional needs of an organization. They are also responsible for the strategic leadership, human resources, managerial leadership, and the politics in and out of school. Therefore, there are many limitations in an organization that requires the administration to leverage the individuals at the district and county level to reach organizational success (Bennett, 2003; Bolden, 2011; Gronn, 2000, 2002, 2008; Harris, 2008; Leithwood et al., 2004; Spillane, 2005, 2006; Spillane et al., 2004). By clearly defining and operationalizing distributed leadership, we can understand how STLs can work with multiple people within their organizations to collaborate and integrate science teaching and learning across multiple subjects within an organization.

How is Distributed Leadership Operationalized?

Distributive leadership is operationalized through a variety of practices that ultimately seek to improve the overall organization (Bennett et al., 2003; Gronn, 2002; Spillane, 2006; Spillane et al., 2004). In order to empower and influence members, it is important to ensure the practices align to dimensions of leadership based on the needs of the organization. For example, contexts differ from one another, and each context does not always need the same thing. In relation to elementary STLs, they are responsible to ensure science gets taught as most if not all elementary teachers are required to teach science as opposed to middle schools and high schools where a handful of teachers teach science and science only. Due to this, elementary STLs need to provide varying levels of support based on the context and individual needs they serve across multiple school settings. Using the four dimensions of distributed leadership allows for organizations to determine a context dependent vision that aligns with the overall organization's vision, how to redesign their organization to meet that vision, and leverage the practices, skills, and knowledge of elementary STLs to develop people and manage science curriculum.

The figure below illustrates the progression of national reform initiatives to the state level and subsequently to the district level, following a "top-down" approach. At the district level, STLs aim to implement national, state, and district science reform efforts using a distributed leadership approach. District STLs then gather relevant data and observations from schools and classrooms to inform future decisions in science education, considering multiple stakeholder perspectives. Following this figure, I describe the roles that district STLs have in enacted science reform efforts through a distributed leadership approach.

Figure 1. Traditional Organization Level



Setting Direction

In the context of distributed leadership, setting the direction refers to the process of collectively establishing and communicating the organization's mission, vision, and strategic goals (Leithwood et al., 2007). Setting a vision also includes ensuring that all members in the organization understand the mission, vision, and strategic goals in order to align their work with these guiding principles (Jenkins, 2009; McBrayer et al., 2020; Mercer, 2016; NCSSE, 2013). When aiming to implement distributed leadership to address reform efforts, organizations need to have a vision, a mission, and strategic goals in mind to help chart the course and the direction setting process (Leithwood et al., 2007).

Specifically, thinking about setting direction with elementary science education STLs help bring the NGSS vision to life as they leverage their knowledge and expertise to ensure elementary students are receiving opportunities to engage in high-quality science instruction that calls on their critical thinking skills and creativity to solve problems (NASEM, 2015; NGSS, 2013). Elementary STLs act as liaisons with teachers, administrators, and other stakeholders to communicate the direction in which science education needs to go and where their organizations are at currently. For example, elementary STLs understand the internal and external barriers to teaching science based on factors such as allocated time, resources, teacher preparation, and high-stakes testing (Southerland et al., 2007). With this understanding and experience, elementary STLs can provide feedback and input for a whole school as well as a district vision that can lead to intentional alignment where science is purposely planned for, while also supporting others within the organization to see the importance of science. STLs can help other actors work to collaboratively plan instruction with strategic goals in mind that respond to science reform efforts. Similarly to York-Barr and Duke’s (2004) teacher leader findings, STLs not only help create a vision for science, but they also coordinate and manage the logistics to ensure that there is space for collaboration, proper implementation of science mandates, as well as opportunities to monitor the organization's work aligns to their vision (Heredia et al., 2023b).

STLs strategic goals backed by data are chosen to support the vision and mission of the school. Strategic goals must be SMART; specific, measurable, achievable, relevant, and time bound (NCSSE, 2013). The strategic goals ensure that alignment across the organization is taking place to ensure that all members are committed to the success of elementary science education within their organization. Therefore, setting a direction for science education and leveraging strategic goals creates alignment within an organization which is crucial as it requires effective communication and engagement to ensure that the vision, mission, and strategic goals flow through the organization and ensure that all members are on the same page (Harris et al., 2007; Martinez et al., 2005). In order for STLs to effectively attend to science reform efforts, it is most important for a clear direction to be in place. Establishing a clear direction for elementary science education facilitates decisions like restructuring organizations with a focus on science, fostering educators' confidence in teaching science, and managing curriculum aligned with the NGSS and its three-dimensional approach (NGSS, 2013; Leithwood et al., 2007; Smith & Southerland, 2007). Ultimately a clear direction for science education serves as the compass that guides organizational efforts and ensures a collective commitment to the success of science instruction.

Redesigning the Organization

Relying on the idea of one leader effectively creating change is an idea of the past as an individual leader cannot meet requirements to lead schools to their full potential (Spillane, 2005). Therefore, distributed leadership allows for an organization to redesign its structure to leverage multiple leaders' expertise to attend to organizational change (Bolden, 2011; Devos et al., 2014; Spillane, 2005). Redesigning the organization to include STLs is key as they have firsthand knowledge and experience of how students learn science and can provide insight to broader decisions that impact the overall success of students within science education (Wenner & Campbell, 2017; Wenner, 2017; Whitworth et al., 2022). Involving STLs to support the redesign of an organization that values science requires STLs to creatively find ways to support the integration of science into core subjects that align with district and state mandates for education. Specifically, district/county level STLs have access to other teacher leaders in other core subjects and have the time and ability to discuss the importance of science, how it fits into other subjects, and where they integrate science content within units. Restructuring an organization can be seen as, “loosening of previously tightly defined and interpreted individual role boundaries, and the exploitation of informal workplace interdependencies in accomplishing tasks” (Gronn, 2003, p.1). Elementary STLs are familiar with finding ways to loosen and creatively push science into classrooms at the elementary level because limited science instruction has been an ongoing battle for several decades (Banilower, 2019; Banilower et al., 2018; NSTA, 2002; NRC, 2007).

Developing people

The idea of developing people and members within an organization aligns closely with instructional leadership practices (Jenkins, 2009). Instructional leadership promotes the idea of an organization working together to learn, develop, support, guide, build, and implement the best instructional practices for teaching and learning (Brolund, 2016; NCSSE, 2013). Through mentoring and coaching, STLs can support teachers to plan science lessons, gather necessary resources, co-teach with them, and then provide time for reflection and feedback (Whitworth et al., 2022). Some other practices that STLs can use to develop people to implement effective science instruction includes leading professional learning, modeling best teaching practices, co-teaching, and mentoring and coaching in other areas aside from lesson planning (Bae et al., 2016; Heredia et al., 2023b; Lotter et al., 2020; York-Barr & Duke, 2004). STLs have specific science content knowledge, science pedagogical content knowledge, resource knowledge, and understanding of the curriculum goals for science education which allows them to choose the best supports for the teachers, contexts, and organizations in which they serve (Stein & Nelson, 2003). Due their specific content knowledge, pedagogical knowledge, resource knowledge, and experiences, STLs have the ability to provide individualized and/or context specific that aligns to the needs of science teachers, schools, and district mandates.

Coaching and Mentoring

Coaching can take on many forms as it can be individual, small group, or as a collective whole within a school or organization (Gallucci et al., 2010; Taylor, 2008; Woulfin, 2014). Some of the activities that caching involves include but is not limited to; (1) assisting teachers with the implementation of new curriculum, (2) trying out new assessments, (3) working with teachers to try out new skills and practices, (4) assisting teachers to conduct classroom research, (5) locating, translating, and sharing resource, and (6) creating book clubs centered around an area of growth (Heredia et al., 2023a; NASEM, 2015). Through these various activities, elementary STLs, actions through mentoring and peer coaching both involve providing individualized and team growth with science specific practices through feedback, reflection, and gathering useful science materials and content (Whitworth et al., 2022). Through the trust that STLs have built within their organizations while also understanding the vision of each context within the overarching organization allows STLs to make decisions to support the end goals for science curriculum based on the needs of the individuals and teams they serve. This knowledge allows

STLs to plan for necessary learning opportunities for the teachers they work with, and their organizations' needs. Coaching is a very important mechanism to support elementary science reform efforts and through the use of elementary STLs, they can provide the individual and collective moves necessary to support the overall vision, growth, and success of the schools in which they serve.

Managing Instruction

Supervising, evaluating, coordinating, and monitoring instruction through a variety of tasks supports one of the most crucial functions of schools (Printy & Liu, 2021). These activities ensure that teaching is effective, curriculum goals are met, and student learning outcomes are achieved. District/county STLs are well-equipped to oversee and manage the implementation of science instruction, due to their experience, deep knowledge of science content, and understanding of ongoing science reform efforts (Whitworth et al., 2022). Therefore, when principals and other district/county personnel provide opportunities for STLs to manage instruction, this allows for teachers to adopt and adapt materials, implement and develop new programs, support student success as a whole, and learn with and from the STLs and their peers (Printy & Liu, 2021). STLs may not always be able to manage the actual instruction taking place in classrooms due to time allocation, but they can manage the opportunities to engage in collaborative planning efforts, adoption of curriculum, and strategies centered around science instruction (Bae et al., 2016; Firestone & Martinez, 2007; Heredia et al., 2012; Lotter et al., 2020; Wenner, 2017). Through collaborative planning efforts, such as professional learning communities (PLCs), STLs serve as a support to unpack standards, select and/or develop an overarching phenomena to investigate, and plan three-dimensional units that allow for students' ideas and understanding to evolve over time and provide a foundation where students leverage their own experiences and learning to access curriculum (NGSS, 2013; Wenner, 2017). While managing curriculum is difficult work, STLs are able to support and guide the transition from traditional modes of teaching and learning science towards ones that empower students and teachers while implementing best teaching and learning practices for elementary science (Campbell et al., 2019; Cobb et al, 2009; Darling-Hammond et al., 2020; Hanuscin & Sinha, 2011; Howe & Stubbs, 2003; Whitworth et al., 2021).

Distributed leadership is seen as a shared dynamic process to enhance the overall success of an organization. Distributed leadership provides four practice dimensions that organizations can implement: (1) setting direction, (2) redesigning the organization, (3) developing people, and (4) managing instruction (Firestone & Martinez, 2007; Leithwood et al., 2007). Leveraging these four dimensions allows leaders to collaboratively create a vision to promote science education and a plan based on the needs of particular organizations. Once the vision has been set, STLs can leverage the needs of teachers, students, administrators, and other stakeholders to redesign the organization to implement effective, high-quality science practices. Through strategic goals for science, STLs can adequately develop science teachers and manage the curriculum to ensure that the strategic goals of the organization are being met, including that effective science instruction is taking place.

Tensions with Implementing Distributed Leadership

Distributed leadership presents ambiguity and "chameleon-like nature" (Harris, 2007 p. 315), which provides avenues for it to be defined and implemented in a multitude of ways (Hickey et al., 2022). For example, many view distributed leadership as a new label for delegation since both share the idea of relinquishing tasks to others (Harris, 2003; Spillane, 2005). For example, distributed leadership could be viewed as principals delegating tasks to individuals that they do not want to do. However distributed leadership is far more complicated as leaders within the organization need to come together with a shared purpose or vision. Tensions could arise when leaders do not have the same vision for the organization which leads to tensions as they feel their idea is not being heard. This is especially salient for elementary STLs, as their goals for science education may not align with those of the administrators focused on high stakes assessments (Southerland et al., 2007).

Contexts must also be considered as distributed leadership work is very context dependent and varies from school to school, or organization to organization depending on the shared vision and goal to be accomplished (Printy & Liu, 2021). In particular for elementary schools, contexts matter as they are far different from middle school and high schools, specifically in regard to science. Elementary schools have less time to teach science due to science only being tested in fifth grade. Contexts also drive the need for what is a necessity to improve reform efforts.

Therefore, "distributed leadership is not a panacea or a blueprint or a recipe. It is a way of getting under the skin of leadership practice, of seeing leadership practice differently, and illuminating the possibilities for organizational transformation" (Harris & Spillane, 2008 p. 33). Distributed leadership will not solve an entire organization's problems, but it does offer an environment where multiple or all stakeholders feel empowered as their expertise is leveraged through collaboration and shared decision making which can lead to improved educational outcomes (Harris et al., 2007; Gronn, 2000, 2002; Spillane, 2005, 2006; Spillane et al., 2004).

Conclusion

Elementary STLs are a necessity to elementary science education as they possess many unique knowledge and skills. For example, to respond to science reform efforts STLs have specific pedagogical knowledge/experiences, content knowledge (Stein & Nelson, 2003), as well as understanding the safety and management of specific science materials and equipment to support their colleagues (Criswell et al., 2018a; Wenner, 2017; Whitworth et al., 2021). With the specific pedagogical and content knowledge, STLs can lead others in their districts and organization by supporting them to find adequate resources, curriculum, and even work together to create exciting learning opportunities for the students they serve. With the emphasis on other high stakes tested subjects, science gets pushed to the side (Southerland et al., 2007). However, STLs understand their elementary contexts and the internal and external barriers that teachers face when it comes to science teaching and learning. Using STLs as a resource, can lead to school and district-wide change where teachers are supported to increase teacher collaboration, generate, and model best practices, and focus on content-specific issues (Curtis, 2013; Muijs & Harris, 2006). In other words, STLs have the pedagogical content knowledge and organizationally knowledge specific to elementary schools that is necessary to support the work needed to implement best practices for elementary science education.

STLs work applies to leadership as they can support, provide educational tools and ideas, and work to reduce both internal and external barriers with elementary science education. Researchers, Stein and Nelson (2003) state that, "Without knowledge that connects subject matter, learning, and teaching to acts of leadership, leadership floats disconnected from the very processes it is designed to govern" (p. 446). In summary, elementary STLs are essential to elementary schools because they not only enhance the quality of science instruction but also foster a culture of collaboration, support the development of teachers and administrators, and advocate for the importance of science education. Their influence positively impacts both students and fellow educators, thus contributing to the overall improvement of science education in elementary schools.

CHAPTER III: METHODOLOGY

Introduction

In this dissertation, a case study methodology (Merriam & Tisdell, 2016) was employed to examine a diverse group of district/county (STLs) across different district and county contexts within a large state on the West Coast in the process of implementing NGSS. This case study aimed to unravel the organizational dynamics of elementary STLs' leadership, relationships, professional practices, skills, and knowledge in various geographical contexts. The specific focus was seeking to understand how these distinct/county STLs understand their roles as science leaders to navigate the internal and external barriers inherent in science reform efforts.

In this dissertation study, I analyzed data collected from a larger NSF project with a focus on a sample of STLs whose work was centered around elementary science. Due to gaps in the literature regarding STLs and the varying roles they serve within science education and reform, it is essential to understand their efforts and support (Whitworth et al., 2017). I chose to use a comparative case study because I wanted to better understand how elementary STLs' roles and leadership practices are organized based on their varying contexts, specifically focusing on the internal and external barriers they must attend to within science reform efforts. Drawing from the work on science teacher leadership through a distributed leadership lens, understanding practices, interactions, skills, and knowledge within organizations allows researchers to better understand how multiple actors can have a seat at the table to improve student outcomes especially for elementary science education (Harris, 2003; Firestone & Martinez, 2007; Gronn, 2008; Leithwood et al., 2009; Spillane, 2008; Taylor et al., 2019). In this dissertation study, I asked the following questions to better understand how STLs make sense of their work within their localized contexts. Specifically, I asked:

Overarching Question: How do district/county level elementary STLs who participated in this study understand their role utilizing the four dimensions of distributed leadership to address internal and external barriers to science reform?

a) What are the commonalities and differences in the internal and external barriers attended to by district/county level elementary STLs within the four dimensions of distributed leadership?

b) What variations exist among district/county level elementary STLs in the enactment of distributed leadership specifically focusing on the four dimensions; setting direction, developing people, redesigning the organization, and managing curriculum to attend to elementary science reform efforts?

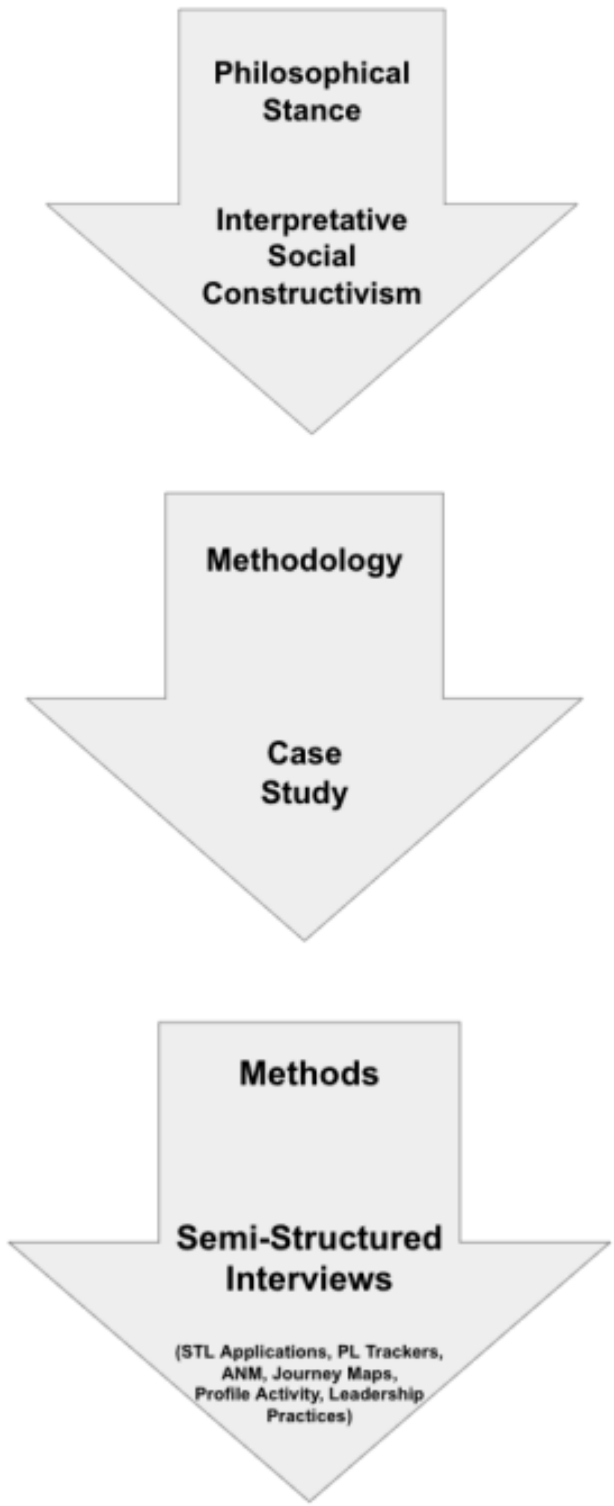
Researcher Positionality

This is my eleventh year in education. My experiences span across elementary and higher education through a variety of positions and grade levels. In elementary education, I spent seven years teaching every core subject in Title one schools. I had the privilege of teaching second, third, fourth, and fifth grade and had various teacher leader opportunities before stepping away from the classroom to pursue my PhD where I have been afforded the opportunity to teach elementary science methods courses and English as a second language seminars to undergraduate and graduate students. I have taught through the beginning implementation of Common Core, Race to the Top, and the remnants of No Child Left Behind. Within these reform efforts, unintended consequences such as teacher autonomy have been replaced with scripted or boxed curricula for the high stakes testing subjects, while also allocating more time to teach these subjects, which leads to minimal or zero time for science. Due to minimal or zero time to teach science, this leads to gaps in teacher knowledge and confidence to execute science lessons to students.

With an emphasis on English Language Arts (ELA) and mathematics, there was limited if any professional development for teachers to learn best practices for teaching science. Therefore, I found myself shying away from teaching science because I did not feel confident, and I knew I needed to produce high test scores in ELA and mathematics. During my fourth year of teaching, I was presented with the opportunity to participate in a STEM Teacher Leaders Collaborative (STEM TLC) science professional development through the University of North Carolina at Greensboro (UNCG). Through this training I realized science was fun and it was not as scary and hard as I once believed it was. I did learn it takes work to ensure you are providing the right content, but with the opportunity afforded with this professional development I got to engage with other teachers across multiple districts who found themselves in a similar boat when it came to science teaching and learning. Therefore, we were all able to exchange information and lean on one another for support.

Following the STEM TLC professional development, UNCG was offering an Elementary science Master's degree. I decided to take the leap and apply. Thankfully, I did, and I was accepted which has led me to where I am today. With this experience, I found a voice to advocate for science education. I took on the role of a science teacher leader within my school and worked to provide support within our building from myself or professors from UNCG. I found that similarly other teachers within my building also wanted to get better at teaching science to their students and we began to meet monthly to plan and support one another across grade levels. Through this science teacher leader role, I wrote a final paper expressing the need for science teacher leaders in schools and that is how I am writing this dissertation today. I am a firm believer that when science teacher leaders are leveraged within school buildings and throughout their districts the proper support and resources can be in place so that all students have the opportunity to engage in science teaching and learning. The purpose of my work is to better understand STLs and how they can be leveraged to attend to internal and external barriers within their localized contexts and how they respond to these barriers to ensure that science education is a priority. My reasoning for using qualitative research and utilizing specific methods such as semi-structured interviews are described next.

Figure 2. Research Process



Research Design

Why Qualitative Research?

Qualitative research goes beyond quantitative and numerical data and allows researchers to explore and analyze more deeply (Merriam & Tisdell, 2016). Qualitative data also allows for researchers to generate hypotheses and address the "why" and "how" in order to make sense of and further understand current ideas and concepts (Merriam & Tisdell, 2016). Merriam and Tisdell (2016), explain the benefits of qualitative research in the following way:

> [Qualitative research] is an effort to understand situations in their uniqueness as part of a particular context and the interactions there. This understanding is an end in itself, so that it is not attempting to predict what may happen in the future necessarily, but to understand the nature of that setting– what it means for participants to be in that setting, what their lives are like, what's going on for them, what their meanings are, what the world looks like in that particular setting–and in the analysis to be able to communicate that faithfully to others who are interested in that setting….The analysis strives for depth of understanding (p.15-16).

Thus, science teacher leadership could benefit from qualitative research as we seek to better understand how STLs understand their roles as science leaders to navigate the internal and external barriers inherent in science reform efforts.

Philosophical foundations of this research study

I approached this research study through an interpretive, social constructivism lens as it is assumed that:

> Reality is socially constructed; that is, there is no single, observable reality. Rather, there are multiple realities, or interpretations, of a single event. Researchers do not "find" knowledge; they construct it. (Creswell & Tisdell, 2016 p. 9).

Constructivism as an ontology suggests reality is subjective as it is constructed through individual experiences or the shared experience of a group (Guba & Lincoln, 1994). The ontology of distributed leadership is built on the belief that leadership is not fixed or static, but something that is constantly evolving and in return, interactions and responsibilities among leaders are context dependent and never clear cut (Crevani et al., 2010). Therefore, qualitative research is necessary as it allows space for participants to share "why" and "how" they are making sense of the ever-changing nature within contexts and work (Merriam & Tisdell, 2016). From a constructivist epistemological perspective, knowledge is subjective, but constructed and known through the interaction between the researcher and participants in the study (Creswell & Plano Clark, 2018; Guba & Lincoln, 1994). The epistemology of distributed leadership is built on the belief that knowledge is created and shared through social interactions that do not reside with one individual, but rather they are distributed throughout a group or the organization as a whole (Bolden, 2011; Gronn, 2000, 2002; Spillane, 2005, 2006; Spillane et al., 2004). Therefore, qualitative research is best suited for this study as it situates "the researcher as the primary instrument for data collection and analysis" (Merriam & Tisdell, 2016, p.16) to better understand participants' interpretations of their experiences.

Methods

For the purpose of this study, a comparative case study methodology (Merriam & Tisdell, 2016) was used to look at a diverse set of elementary STLs from within a larger network of STLs supported by a museum on the West Coast. This case study was employed to understand how elementary STLs describe the organization of their leadership work and how they understand their roles as science leaders to navigate the internal and external barriers inherent in science reform efforts. The purpose of using a case study allowed for research to be exploratory while also providing rich descriptions of the phenomena at hand (Merriam & Tisdell, 2016). In particular, a case study was the preferred methodology as this research was not intended to focus on all of the STLs from the statewide network, but rather focus on STLs associated with elementary science through multiple data sources and real-life activities (Noor, 2008). In order to better understand the context and larger study that this research derived from, I describe the larger network context and study, the purpose of my research, my sample, and my sources of data that were used to help better understand science teacher leadership, STLs, and why they are necessary in elementary schools.

Spanning Boundaries Research Project Background

The following dissertation pulls from data that was collected from a larger NSF grant project, Spanning Boundaries [1907460] that began in 2019 and concluded in 2022. The data from Spanning Boundaries was collected by me and a team of UNCG researchers and museum staff. The participating STLs were already participants in a statewide teacher leadership network supported by the Exploratorium, a museum of art, science, and perception in California. The Exploratorium established the STL network in 2016 to support the implementation of the Next Generation Science Standards [NGSS] across the state. The Exploratorium recruited STLs from all over the state to create an equitable distribution of resources in attempts to be representative of all regions as well as being inclusive to the variety of roles STLs encompass as defined by their context and experience. To be considered and to participate in the network, all STLs had to work formally or informally with other science teachers and all STLs had to go through the application process.

Science Teacher Leader Network

The science teacher leader network created by the Exploratorium has been in place since 2016 to support statewide efforts to implement the state's next-generation science standards with funding by the state. Twice a year, the Exploratorium offers a one-week professional development for STLs who provide some form of professional learning for other science teachers in their context. The professional development focused on understanding NGSS standards and implementation as well as learning how to develop as an STL. After the PD, STLs have access to a number of resources at the museum, including opportunities to participate in alumni workshops to continue their growth as an STL and access to a listserv where activities, resources, and other PD around the state are shared. The STL network is committed to ensuring that science teachers in leadership roles feel supported through an equitable, diverse, and inclusive community (see Appendix D for more information on the STL network).

In 2020, the Exploratorium added a virtual professional learning program to extend the in-person workshops offered to STLs in the network. There were two cycles of the virtual professional learning program implemented as part of the Spanning Boundaries project. The participants were recruited from the existing network and submitted an application for admission. Museum staff chose STLs who represented a range of geographic regions in the state and the range of teachers supported by each STL. In year one (2020-2021), 24 STLs were chosen to participate in the Spanning Boundaries project and represented 14 of the state's 58 counties ranging from some of the state's most rural school districts to some of the most urban school districts in the state. The 24 STLs supported a range of five teachers to 1,200 teachers and a variety of grade-level bands (K-12), (K-6), (6-8), and (9-12). In year two (2021-2022), 32 STLs participated in the second iteration of the virtual professional learning program, 20 STLs returned from year one, and 12 new STLs were recruited to join. Similar to the participants in year two, these STLs also represented a range of geographic regions in the state and a range of teachers served by each STL. The sample of elementary STLs in this dissertation came from participants in the virtual professional learning program.

Science Teacher Leader Virtual Professional Learning

STLs were grouped into small cohorts focusing on specific problem areas identified within the museum-based network. A series of interviews with STLs highlighted four common challenges, subsequently chosen as focal points for the virtual working groups. The following table includes the problems of practice identified for both year one and year two of the virtual working groups.

Table 2: Focus Problem of Practice Groups

Group Number	Focus Problem of Practice Year One (2020-2021)	Focus Problem of Practice Year Two (2021-2022)
1	Implementing hands-on NGSS-aligned activities	Supporting an equity-oriented science classroom
2	Using collaboration tools and processes (for students in classrooms and for teachers) effectively	Designing and creating phenomena based NGSS sequences
3	Using equitable teaching practices (access, instruction, assessment)	Supporting an equity-oriented science classroom, building relationships to improve science instruction
4	Understanding antiracism and using culturally responsive teaching in science	Supporting an equity-oriented science classroom, Investigating racially-just science teaching

5	Understanding antiracism and using culturally responsive teaching in science	Supporting an equity-oriented science classroom, Investigating racially-just science teaching

Each working group comprised four to five STLs, a museum staff member, and a university-affiliated researcher. Facilitation was primarily led by museum educators, with one group overseen by the university-based Principal Investigator (PI). Together, the groups analyzed and defined their respective problem areas, identified knowledge and practice gaps, and collaborated on innovative solutions tailored to their unique contexts. While specific approaches varied depending on leadership contexts and the identified problem, an overarching structure was established for the professional learning program.

The program framework was designed to be learner-centric, allowing for differentiation and choice among participants. STLs were empowered to select their preferred group based on individual interests and local needs. Resource sharing and modeled pedagogy were central components of the program, facilitating informal exchanges and formalized protocols for feedback and resource dissemination.

Monthly facilitator meetings provided an avenue for reflection, idea-sharing, and troubleshooting among facilitators, overseen by the PI's and attended by the museum-based researcher/facilitator. These sessions served to monitor progress, refine activities, and address any emerging challenges encountered during the professional development process.

Sources of Data

In Spanning Boundaries, researchers collected a variety of data. The table below shows all of the data that was collected from the larger NSF study but details the pieces of data I used for my analysis in this dissertation study.

The following table details the data sources collected from the larger NSF study and describes which pieces of data I analyzed for this dissertation study. Following the table, I describe my data sources, how I used them, and why I used them.

Table 3: Data Sources from Spanning Boundaries and Data Sources Used for Dissertation

Project Data	Data Used for this Dissertation	STLs represented
STL application to Professional Learning Program	Used to sample elementary STLs	Maxine, Otto, Levi, Dawn, Brad, and Stephanie
Video Data	Did not use because I did not study their professional learning	N/A
Actor Network Maps	Used to validate findings	Maxine, Dawn, Brad, Stephanie
Artifacts of teachers' collective work from CoP	Used to validate findings	Maxine, Otto, Levi, Dawn, Brad, and Stephanie
CoP agendas and resources shared	Did not use because I did not study their professional learning	N/A
PL Tracker	Used as a validity check	Maxine, Otto, Levi, Dawn, and Brad
Interview		
Year 1 Midpoint	Used to understand the context in which STLs worked, how they	Maxine, Otto, Levi, Dawn, and Brad
Artifact: Leadership practice	Used to better understand how STLs were supporting elementary science within their localized contexts as well as how STLs understood and enacted their role.	Maxine, Otto, Levi, Dawn, and Brad
Year 1 Final	Used to better understand how STLs were attending to problems of practice (barriers) within their localized contexts.	Maxine, Otto, Levi, Dawn, and Brad

Year 2 Final	Used to better understand how STLs described their pathway to becoming a STL and how they understood and enacted their role as an STL in their localized contexts.	Maxine, Otto, Levi, Dawn, and Stephanie
Artifact: Journey Maps	Used as a validity check	Maxine, Otto, Levi, Dawn, and Stephanie
Artifact: Profile Activity	Used as a validity check	Maxine, Otto, Levi, Dawn, and Stephanie
Artifact: Leadership Practice	Used as a validity check	Maxine, Otto, Levi, Dawn, and Stephanie

As the university researcher for groups three and five in year one, and groups one and three in year two, I supported and actively collected data for the overarching project with my university research team. Of the data collected for the participants in this dissertation, I conducted four out of the five (Stephanie did not participate in year one, therefore there were five total participants interviewed) semi-structured interviews for both the mid-point interview and final interview for year one. The one interview I did not conduct was completed by a fellow researcher on our team. In year two, I was responsible for conducting four out of the five semi-structured interviews (Brad did not participate in year two, therefore there were five total participants interviewed). The one interview I did not conduct was completed by a fellow researcher on our team.

STL Applications to Professional Learning Program

The STL application was the initial data source that helped me identify which STLs supported teachers in K-6 settings to sample participants for the comparative case study. The application to participate in the study specifically asked STLs for important information about their organizational context and how it related to their work as an STL. The specific information included their official job titles, the primary entity (e.g. school, district, county) in which they worked, how much of their time was allocated for direct work with science and other teachers, the number of science teachers they supported, their school context [public, independent, or charter; Title 1 status; grade levels], as well as their responsibilities and goals as an STL. This information provided access to the types of contexts in which STLs worked, and how they are describing their roles within them. The applications also provided background information in which the STLs described their past roles within education, which allowed for a better understanding of their prior knowledge.

Semi-Structured Interviews

There were two semi-structured interviews conducted in year one of data collection; a midpoint interview and a final interview, followed by one more final interview conducted in year two. The research team chose to combine the two interviews from year one to one final interview in year two in response to the needs of the STLs in the professional development. Collectively, these interviews asked questions to better understand how STLs described and understood their roles as an STL within their localized contexts. Specifically, questions were asked so STLs could describe a typical work week; the work they engaged in formally and informally to support science education; and what activities they used and designed to support science education. We also asked STLs to tell us why they chose to work on their group's problem of practice and what they were learning about that problem in their local context. For each interview, STLs were asked to share and describe an artifact that they developed and or shared with other teachers, STLs, administrators, and other stakeholders that were representative of their leadership practices. The chosen artifacts reflected their work as an STL and the problems of practice they were working to address within their localized, organizational contexts. The purpose of using a participant chosen artifact for this research study provided an entry point into the discussion while also allowing the participants to critically think and describe how their artifact supported their work as an STL and their future work moving forward (Douglas et al., 2015).

Following the interviews for year one and year two, I also used the actor-network map (ANM) as a validity check. The actor-network maps were created to help STLs map their complex organizational contexts (Reidy et al., 2018). The actor-network maps helped the STLs to see the big picture in regard to science education reform efforts where they could identify gaps within science education. STLs were able to use these maps as a starting point to identify problems of practice, influential people, and the best ways to find coherence within their organizations (Reidy et al., 2018). The purpose of using the actor-network map provided an opportunity for STLs to identify and describe their relationships within their localized contexts and determine identified knowledge and practice gaps.

In the final interview in year two, we also asked STLs to describe their pathway to becoming a STL. The science teacher leader journey maps (modified from Annamma, 2017) allowed the STLs to map out pivotal points that led them to their current work as a STL. The STL journey maps included positive encounters, frustrations, relationships, knowledge, practices, skills, and support that STLs named as they reflected on their journey that they described during their interview. The STL journey maps were useful and supported the qualitative research approach as they allowed STLs and researchers to create a personal narrative during their interview and privilege the experiences of the participants (Futch & Fine, 2014).

Another artifact discussed during the final interviews in year two was the role identification activity. In previous work from the Spanning Boundaries researcher project, the research team identified seven STL roles (activist, ambassador, collaborator, innovator, networker, organizer, and translator) based on the narratives of STLs' practice (Heredia et al., 2023a for description of activity). Each role was described from the perspective of STLs themselves and highlighted a set of practices they enacted while engaging in their leadership work.

Professional Learning Tracker

The PL (Professional Learning) tracker was a survey that STLs filled out to explain the professional learning activities they organized or engaged educators in if they engaged teachers in any informal activities, the time they spent organizing professional learning (both formal and informal), and the number of educators they supported. The PL Tracker was also used to validate STLs' descriptions of their work from the semi-structured interviews. In year one, the PL tracker was completed each month, and in year two, it was completed every three months. These PL trackers were another validation and chance for the STLs to describe how many K-6 educators they supported and how they supported them.

Artifacts

According to Merriam and Tisdell (2016), documents and artifacts are readily available sources of data that are grounded in the research study and can help researchers uncover meaning, deeper understanding, and rich descriptions that other forms of qualitative data may not quite reach. Artifacts and documents can support researchers to creatively use them in combination with other data sources to construct a holistic and multifaceted understanding of the social and cultural contexts within their study (Merriam & Tisdell, 2016). The following artifacts were collected from all participants in the Spanning Boundaries project: participants' chosen artifact of their leadership practice, participants' actor network maps, science teacher leader journey maps, and role identification activity data. Artifacts and documents also allowed the researcher to determine how the STLs used their knowledge and skills to design and refine activities and practices to address the needs of their organization.

Research Study Sample

To better understand the work of STLs in elementary schools, I sampled STLs from the network that focused on K-6 science teaching and learning. To determine who those STLs were, purposive sampling (Campbell et al., 2020; Merriam & Tisdell, 2016) was used. I used the STL applications to the network professional development program and semi-structured interviews to identify my study sample. Below, I describe the steps I used to determine which STLs would be used for my case study.

Study Sample Identification Step One

Purposive sampling was used for this research study as it allows for an in-depth analysis on a small sample (Campbell et al., 2020). Purposive sampling involves intentionally selecting specific individuals, cases, or elements for inclusion based on predefined criteria or specific characteristics to best serve the research goals and objectives (Campbell et al., 2020; Merriam & Tisdell, 2016). For this research study, STLs were chosen from the larger network context based on the grade level band in which the STLs supported teachers. In order to be considered for this research study sample, the grade level band that STLs needed to support was K-6. To determine which STLs employed science teacher leadership practices with K-6 teachers and educators, STLs' applications were used for participant selection. The applications for both year one (2020-2021) and year two (2021-2022) applications were used to identify STLs who stated that they worked and supported elementary science teachers and educators. The tables below show the following questions that were used from year one and year two applications to identify the first pass of individuals who could potentially be chosen and analyzed for this study.

Table 4: STL Application Initial Sample Analysis

Questions	Example of Answer
Questions in Year One and Year two	
What is/are your current position(s)?	STLs shared the following positions they held within their contexts: "Instructional coach, program specialist, STEAM coordinator, science specialist, full time teacher, Teacher on Special Assignment"
What is the primary entity you work for?	"District Office, or school"
Please describe the positions in education you have held, including how many years you have spent in each role.	STLs provided the researchers will the background of their educational experience, below is an example: "6 Years as an elementary classroom teacher, 9 years as a K-12 technology coordinator, 5 years as an elementary school coordinator, 5 years as an elementary science specialist, 5 years as a K-12 STEAM Coordinator, 9 years as a science methods instructor." HS
What do you expect will be your role(s) in a leadership capacity in fall 2020? (check all that apply) -mentoring other teachers -one to one coaching -curriculum design -planning/leading PD for other teachers -supervise student teachers -science department head	STLs mentioned variations of the following: "mentoring other teachers, 1-1 coaching, curriculum design, planning/leading professional development for other teachers"
Please briefly describe your responsibilities as a teacher leader in 2020-2021, providing details for the above question.	STLs were briefly asked to describe their responsibilities as a leader for the 2020-2021 school year. The following is an example: "Induction Lead Mentor (supporting a cohort of other mentors in our induction program); Induction Mentor

Please briefly describe your responsibilities as a teacher leader in 2021-2022, providing details for the above question.	(supporting new hires of Science Specialists); I'm a quasi-assistant principal for our Science Specialists with a goal of pushing into classrooms of all our new hires to co-teach, model teach, and/or observe & provide feedback. I'll be presenting at 'Science Teachers After School' Meetings which are PD opportunities open to K-12 teachers in the district."
In a typical calendar year, how many teachers do you serve through your science leadership role(s)?	STLs shared a range of teachers supported with the lowest being 5 teachers and 1,200 teachers as the highest. "5-1,200"
Please check the grade level band(s) of the teachers for whom you provide professional learning.	Teachers provided the following as grade level bands they supported: "K-6", "TK-12", "K-5, 6-8, 9-12"
New Question for year 2	
Returning or New STL?	Answer was yes or no (We had 20 returners and 12 new STLs join for year 2).

After using the STL Applications to the Professional Learning Program for year one and year two of communities of practice, potential STLs were identified. A total of twelve STLs were identified as the potential sample for this study. Seven of the STLs participated in both years of the study, one STL who participated in year one of the study only, and four STLs who participated in year two of the study only. The following table details the 12 potential STLs identified in study sample identification step one.

Table 5: Research Study Sample Identification

Year 1 STLs	Year 2 STLs	STLs who participated in Year 1 and 2
Kaia (Group 1)	Otto (Group 1)	Kaia (Group1 and 1)
Maxine (Group 2)	Stephanie (Group 1)	Maxine (Group 2 and 1)
Levi (Group 2)	Maxine (Group 1)	Levi (Group 2 and 2)

Otto (Group 2)	Paige (Group 1)	Otto (Group 2 and 1)
Dawn (Group 3)	Maeve (Group 1)	Dawn (Group 3 and 3)
Brad (Group 3)	Levi (Group 2)	Avery (Group 4 and 4)
Avery (Group 4)	Dawn (Group 3)	Anna (Group 5 and 5)
Anna (Group 5)	Kaia (Group 3)	
	Avery (Group 4)	
	Ridetta (Group 4)	
	Anna (Group 5)	

Study Sample Identification Step Two

Next, I looked at interview data from year one (midpoint and final interviews) and year two (final interviews) to confirm if STLs referenced and elaborated on their work with K-6 teachers and educators. Some of the interview questions that supported the efforts for STLs to reference and elaborate on their work included:

Table 6: Semi-structured Interview Questions for Sample Identification

Interviews	Questions to Support Sample Identification
Midpoint Interview Year 1	What are you doing right now both formally and informally to support other teachers in your school or district? How do you define your sphere of influence within your role in your school or district? Tell us about an artifact you have chosen to share with us (inspiration behind it, how did it represent your goals, etc).
Final Interview Year 1	What was the problem of practice that your group was working on (why did you choose it, were you able to attend to it/develop solutions, how did the work within the CoP impact your understanding of your problem of practice)? Did you use any of the activities or protocols from your CoP within your context?

Final Interview Year 2	Tell me about your work as a science teacher leader this year. Returners: (How has your practice or sphere of influence changed from last year)? If new to the CoP (describe your context, sphere of influence, typical workday and work week, and resources provided from your district to support your work). Show leadership journey map picture. Ask about these critical moments/experiences that lead them to where they are today? What was the problem of practice that your group was working on (why did you choose it, were you able to attend to it/develop solutions, how did the work within the CoP impact your understanding of your problem of practice)?

After using the semi-structured interviews to determine STLs that referenced and elaborated on their work with K-6 science teachers and educators, I created a key to look at the initial sample from the application data to determine which STLs could be used for this study sample and which STLs could not be used for this study sample.

Table 7: Semi-Structured Interviews Criteria for Inclusion

Include STL	Criteria for inclusion
Yes	STLs referenced and elaborated on their work with K-6 teachers and educators
Possible	STLs referenced elementary school, but they did not elaborate or state their current work with K-6 teachers or educators
No	STLs did not reference or elaborate on their work with K-6 teachers and educators.

I examined eight interviews from year one and eleven from year two to identify STLs discussing their work with K-6 teachers and educators. Using the inclusion criteria outlined in Table 3.5 (*Semi-Structured Interviews Criteria for Inclusion*), I selected STLs who elaborated on their interactions with K-6 educators. Five interviews in year one and five interviews in year two met the criteria, resulting in a sample size of six STLs. The sample size of six STLs included four STLs who participated in both years, one STL who participated in year one, and one STL who participated in year two only. Below is a table detailing the selected STLs, their participation years, self-reported identities (gender and race/ethnicity), leadership context (Level of STL within the system and geographical location), and the number of science educators the STLs supported.

Table 8: STLs Sample Demographic Information

Demographic	Maxine	Levi	Otto	Dawn	Brad	Stephanie
Years Participated in CoP						
Year 1	Yes	Yes	Yes	Yes	Yes	No
Year 2	Yes	Yes	Yes	Yes	No	Yes
Self-Reported Identities						
Gender	Female	Male	Male	Female	Male	Female
Race/ Ethnicity	White	East Indian American	White	White	White	White
Leadership Context						
Level of STL within system	District	District	District	District	County	County
District/ County	Midtown County	Mission County	Beach County	Resort County	Citrus County	Mission County
Geography	Urban	Urban	Urban	Suburban	Suburban	Urban
Number of science educators STLs supported						
Year 1	200	30	1,200	700	500	N/A

Year 2	300	90	800	50	N/A	200

* Note: For the purpose of confidentiality, pseudonyms are used for STLs' names and the counties in which they work.

Profile of Sample STLs

The following profiles briefly describe the district/county-level STLs who were participants in this dissertation. The profiles include the positions held by each STL, the districts in which they served, educator experience, and the number of years they have been in education.

Maxine

Throughout the Spanning Boundaries project, Maxine served as a Program Specialist, supporting TK-12 education in science and health. Since 2016, Maxine has held this position in an urban district within Midtown County. Her educational background includes twelve years teaching elementary grades (specifically 4th and 5th grades from 1997-2008), followed by six years as a middle grade's teacher covering science, math, and electives for 6th and 7th grades from 2009-2014. Additionally, she spent three years as a math teacher on special assignment (TOSA) from 2014-2016. Maxine's tenure in public education within the same district totals 24 years.

Levi

Levi served as an Instructional Coach, providing support to K-6 and 6-8 science teachers and educators in an urban district located in Mission County. With eleven years of experience as a middle school science teacher, he spent ten of those years as the head of the science department. Additionally, Levi worked as an elementary school instructional coach for three years before transitioning to his current role as the STEAM and science instructional coach for the district. He has held this position for the past three years, accumulating a total of 17 years of educational experience.

Otto

Otto served as a full-time PK-12 STEAM coordinator, providing support to PK-12 science teachers and educators within an urban district located in Beach County. With a diverse background in education, he spent six years as an elementary classroom teacher, followed by nine years as a K-12 technology coordinator. Additionally, Otto served four years as an elementary school coordinator, six years as an elementary science specialist, and two years as a K-12 science specialist. He then transitioned to his current role as a PK-12 STEAM coordinator, which he has held for four years. Throughout his career, Otto also dedicated nine years to serving as a science methods instructor. In total, he accrued 31 years of educational teaching experience.

Dawn

Dawn held the position of Full-Time Elementary Science Teacher on Special Assignment (TOSA), providing support to elementary science teachers, particularly those in grades fourth through sixth, and new elementary teachers within a suburban district located in Resort County. With a diverse background in education, she spent ten years teaching elementary school (five years in a public school and five years in a private school). Additionally, Dawn served one year as a reading intervention teacher, substitute, and tutor, followed by three years as a Science Specialist for fourth and fifth grade, as well as providing sixth-grade support for middle school science. She then spent three years as a Teacher on Special Assignment (TOSA), working at the district level with K-6 teachers in science and a group of elementary science specialists (grades fourth through sixth). In total, Dawn accrued 17 years of educational experience.

Brad

Brad served as a Full-Time Science/STEM Administrator within the Citrus County Office of Education. In this capacity, he provided support to all 23 districts, both directly and indirectly. Education marked a second career for this individual, who previously worked as a biologist before transitioning to education. His educational background encompassed 15 years as a high school classroom teacher, where he taught Biology, AP Biology, Environmental Science, Chemistry, Earth and Space Science, Conceptual Physics, and Anatomy/Physiology. Notably, he spent ten of those 15 years as the science department chair of a twenty-teacher staff. Subsequently, he served three years at the district level as a Science and Technology Coach before assuming his current role as an Administrator for the Citrus County Office of Education. In total, he accumulated twenty-two years of educational experience.

Stephanie

Stephanie served as a science coordinator within the Mission County Office of Education. In this capacity, she provided support for thirty-one school districts and twenty-one charter schools and districts, focusing on NGSS and Environmental Literacy support. Her background in education included three years as a Middle School math and science teacher, during which she also served as a County NGSS Leadership member supporting four NGSS Rollouts. Additionally, she accrued thirteen years of experience as an Elementary math and science teacher, concurrently holding roles as a District Science leader involved in curriculum adoption and course of study development. Subsequently, she assumed her current position as a science coordinator for the Mission County Office of Education during the second year of the communities of practice study. In total, she accrued eighteen years of educational experience.

The preceding STL profiles offer a glimpse into the educational backgrounds and professional environments of each individual. These STLs were selected as the study sample based on their applications and semi-structured interviews, during which they articulated their contributions to K-6 science education initiatives within their respective contexts.

Data Analysis

Semi-structured interviews were used as the primary source of data to learn how the STLs described their roles as they worked to set a direction, develop people, redesign their organization, and manage curriculum for elementary science teaching and learning within their localized contexts. A case was developed from the semi-structured interviews through four phases of data analysis for each STL. The case study aided in the understanding of how STLs leveraged the four dimensions of distributed leadership to attend to internal and external barriers within their districts/counties.

Accountability Partner for Data Analysis

In qualitative research, accountability partners are often used. An accountability partner can be described as a peer or colleague that is used as a thought partner to review the researcher's progress, provide feedback, discuss data, and assist in resolving emerging discrepancies or issues within the data (Guba & Lincoln, 1985). An accountability partner is well versed and educated on the research study, the context in which the study was conducted, and the methodologies and conceptual framework(s) used for the study (Guba and Lincoln, 1985). Having an accountability partner that is well versed with the research allows for the researcher to hear a fresh perspective that can lead to greater depth and quality of the research. In order to ensure the research remains rigorous and credible, the researcher and the accountability partner meet regularly, discuss and analyze data to attend to discrepancies, and work together to come to a consensus.

In this study my accountability partner was a third-year doctoral student at the time of the study, specializing in Special Education within the School of Education in the Department of Teacher Education and Higher Education. Our initial connection stemmed from our mutual enrollment in a qualitative research methods class during my second year of the doctoral program, her first year. With a shared interest in qualitative research, we seamlessly collaborated on numerous partner projects in class, establishing a strong working relationship. Given our compatibility and rapport, she was a natural choice when an accountability partner was sought for my dissertation. Although initially unfamiliar with the overarching project, we committed to regular and rigorous meetings over the course of three weeks where we met three times a week for two hours, during which I provided comprehensive training on distributed leadership, science teacher leadership, and the specific objectives of my dissertation. Once she felt sufficiently confident in these areas, we commenced the phases of the coding process in tandem. The Table below shows the phases in which data were analyzed by my accountability partner and myself.

Table 9: Phases of Data Analysis

Phases of Data Analysis	Details of Data Analysis
Phase 1: Segmenting the Data	Segments were extracted for setting direction, redesigning organization, developing people, managing curriculum.
Phase 2: Coding the Data	Extracted segments were coded for internal and external barriers.
Phase 3 and 4: Creating cases for each STL to compare and contrast	Cases were created for each STL to compare and contrast ways their enacted their work.

Phase One: Segmenting the Data

The first phase of data analysis included segmenting the data from the semi-structured interviews which involved breaking down the interview transcript into manageable segments or units of analysis based on the distributed leadership conceptual framework. The data was segmented based on the four dimensions of distributed leadership; (1) setting direction, (2) developing people, (3) redesigning the organization, and (4) managing instruction (Firestone &

Martinez, 2007; Leithwood et al., 2007). The following process was used to accurately segment the data for analysis.

1. Semi-structured interview transcriptions: The semi-structured interviews were transcribed verbatim by a third party where they captured all spoken words, pauses, and nonverbal cues. The semi-structured interviews were transcribed to ensure that participants' confidentiality was honored.
2. Initial reading: I read through the entire transcript for each participant interview to gain a broad understanding of the content and context.
3. Deductive Coding: I worked with an accountability partner that I trained in regard to the research and the overarching goals for this dissertation. Once my accountability partner was trained, we worked in tandem to identify and label segments of text that corresponded to the distributed leadership conceptual framework. The following codes were used to highlight and mark relevant sections of the transcripts (setting direction, redesigning the organization, developing people, and managing curriculum).

In order to identify and label segments of the text using the four dimensions of distributed leadership, the following table operationalizes the ways in which my accountability partner and I made sense of the four dimensions within the framework of distributed leadership and my researcher to identify the segments.

The table below includes the operationalization of each definition and the ideas that my accountability partner and I included when working work segment interviews together. We added these details to ensure that the dimension was operationalized to include all details that support the dimensions of distributed leadership enacted by STLs.

Table 10: Operationalizing the Four Dimensions of Distributed Leadership for Data Segmentation

Distributed Leadership Dimension	Initial Operationalization of Distributed Leadership	Revised Operationalization of Distributed Leadership	Examples
Setting Direction	- Creating a focus that is central to the work needed within the contexts -Organizing/communicating/translating a district/school vision to teachers in different ways (PD, documents, coaching conversations). - Identifying a vision and providing steps to potentially reach this.	-Creating a shared understanding of activities and goals that support the vision of an organization. -Goals are achievable yet challenging to keep members and the organization motivated. -Goal setting at the organization level (cannot be an individual goal).	"So, we, my boss and I work together to translate that into what it means for us in elementary science …with our districts focus on equity"- Dawn Year 2 Final Interview "Elementary kids are not getting equitable access to science education and critical thinking skills… So, the low hanging fruit would just be to bring it into the classroom" - Brad Year 1 Final Interview.
Redesigning the Organization	- Developing networks of collaboration around improvement - Influencing instructional shifts in order to move an organization forward and towards improvement.	-Creating or recreating systems with new ideas or improved ideas that allow for	"We soon realized we had a problem, that a classroom teacher just wasn't getting

	- Creating a system within an organization where new ideas form and filter throughout (cohesively top to bottom and bottom to top) the state, county, district, and into classrooms. - Data from classrooms is collected and shared with the district, county, and state to ensure that the right goals and ideas are being implemented to move towards improvement.	fluidity through the organization. -Top-down, then bottom-up fluidity to ensure organizations move towards improvement.	this information" - Brad Year 1 Midpoint Interview "In essence, what we've done is created a throughput from the state through the county into the districts and then directly into the classroom." - Brad Year 1 Midpoint Interview "But the biggest part was not we're getting data and info from the classroom back so we can take it back up to our meetings" - Brad Year 1 Midpoint Interview
Developing People	- Coaching conversations - Providing feedback - Co-Teaching - Modeling various teaching practices - Observing teachers -Individualized coaching	-Individual coach or leader(s) who understand the core of science and can support individuals. -Coaching entails: individualized coaching, observations, feedback,	"Just thinking about coaching conversations, just letting them talk rather than having me be the one that points out this and that"- Otto Year 1 Midpoint Interview

		modeling, co-teaching. -Developing people seeks to improve teaching and learning for elementary science.	“I like to start the conversation with that question. How is the delivery of the lesson different from what you intended?” - Otto Year 1 Midpoint Interview
Managing Curriculum	- Providing research to support the why behind strategies - Providing planning tools to support teaching moves and strategies - Sharing and providing resources to support curriculum - Working with standards, understanding them and how to create standards-based lessons. - Connecting with individuals to help and support. - Planning conversations (open and honest, okay not to know) what to teach, what materials to use. -Teachers can create groups to support the efforts of planning and implementing curriculum.	-Providing time and space for deep, thoughtful planning. -Support and tools are provided to ensure planning includes standards-based instructional practices. -Looking across and understanding instructional materials needed for lessons.	“So, we had what our purpose was and we pulled from different things including stem teaching tools and some other things like ambitious science teaching.” - Dawn Year 2 Final Interview “We basically provided some of the research, some of the tools, and the strategies they could use” - Dawn Year 2 Final Interview

After segmenting the data using the distributed leadership conceptual framework (setting direction, redesigning the organization, developing people, and managing the curriculum) I used these four dimensions to organize the data in an excel spreadsheet to further code.

Phase Two: Coding the Data

Following the segmentation of data, deductive coding was used to analyze the segmented transcripts to better understand how STLs described their work through a distributed leadership lens and how they attended to the internal and external barriers they faced within elementary science reform efforts. The following steps were used to ensure that deductive coding was conducted properly between myself and the accountability partner.

First, we determined the deductive codes based on the literature. The researcher and accountability partner identified internal and external barriers within elementary science education to support findings (Smith & Southerland, 2007). The following codes were used to code for internal and external barriers:

Table 11: Deductive Code Book for Internal and External Barriers

Internal Barriers		
Child Code	Description	Examples
Teacher Confidence to teach science	Sense of self-assurance, competence, and/or comfort in delivering science content and engaging students in meaningful scientific inquiry.	“...maybe are fearful of teaching science” (Stephanie Year 2 Final Interview).
Science Content knowledge	Level of understanding scientific concepts, standards, and content.	“...science teachers are at a point where they really just need time to learn content because you can't really plan effectively unless you deeply understand…” (Levi Year 2 Final Interview).
Science pedagogical	Ability to communicate complex ideas clearly, design	“...the shift away from just students passively learning about figuring out with

Content knowledge	engaging lessons, and facilitate hands-on experiments or activities.	NGSS where they're doing more of the figuring out, of figuring out science ideas…" (Otto, Year 1 Midpoint Interview)
Teacher Beliefs about teaching science	Attitudes, values, and assumptions about the nature of science, the teaching and learning of science, and the role of science in education.	"...But oftentimes, even when we see it, it's oftentimes treated like a reward or something, and there's a lot of kids that get pulled out and don't get to experience it, that also is not equitable. There's for some reason, the thought that just because kids can't understand English very well, that they can't handle the science which is ridiculous…" (Brad Year 1 Final Interview).
Teacher experience teaching science	Background, training, grade level, and the resources available to them	"...What I've noticed is the background of the teacher kind of helps. It kind of shows you where they're going to feel more comfortable…" (Levi Year 1 Midpoint Interview).
Teacher Buy-in	Getting teachers on board through motivation, love for a subject, providing them with things they asked for, or monetary compensation.	"A lot of them brought their whole teams with them so they were able to do planning together…(Maxine Year 2 Final Interview).
	External Barriers	
Time Allocation for science	Time allocated to teach science in comparison to other subjects.	"And so, if they're not getting it at all in elementary school, they've lost like half of the scaffolding that's provided for them in science education…" (Brad Year 1 Final Interview).
Science Resource Allocation	Knowing what resources are there and how to use them, or the lack of resources available.	"...Definitely, we find the resources for teachers, we help them with curriculum adoption, we also help them with partnerships…" (Stephanie Year 2 Final)
Administration and Policy Priorities	"focus" on particular items/subjects based on district mandates, state mandates, SIP goals, and standardized tests.	"...But site level administration, district level administration, that's a hit and miss because those guys have got different pressures on them. You know as well as I do, everything in education rolls

		downhill" (Brad Year 1 Midpoint Interview).
Professional Learning	Lack of professional learning opportunities, or teacher asking for opportunities to plan and engage in science PD	"We heard specifically at the elementary level…they wanted collaboration time by individual grade levels…" (Maxine Year 2 Final Interview).
Curricular Constraints	Presence or lack of an engaging rigorous curriculum that allows for teacher flexibility and autonomy	"...What those materials look like is really going to impact how our kids see science, because right now they're getting a lot of worksheets, reading, and boring stuff." (Maxine Year 1 Final Interview).
System Constraints	Policy inconsistencies (different agendas of teachers, admin, districts, county, and state) could lead to confusion and/or exhaustion and Teacher recruitment/retention	"... "But we dealing with now a teacher shortage? Yes. Are people leaving a profession? Yes. Oh man. So, what does that create? All kinds of challenges. Are we now dealing with less experienced people trying to fit into a system" (Levi Year 2 Final Interview)
Standardized Testing Pressures	Particular focus to testing in subjects such as ELA and Math, over science which leads to lack of teaching and learning science	"...It's always been hard to find time in science, because ELA and math dominate, and they always have and always will" (Otto Year 1 Midpoint Interview).

Second, once the codes for internal and external barriers were determined, the accountability partner and I selected two segments of data from each of the four distributed leadership dimensions to code together using the internal and external barriers deductive codes. We reviewed each segment of the data together and identified if there were internal or external barriers that surfaced from the segments of data.

Next, the accountability partner and I reviewed and applied the internal and external barrier deductive codes to the segments of data that best represented the content of the segment. After the initial pass of reviewing and applying the detective codes to the chosen segments, the accountability partner and I refined the codebook. For example, an external barrier originally had a code for administrative priorities which defined administrators focusing on; district mandates, test scores, school improvement goals (SIP Goals), and state goals. As the accountability partner and I coded together, we realized that this code needed to be refined to administration/policy priorities to encompass; "focus" on particular items/subjects based on district mandates, state mandates, SIP goals, and standardized tests.

Reaching coding reliability was the last step in this phase of data analysis. The accountability partner and I worked together to code one more segment for internal and external barriers for each of the four distributed leadership dimensions. We talked through the segments of the data to decide if we had consensus with the internal and external codes. After coding for internal and external barriers together, we used a randomizer website to select two more segments of data from each of the four distributed leadership dimensions to code for internal and external barriers independently. After individually coding the same segments, we looked across their segments for adjudication. We were able to reach reliability of seventy-five percent agreement for the internal and external barriers coding. Once reliability was reached, I finished internal and external coding for the rest of the data segments for each of the dimensions of distributed leadership.

Phase Three and Four: Creating Cases for each STL to Compare and Contrast

Once the data were segmented and coded for internal and external barriers, I began to read through all the segmented, coded data for each STL. I looked for patterns and themes in the ways STLs were making sense of their roles through a distributed leadership lens and the internal and external barriers STLs were naming within their localized contexts. I looked at each dimension of distributed leadership for all interviews for each STL and created detailed memos based on the internal and external barriers the STL surfaced for each dimension. I created detailed memos for each of the dimensions to determine themes across the varying contexts. These themes allowed me to determine how STLs are making sense of their roles and the ways in which they leveraged the four dimensions to better understand their localized contexts to attend to the internal and external barriers they are facing within elementary science reform efforts. I then used each distributed leadership dimensions memo and compared and contrasted across the case study to enhance understanding of how STLs strategically utilized and articulated their response to attend to barriered within reforms. Memos helped me to create my full case studies for each STL. The case studies described how each STL leveraged the four dimensions of distributed leadership to attend to internal and external barriered within their localized contexts. Once the case studies were written, I did a cross analysis of all STLs.

Reliability

In this qualitative case study, reliability was ensured through a collaborative process involving an accountability partner and myself to achieve an interrater reliability rate of 75% for both segmenting and coding of the data (Merriam & Tisdell, 2016). The research partner underwent extensive training and familiarization with the study objectives, research questions, and qualitative data analysis procedures. Initially, the researcher and accountability partner collaboratively segmented the data and then coded subsets of the data segments for each of the four dimensions of distributed leadership to compare interpretations, resolve discrepancies, and refine the segmenting and coding process. There were two instances where reliability needed to be reached (1) segmenting data by the four distributed leadership dimensions and (2) coding segmented data for both internal and external barriers. Reliability needed to be reached to ensure the research was consistent, credible, reproducible, unbiased, high-quality, ethical, and useful for informed decision-making. Reliability was described above throughout the segmentation and coding of the data (Merriam & Tisdell, 2016).

Validity

In this qualitative study investigating how elementary STLs leverage the four distributed leadership dimensions (setting direction, redesigning the organization, developing people, and managing curriculum) to address internal and external barriers, validity plays a crucial role in ensuring the trustworthiness and credibility of the research findings. Validity in this context refers to the extent to which the study accurately captures and represents how elementary STLs understood their roles within their localized contexts to attend to the varying internal and external barriers. To ensure that validity was properly met, several strategies were employed to enhance validity throughout the research process.

The first strategy was the selection of the participants. The participants were carefully considered to ensure that they possessed relevant experiences and insights related to elementary science reform efforts. Purposive sampling was employed through the STL applications for year one and two of the larger study to determine which STLs supported elementary science and educators. This helped to ensure that the data collected was relevant and representative of the population of interest.

Secondly, the use of semi-structured interviews as the primary data collection method allowed for in-depth exploration of participants' perspectives and experiences. The interview protocol was developed based on a thorough review of the literature and consultation with researchers, museum staff, and principal investigators (PIs) on the grant to ensure that the questions elicited rich and detailed responses relevant to the research questions and gaps in the literature (Merriam & Tisdell, 2016). Additionally, probing questions were utilized to encourage participants to elaborate on their responses and provide nuanced insights.

Lastly, during data analysis, multiple strategies were employed to enhance validity. Thematic analysis was conducted to identify patterns and themes within the data, with careful attention paid to the consistency and coherence of the findings to compare and contrast across the STLs.

Trustworthiness

Trustworthiness refers to the credibility, transferability, dependability, and confirmability of the research, all of which are essential for establishing the validity and reliability of the study. To enhance trustworthiness, several strategies were implemented throughout the research process.

Credibility

In order to establish credibility for this study, the researcher utilized triangulation of the data through peer review and other data sources. Through the use of multiple data sources to collect information, the researcher was able to compare data across the different sources to confirm or disconfirm findings within the data. Peer checks helped establish this credibility to ensure that the data was collected and analyzed accurately to eliminate any biases (Merriam & Tisdell, 2016).

Transferability

Transferability was addressed by providing a detailed description of the research methodology, including the sampling strategy, data collection procedures, and data analysis techniques. This allowed my readers to assess the applicability of the findings to other contexts and determine the extent to which they can be generalized.

Confirmation through Reflexivity

Reflexivity was another method used to ensure credibility for this study (Merriam & Tisdell, 2016). It is important for the researcher to address and disclose potential biases, beliefs, and assumptions within the data and this study (Merriam and Tisdell, 2016). To address personal beliefs and potential biases, it is important to note as the researcher, that I have vested interest in creating an environment for K-6 settings to equally distribute leadership through a collective, supportive, and collaborative manner where individuals feel a sense of belonging to enact leadership roles to promote and enhance science education within their organization. Therefore, it is important as the researcher to recognize my own biases and experiences so I do not skew or form hypotheses that could create the potential for the study to lose credibility.

Finally, reflexivity was emphasized throughout the research process, as I continuously reflected on my own biases and assumptions to minimize potential sources of bias and enhance the credibility of my findings. By employing these rigorous methodological strategies, this study aims to ensure the validity of its findings and its contribution into the ways elementary STLs leverage distributed leadership to address internal and external barriers in their localized contexts to respond to science reform efforts.

By employing these strategies to enhance trustworthiness, this study aims to produce credible, reliable, and meaningful insights into how elementary science teacher leaders leverage distributed leadership to address internal and external barriers in their practice.

Consistency

Qualitative research is not easily replicated due to the nature of the study as it is hard to create the exact same study due to different participants and contexts (Merriam & Tisdell, 2016). To ensure that a qualitative study reaches consistency, triangulation, peer reviews, and reflectivity of the researcher must be addressed through the use of memos and data audit trails (Merriam & Tisdell, 2016). In this research study, data analysis was well audited, memos were used and reviewed by peers, and triangulation across data sources was used to ensure that research and analyses were dependable (Merriam & Tisdell, 2016). Peer checks were done with my advisor who was a principal investigator on the Spanning Boundaries project as well as a fellow graduate student who had knowledge and understanding of the research study. Together we looked across each piece of data used in this dissertation, and we coded it together to ensure we are aligned and reached reliability. Once we coded together, we coded the rest of the data independently and then checked for agreement.

Affordances and Constraints of this Research Study

This study will add to the literature base in regard to defining and describing the relationships, practices, skills, and knowledge of STLs and how they attend to the internal and external barriers across varying contexts within science reform efforts. Using the conceptual framework of distributed leadership allows for an organization to leverage the expertise of STLs to support elementary educators and attend to the various internal and external barriers which in return leads to improvement within an organization (Harris, 2007; Spillane et al., 2004). This particular study focused on the four dimensions in which distributed leadership can be practiced within organizations. The following practices include: (1) setting direction, (2) developing people, (3) redesigning the organization, and (4) managing instruction (Firestone & Martinez, 2007; Leithwood et al., 2007). Analyzing data within these practices provided insight into how distributed leadership allowed for members to collectively engage in shared, emergent decisions within science reform efforts specifically within elementary schools (Bolden, 2011; Gronn, 2000).

One constraint of this study is the small sample size of STLs, which can make the findings difficult to generalize to a larger population. Additionally, another constraint could be due to the nature of the sampled STLs and their participation in a research practice partnership between a university and a teacher leader network within a museum context, which could create potential for bias to occur. Bias could occur because STLs from this sample are currently receiving other support(s) that may contribute more to their understanding of teacher leadership and science teacher leadership in comparison to teachers who do not have access to this type of network. Therefore, there could be some skewed data due to potential affordances provided by the network as opposed to others who do not have this type of support and resources to draw from. This could make the study hard to generalize to a larger population.

Summary of Chapter

This case study analyzed data from various sources (STL applications, semi-structured interviews, participant chosen artifacts, actor network maps, science journey maps, and STL role identification activity) through a distributed leadership lens. This study adds to the literature base in regard to researchers understanding how STLs leverage necessary dimensions of distributed leadership to attend to localized barriers in regard to science education. Specifically, this dissertation defines what STLs are naming as internal and external barriers and how they are responding to these barriers within their localized contexts to respond to elementary science reform efforts. Following this chapter, are the findings of this research study.

CHAPTER IV: FINDINGS

Introduction

When it comes to science teaching and learning, elementary schools are unique entities and significantly differ from middle and high schools (Wenner, 2017). Due to elementary schools' unique needs this multiple, embedded case study was conducted and draws on literature from distributed leadership and science teacher leadership. A review of the literature yielded a common theme regarding elementary science education and the need for elementary students to engage in opportunities to learn science as it builds a foundation centered around experience and knowledge that students can build upon in middle, high school, and beyond (Jirout, 2020; National Research Council [NRC], 2007). However, elementary science researchers have found that science teaching and learning is limited or non-existent due to internal and external barriers that prevent the implementation of effective science instruction. In order to better understand supports necessary for elementary science education this study examined how STLs in district and county level positions in a large NGSS state understood their role in science reform efforts utilizing the four dimensions of distributed leadership (setting direction, developing people, redesigning the organization, and managing curriculum) to address internal and external barriers to science reform. I conducted my research through a case study using six participants. The participants explained through their interviews how they leveraged the dimensions of distributed leadership and uncovered how they understood their roles in their localized contexts and organization levels. Therefore, my findings add to the literature about why STLs are an important mechanism in addressing internal and external barriers to science reform in elementary settings.

This study was driven by one overarching research question:

How do district/county level elementary STLs who participated in this study understand their role utilizing the four dimensions of distributed leadership to address internal and external barriers to science reform?

Two sub-questions were created to help clarify how data was analyzed and interpreted to answer the overarching research question. The sub questions included:

a) What are the commonalities and differences in the internal and external barriers attended to by district/county level elementary STLs within the four dimensions of distributed leadership?
b) What variations exist among district/county level elementary STLs in the enactment of distributed leadership specifically focusing on the four dimensions; setting direction, developing people, redesigning the organization, and managing curriculum to attend to elementary science reform efforts?

The findings of this case study reveal distinct patterns in how STLs understand their roles leveraging the four dimensions of distributed leadership (setting direction, redesigning the organization, developing people, and managing curriculum) to help navigate internal and external barriers within their localized contexts.

Each STL in this study worked in a large NGSS state where varying educational organizational levels aimed to work together for the best interest of students, teachers, schools, and science teaching and learning. The levels in which STLs could work were at the state level, county level, and local level which I refer to as the district level based on interviews and data from the research. The state level work oversees the overarching pillars that enable an educational system to function. These pillars include determining funding, enacting policy, and paving the way for the regulations of a sound science education (Merced County Office of Education, n.d.). The county level mirrors the work of the state, but employees work with districts to ensure that a quality science education is being provided to students through assistance in attending to their mission and visions for science education within the districts and schools (Merced County Office of Education, n.d.). The local level which is referred to as the district level in this dissertation revolves around ensuring daily school functions are under wraps and science education is taking place in classrooms (Merced County Office of Education, n.d.). Together, these three organizational education levels work to ensure that students are privy to science teaching and learning.

Maxine - Relaunching Science Teaching and Learning Study

Maxine was a district-level STL who wanted to meet science teachers where they were and develop them to feel comfortable teaching science, planning science, integrating science into their classroom instruction, and taking NGSS seriously. However, external barriers such as administration and policy priorities that focused more on ELA and math posed challenges within her district and the ways in which educators prioritized and viewed elementary science. Due to these external barriers in regard to instructional priorities, Maxine was faced with several internal barriers. Maxine worked to address internal barriers such as increasing teacher science content knowledge, teacher science pedagogical content knowledge (PCK), and teacher beliefs about science teaching and learning.

To attend to the internal barriers of increasing teacher science content knowledge, science PCK, and teacher beliefs Maxine leveraged her ability to create a “Relaunch” professional development that was used to develop people and manage curriculum within her district. To ensure she was helping develop her teachers in the right areas, she sent out surveys to gather data to determine the areas they felt they needed the most support. From there, she worked with teacher leaders in her district to design, create, and launch professional development that supported the needs of science education, specifically elementary science within her district.

Internal and External Barriers

Maxine set a direction for her organization to work towards teachers feeling comfortable to teach science, plan science, integrate science into their classroom instruction, and take NGSS seriously. Maxine had been working on how to support teachers to get on board with NGSS as she still heard, "'NGSS too, shall pass.' I'm like, 'No, it's not passing.' I would say that's probably what I'm grappling with the most, and then, how do we make it, so it's not overwhelming" (Maxine, Year 1 Midpoint). This statement displays the internal barrier of teacher beliefs towards science, specifically NGSS. Maxine knew that in order to overcome teacher beliefs about science, she needed to figure out where teachers were struggling and determine the best ways to develop teachers in her district. Specifically, how to increase the teachers' science content knowledge and science pedagogical content knowledge.

However, teacher beliefs about science were not the only barrier that Maxine faced with elementary education in her district. Maxine also faced administration and policy priorities that created an overarching barrier that played into the internalization of science in classrooms. Science was not viewed as a priority in her district like ELA and Math. In order for science to be seen as a priority and at the same level as the other core subjects, Maxine knew she needed administration to be on board as well. Maxine often found herself reflecting, "I think probably one of the biggest questions that I ask myself is, how do I effectively work with our district administrators and leadership that's above me to be able to help get science to be a priority" (Maxine, Year 2 Final Interview). There were many administrators who were still not on board with science as a priority and added to the reasons elementary science was taking the back burner.

Leveraging Distributed Leadership

To address the external barrier of administration and policy priorities in regard to making science a priority Maxine knew she needed to set a direction for her organization to see science in the same light as ELA and math. To do this, first, Maxine asked herself questions about partnering with administrators,

> So how do I help get this to be more of a district initiative and prioritize science instruction? And how do I help administrators understand that it's more than just a science experiment every once a month or every other Friday? So, I feel like if I can get more time with district leadership, that may help to get them to talk about it with their staff. (Maxine, Year 2 Final Interview)

However, getting more time with district leadership called for a redesign of the organization and Maxine was not at a level within her district to call the shots and schedule meetings with those above her. Therefore, Maxine focused her efforts on things she could control and that was supporting the adoption process for their new science curriculum and supporting science teachers. Specifically, Maxine knew that she could manage and oversee science curriculum and she could provide specific support and professional learning opportunities to develop teachers within her district.

Maxine leveraged the distributed leadership dimension of managing curriculum at the start of her district's elementary science curriculum adoption by supervising and coordinating the curriculum to ensure it aligned with reform efforts and district initiatives. Maxine worked collaboratively with a group of teachers who helped pilot the new science program and provided extensive feedback on the strengths and next steps of the curriculum, to determine how well it encompassed and supported a three-dimensional approach to teaching and learning science. To ensure there was thoughtful feedback on the curriculum adoption, Maxine created a rubric that assessed the curriculum and its ability to attend to the three-dimensions of NGSS. She shared,

> So, it's really looking at the three dimensions of NGSS phenomena. The three dimensions and then program design […] And then, we have teacher support; kind of board room support, and then assessment, and then equity and social context[…]this seems to condense it all in a way that we can really look at these key pieces, and then asking them to come up with evidence to support each thing (Maxine, Year 1 Midpoint Interview).

Looking closely at the materials and resources was necessary as Maxine knew there was a need in her district to move away from superficial materials to materials that aligned and supported NGSS. Leveraging the concept of managing curriculum allowed Maxine to ensure that her district used resources that promoted critical thinking and were applicable to the real world.

Maxine's efforts to manage the resources used to support curriculum in her district specifically addressed the barrier to teacher beliefs, "but this is what we have always done". This was particularly important because Maxine knew she needed to develop her teachers to see how resources support and connect science learning for students which was a shift from "pretty colored worksheets". Working to find appropriate resources and attend to the required shifts in prior beliefs called for intentional planning and next steps, Maxine stated,

> I feel like it's creating a way of vetting materials in a way that's much different than what we used to do. Even when I went through this process with elementary, they would just want to say things like, "We like the color......these things look fun and..." So, it's trying to get away from the superficial stuff into what [...] Is it helping kids figure out science

> concepts or is it just one and done activities that are not leading to that next step (Maxine, Year 1 Midpoint Interview).

The superficial worksheets needed to be replaced as they did not provide students with an equitable science education that promoted critical thinking skills. Maxine felt very passionate about the resources teachers were using to support learning, because the worksheets being shared, or resources being used were the interactions that students had in science and ultimately became the way they came to view science. Therefore, Maxine worked to develop her teachers to understand the difference between superficial resources and resources that pushed students to extend their learning. Through coaching, she emphasized the importance of choosing resources that fostered critical thinking and facilitated meaningful discussions in science. By nurturing teachers' ability to make informed choices, she ensured students received equitable science instruction that aligned with the three-dimensional aspects of NGSS.

In order for students to have an equitable education, Maxine worked hard to create a space for science within her district. She knew that teachers needed support to effectively implement science instruction so that equitable opportunities for all students to participate in high-quality instruction were available. To support these efforts, Maxine and her team created science learning opportunities for teachers and tailored the professional learning to support elementary science needs within her district.

> In the past we were trying to meet people where they were at, but they were all off. It was just so different that we are just trying to put out a lot of fires. And I feel like we're still putting out fires this year, but we've been trying to be more strategic about the way that we are doing that. And just for example, we had a, we called it a relaunch professional learning with our elementary science teachers (Maxine, Year 2 Final Interview).

The relaunch professional learning was a two-day workshop created to support elementary teachers. Seeking to develop teachers, these sessions were strategically planned around the new program adoption and other science specific needs elementary teachers were asking for. The relaunch professional development provided an opportunity for Maxine to determine where elementary science teachers' development was at collectively to help her strategically plan the best ways to develop them. While there still were many fires to put out, Maxine and her team were strategic in planning and attending to the science needs of their teachers. Maxine's statement below describes the intentionality behind planning and implementing the relaunch professional development,

> Things that we are hearing over and over again from what folks needed, the idea of, "Well, I don't know how to manage the kits and hands on things or how to put kids in groups to do messy science. And then what does sense making look like? How do we organize our science instruction around phenomena-based approaches because that's the way that our new adopted curriculum does as well." And then there was always the trade off, "Well, I don't have time for science because I have to teach reading and how do we infuse the two so we can free up some time for science?" So that's how we identified them (Maxine, Year 2 Final Interview).

To also support the relaunch professional development sessions, teacher leaders who had already piloted and critiqued the program presented at the sessions and circulated during planning time. This was an intentional support planned by Maxine to help develop her teachers as she knew that the teachers who piloted the program could help support and plan for the questions and concerns teachers might have around implementing the new curriculum. Below is the professional learning schedule Maxine shared from the 3rd-5th grade Relaunch professional development.

Figure 3. Relaunch Professional Learning Agenda (3rd-5th grade)

Thank you for participating in our Twig Science relaunch PD. We hope this day is helpful for your planning and implementation of the Twig Science curriculum. **Please refer to your name tag for your customized schedule**. You will need to sign in at the beginning of each session.

Resource Document: https://bit.ly/Twig-Relaunch-PD-SJUSD

Time	Activity / Session(s)	Location(s)
8:30-9:25	Introduction to Twig Science (Facilitated by XXX and XXX)	C209
	Integrating Twig Science and ELA (Facilitated by XXX)	D209
	Hands-on Learning in Twig Science (Facilitated by XXX)	D207
	Sensemaking and Inquiry in Twig Science (Facilitated by XXX)	B208
9:30-1025	Integrating Twig Science and ELA (Facilitated by XXX)	D209
	Hands-on Learning in Twig Science (Facilitated by XXX)	D207
	Sensemaking and Inquiry in Twig Science (Facilitated by XXX)	B208
10:30-11:25	Integrating Twig Science and ELA (Facilitated by XXX)	D209
	Hands-on Learning in Twig Science (Facilitated by XXX)	D207
	Sensemaking and Inquiry in Twig Science (Facilitated by XXX)	B208
11:30-12:30	Lunch	On your own
12:30-3:20	3rd Grade Planning and Collaboration (Facilitated by XXX and XXX)	D209
	4th Grade Planning and Collaboration (Facilitated by XXX and XXX)	D207

	5th Grade Grade Planning and Collaboration (Facilitated by XXX)	B208
3:20-3:30	Closure and Feedback	

***Some of the sessions were led by TOSA's who were able to pilot the program. These TOSA's were asked to present and support teachers during thor planning sessions as they have had experience with the curriculum and they would be able to answer questions that the teachers had about challenges, adaptations and anything else regarding the curriculum.**

A similar agenda was in place for the TK-2 teachers and TOSA's also presented and were present during planning sessions for the teachers. They also had a language development portion for the TK-2 sessions.

The professional learning sessions were strategically created and planned around needs expressed by the teachers in her district. Maxine, her team of TOSAs, and science teacher leaders from TK-2 and 3rd-5th grade planned and led the professional learning for teachers. Maxine knew it was important to ensure that all teachers received the introduction session of the program in order for the other sessions to make sense, and for NGSS teaching and learning to make sense. Therefore, there was one introduction session to kick off the professional learning. From there, teachers received a survey with session choices. Maxine shared, "We asked them to fill out a form in order to participate, a Google form, and we checked, we had them select first choice, second choice, third choice, fourth choice, fifth choice" (Maxine, Year 2 Final Interview) and strategically, they tried to provide participants their top three choices.

Customizing sessions according to the needs voiced by elementary teachers and granting them the freedom to select the sessions they felt were most beneficial helped to address internal barriers in regard to science content knowledge and science pedagogical knowledge hopefully leading to more confidence in teaching science. These sessions facilitated teachers in comprehending science concepts within the NGSS framework, acquiring effective instructional strategies for classroom implementation, and knowledge of the curriculum resources as well as other science resources. The external barriers this relaunch professional development attended to were opportunities for teachers to have professional learning and how to leverage more time for science as there was a session to support the integration of science and ELA. Following the sessions, teachers also got to participate in grade level planning. Maxine shared,

> They had the opportunity to participate in three, one hour morning sessions and then they got to do grade level planning supported by folks who have really tried it out this first year. All of these three teacher leaders as well, they were also pilot teachers (Maxine, Year 1 Midpoint Interview).

Considering the implications of NGSS for science education and acknowledging the distinct scaffolds for learning in grades TK-2 and 3-5, Maxine created two cohorts of teacher leaders and facilitated two separate relaunch professional development sessions, tailored to each group's specific needs. Maxine acknowledged the importance of separating TK-2 and 3rd-5th grades into distinct sessions due to the varying needs and challenges within each scaffold. As she stated, "And the day before that we had TK one and two. So, we had a different set of leaders, teachers to provide support as well" (Maxine Year 2 Final).

At the conclusion of the Relaunch professional development, Maxine and her team solicited feedback. Specifically,

> We solicited feedback at the end, "What support do you need, do you anticipate needing or do you see needing?" And trying to get as much, "What can we do to continue this so it's not a one and done so that we determine best practices that are going to meet the needs of our folks (Maxine, Year 2 Final Interview).

Leveraging this feedback, Maxine began to think ahead about future professional learning opportunities for teachers she could potentially provide even if it had to be a Saturday because she did not feel like she was able to completely support teachers with all the shifts, newness, and teacher needs. Maxine shared,

> We just had a lot of newness and trying to support shifts to equitable NGSS science practices where students are engaged in sense making, and trying to help teachers work together to talk about it and support them because otherwise they just are in their classroom doing their own thing, and it either feels overwhelming or for folks that have just been doing what they've always done, it's too difficult to make a change. So, I feel like the opportunity to bring folks together and use those resources trying to implement new adoption, but I feel like the key piece is making it feel like it's accessible, meaningful for kids, and helping them see the impact that they're able to make (Maxine, Year 2 Final).

While Maxine was able to provide support to elementary teachers based on needs that surfaced from them, she recognized that there is still a lot of work to be done for supporting teachers as well as getting administration and upper leadership to prioritize science. Although Maxine might not feel like everything came to fruition, she did listen to teachers and she was able to provide time for them to learn, plan, use resources, and collaborate with one another.

In regard to leveraging distributed leadership, Maxine aligned her efforts with the overall direction of her organization to prioritize science and created the relaunch professional development to support these efforts and ensure science was being taught daily. Gathering feedback from multiple stakeholders within her organization she was able to determine where the biggest areas of need were for teaching and learning science. Leveraging the knowledge, experiences, and skills of her science teacher leaders who piloted the new science adoption curriculum she worked closely with them to plan sessions centered around science needs identified by the teachers. After the completion of the relaunch professional development, Maxine was already thinking ahead and setting new goals to get more administrators and upper-level leadership to prioritize elementary science, as well as how to provide continuous professional learning that built upon the initial relaunch professional development. Maxine dedicated her work to address the internal barriers of improving teachers' science content knowledge and teachers pedagogical content knowledge as well as attending to the external barriers of administration and policy priorities in hopes of being able to provide equitable science experiences for all students, while meeting teachers where they are to implement effective science instruction.

Otto - New Teacher Learning and Development

Otto was a district level STL who reflected on his own experiences as a science teacher to support teachers in his district to make science a regular practice in their classrooms. Specifically, he recognized that his biggest influence was with new teachers. In order for science to become a regular practice in classrooms, Otto had to find ways to address external barriers such as time allocation for science teaching and learning, time for science professional learning opportunities and system constraints. Due to these external barriers in regard to system constraints pertaining to the number of science coordinators in comparison to ELA and math, Otto had to be very strategic with his time to ensure he was supporting his teachers effectively. These external barriers also aided in Otto working to address the internal barriers of increasing teacher science content knowledge and teacher science pedagogical content knowledge.

To attend to the internal and external barriers, Otto leveraged his connections within his district to identify new teachers to support and develop. Due to being in a large urban district that served a large number of teachers, Otto worked closely with administration to identify new teachers who needed support. With these recommendations, he provided office hours, cadre meetings, and Nearpod professional development with an emphasis on science to support these new teachers to understand and implement science curriculum. Levering the dimensions of developing people and managing curriculum, Otto worked to provide thoughtful learning opportunities that reflected teachers' needs as well as his reflections of what he wished he had received when he was a new teacher.

Internal and External Barriers

In order for science to become a regular practice in classrooms, Otto recognized that there were external barriers that needed to be addressed. Particularly, system constraints as Otto reflected on the shifts science encountered with the number of coaches/coordinators in comparison to other core subjects. Otto shared that when he was first a science coordinator for his district there used to be a science coordinator for elementary and one for secondary. However, "That was back in 2007" (Otto Year 1 midpoint Interview). In 2007, Otto left his position as a science coordinator to go back to a school site for a little bit, and when he returned to this position there were no longer two specialists (one for elementary and one for secondary), instead there was one science coordinator who now served K-12 and took on the role as STEAM coordinator. Otto reflected on the past and recognized that science education faced system constraints within coordinator positions which also led to limited support to address internal barriers and support teachers. Otto shared the following statement which supports the external barrier of system constraints that he was faced with,

> "It's always been the case. We always, for the longest time in Beach County, elementary and secondary ELA and math have had their own coordinator. For health, we just have one person in the whole district who's overseeing health. Depending on the priorities and

> how important, and the testing, of course, right? We have lots of interim testing and of course there's state testing in math and ELA and we have very little of it. Of course we have the CAST for science. But we don't have any interim testing for that. So, there's less of a light being shown, I think, on science" (Otto Year 1 Midpoint Interview).

Unfortunately, because science is not as heavily tested as other core subjects, districts prioritize allocating more coordinator positions for ELA and math. In return, time for teaching and learning science is limited. As a district STL, and having similar experiences, Otto's work prioritized the supporting teachers, specifically new teachers with the daily instruction of science within their classrooms.

Otto worked to make science more of a regular practice within his organization. Addressing internal barriers such as increasing teacher science content knowledge and science pedagogical content knowledge Otto provided zoom sessions, office hours, and cadre meetings to support teachers to look at the standards, materials, and learn how to use interactive slide decks that were available for teachers to use. Through zoom sessions offered two times a week for two house, Otto details how he and he team support teachers with science instructional needs,

> We put together a 22-day curriculum for the teachers to use. 22 days of slide decks that are interactive. There are prompts for the teachers to lead discussions with students […] The first hour is a whole group and the second hour is a small group. So, we've decided to use the slide decks to facilitate these large group discussions and then getting them into small groups to get them to talk more in a smaller, safer environment. (Otto, Year 1 Midpoint Interview).

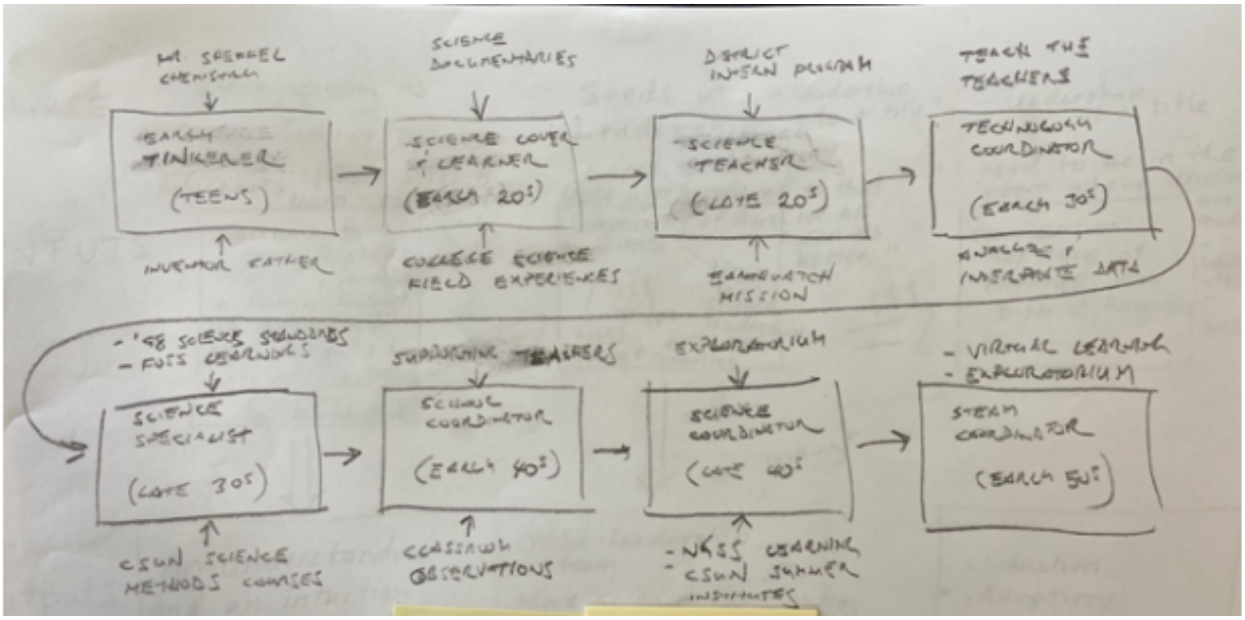
These zoom sessions were created for teachers to see how to model science teaching practices using materials that they could easily use in their classrooms. Then, Otto also embedded time for teachers to work in small groups to potentially discuss and ask their peers questions that revolved around science.

Leveraging Distributed Leadership

Otto wanted teachers to feel comfortable teaching science in their classrooms and making it a regular part of their daily instructional schedule. For this to happen, Otto knew he needed to provide intentional support to develop teachers and manage curriculum to ensure that best practices were being used in science classrooms. In order to ensure that the supports he provided were effective and served those who needed the most support and development, he reflected on his own personal experiences as a science teacher through the science journey map activity. This particular activity allowed Otto to pinpoint new teachers as his area of focus. The reason Otto identified the new science teachers as a focus was because he remembered what it was like when he was a first-year teacher. Based on his own personal experience as a new teacher, Otto shared the following reflection when describing his journey map,

> Well, I think I've become more empathetic over time and understanding. You know, thinking about my own journey and how I'm an incremental learner. Over time, it's taken some steps to get to where I am today. So being empathetic with new teachers. I think I'm a lot more empathetic now. Now that I have the perspective of looking back and seeing how I struggled as a new teacher, it took some time to get good at being a teacher and being a science teacher, so I've increased my empathy over time (Otto, Year 2 Final Interview).

Figure 4. Otto's Journey Map; Reflection for Choosing New Science Teachers as a Focus



Reflecting on his previous experiences, Otto expressed his passion for coaching and that a coach to him meant helping them (teachers). This personal reflection served as an important structure for the opportunities Otto created to develop teachers because when he was a new teacher, he did not feel he got all the support necessary to truly grow within the realm of science. Therefore, Otto enjoyed coaching teachers to talk through their problems of practice and providing them support beyond the typical check-in. He specifically shared,

> See helping them talk through their problem of practice, and not being the one to quickly give them advice, but to kind of tease out what they think should be their next move. To empower them, so that I'm not some crutch that they feel like they can lean on (Otto, Year 2 Final Interview).

Otto surfaced the idea that sometimes new teachers might not want to ask for help, or that they do not feel confident asking questions, especially when they know STLs, and other supports had many years of experience. In particular, this resonated with Otto and what he shared when describing his science journey map during his final interview in year two. Based on his own personal reflections and interactions with new teachers, Otto emphasized when names were provided by administration as teachers who needed support, he was strategic with his words and invitations. When inviting new teachers to attend office hours, cadre meetings, or other growth opportunities he worded the invitations in a way, so they did not shy away from the opportunities or feel like they were must-dos. Developing new teachers was a priority for him and he wanted to invite them and allow them to share specific needs they had so he could ensure he provided support and opportunities for them to develop and increase their science content knowledge, science pedagogical content knowledge, and overall confidence.

Recognizing that new teachers might shy away from asking for help, Otto reached out to administrators in his localized contexts to partner with them and provide strategic support to the teachers that administrators identified. Otto specifically focused on developing people, new teachers, to address these barriers, Otto shared,

> Most principals let me know which new teachers at elementary, middle, and high school who are in need of some support, you know, because I serve 120 schools. So, I had to prioritize…so I've been relying on the principals, assistant principals, and the folks who walk into classrooms at some of our bigger schools. I've asked them to recommend teachers (Otto, Year 2 Final Interview).

Partnering with administrators and valuing their input aligned with the dimension of developing people, as it emphasized the importance of investing in the growth and professional development of individuals within the organization. The teachers that were recommended by administrators were not mandated to attend professional development opportunities, but they were offered various supports through Otto's office hours, zoom professional learning, and cadre meetings. The cadre meetings were:

> An opportunity for them (teachers) to share their successes and challenges. And for me (Otto) to provide any updates about upcoming professional development. I love getting them into breakout rooms with a question to respond to, and then just cycling through and getting to talk to them (Otto, Midpoint Year 1 Interview).

Otto recognized that in order to develop new teachers and manage the curriculum to ensure they were getting the right support, he provided opportunities for teachers to share their successes and challenges. Sharing their successes and challenges in regard to science content knowledge, science pedagogical content knowledge, curriculum, and science as a whole, allowed Otto to plan different supports to help manage science instruction and develop their content knowledge and ways to engage students in instruction.

He also used challenges shared by individuals, to help support his work in further developing people. For example, he shared,

> One of the things I've been able to do is pair up some of the struggling teachers with more seasoned teachers at the cadre meetings that I run and get them into breakout rooms, and you know throw out a problem of practice that the teacher's having and to get some help from a veteran teacher (Otto, Year 2 Final Interview).

Leveraging his veteran teachers who he had worked with in his cadre meetings for years also helped to provide support to the new teachers. Having new teachers work with veteran teachers helped them to see that they were not the only ones who run into challenges when it comes to science teaching and learning. In fact, these cadre meetings served as a professional development where individuals were able to share challenges and success, learn from another, gather new ideas to try out new strategies to implement science, and make it a regular practice in the classroom.

When Otto was not providing zoom sessions, cadre meetings, or office hours, he enjoyed coaching and shared that it was one of the things he enjoyed the most. He stated,

> The thing I enjoy the most is visiting classrooms and seeing kids, seeing kids interacting with their teacher and learning about science ideas. That's what I enjoy the most. I get to do that with Levi, and I get to do that with my district as well. That's probably the top of the list. I really look forward to getting into classrooms. Good, bad, or ugly. Sometimes it doesn't go that well (Otto, Year 1 Midpoint Interview).

He went on to elaborate that following the observations, providing feedback, and talking through the lessons getting teachers to reflect was one of his favorite ways to develop teachers. He highlighted the following questions he liked to ask,

> Providing feedback to the teacher and having conversations with the teacher about what was the intention of the lesson. How was the delivery different from what you intended is always a good question to start with? Just thinking about coaching conversations, just letting them talk rather than having me be the one that points out this and that, or did you think about doing it this way? There's always room for that, but I like to start the conversation with that question. How is the delivery of the lesson different from what you intended? And great conversations come out of that (Otto, Year 1 Midpoint Interview).

The previous questions served as a roadmap for Otto to help his teacher think critically about the WHY behind their lessons and their intentions with instruction. These conversations not only supported the development of his teachers, but they also enhanced the instruction and content taking place in classrooms.

In order to ensure that Otto reflected on his own observational skills and ability to support new teachers he worked closely with another group member, Levi. Together, Otto and Levi revisited a coaching continuum that they both had used in the past to identify look-fors in observations for both students and teachers. Specifically, Otto shared that he and Levi had opportunities to observe a classroom via zoom and use the continuum, he shared,

> On two occasions, we went into zoom rooms and watched teachers and students and used the continuum as a way to discuss what we saw. We could place these classrooms somewhere on the continuum whether it bridges across a couple of the columns, which it did in many cases. Engagement kind of flowed from across the continuum, I would say, from active...components on both sides, so are the students participating, are they drifting, or are they avoiding (Otto, Year 1 Midpoint Interview).

This continuum and work with Levi supported Otto to “collect evidence with a little bit more specific learning targets” (Otto Year 1 Midpoint Interview), which supported his coaching conversations and work with developing new teachers. Continuing to reflect and refine his ability to coach new teachers allowed him to ensure he was providing the right support based on the needs observed.

In response to the needs expressed and observed with new teachers, Otto provided tailored learning opportunities focused on familiarizing them with the primary curriculum, as well as potential pedagogical strategies to support the implementation of the lessons. Otto provided both live sessions and zoom sessions for professional development. He detailed the following agenda that spanned over the course of several meetings.

Figure 5. Meeting Agenda for Otto's Live Sessions

Meeting	Objectives for the Session
Live Meeting One	1) Open up Amplify kits. Otto modeled how to open the kits and determine what was in them 2) Otto modeled for new teachers how to prep the kits. He modeled how to get the materials organized and set for the lesson. He then modeled how teachers could pass out their materials. He specifically modeled how teachers could have the kits ready to go on students' desks, or how to call students up to get their kits. The purpose of this session was to inform teachers that the kits take time to prepare. The preparation for these kids takes time and it is something you want to have prepped before you get ready to teach your lesson.
Live Meeting Two	Model Introductory Lesson of Unit(s) Model Lesson one of Unit(s) The purpose of this session was to model how to engage students in the lesson. Otto modeled teaching strategies that could support teachers to implement the curriculum in their own classroom.
Live meeting Three	Otto would hold another session a few weeks later after teachers have had the opportunity to teach at least their own introductory lesson and possibly lesson one. The purpose of this session was for teachers to share out how things went, and where they needed some help. Otto also used this session to offer his assistance to come out and co-teach with them.

Note. This agenda was created based on details provided in Otto's year 2 final interview.

In the third live meeting, Otto offered opportunities for co-teaching. While many new teachers did not take Otto up on co-teaching opportunities, they did continue to come back to his learning sessions. While at times, Otto shared that the teachers were looking for quick fixes, which he understood, he took the sessions to remind them that science teaching and learning takes time. He said he often shared the following with his new teachers,

> This takes practice, you're going to have moments where you feel like it's not working and you're going to want to give up and not you know when you try to get kids to talk to

> each other and no one else at the school is getting kids to talk to each other you're going to. You're going to have a hard time with it, because the students are unaccustomed to that and they're going to act out and it's going to be noisy and you're not going to be comfortable with that (Otto, Year 2 Final interview).

When developing people, Otto recognized the importance of reminding them that change does not occur overnight as a lot of this support was new learning and far different from the experiences that most people had when they were students engaging in science.

When Otto was not working with new teachers, he was working to find a way to garner more time for science professional development. Recognizing the challenge of limited time for science professional development in his district, Otto took an innovative approach to address this issue. Leveraging Nearpod, a technology tool aimed at enhancing engagement, Otto offered targeted training sessions for Nearpod that focused on science. Despite the prevalent prioritization of ELA and math in his district, Otto recognized Nearpod as a valuable avenue to bolster science education while also paving the way for collaborative professional development initiatives spanning all core subjects. In expressing his perspective, Otto remarked,

> I don't get a lot of time with teachers to do professional development on science right now, because our leadership doesn't want to pull them out to do that. It's always been hard to find time in science because ELA and math dominate and they always have and always will (Otto, Year 1 Midpoint Interview).

Although Otto spotlighted science to promote Nearpod, he underscored its versatility across all core subjects. Essentially, Otto managed to carve out time for science professional development while laying the groundwork for broader collaborative professional development efforts that could integrate multiple disciplines.

In summary, Otto effectively employed coaching opportunities and professional learning opportunities to address internal and external barriers within his localized context. Otto partnered with administrators and provided science teaching and learning support to develop new teachers to implement the curriculum and increase their science content knowledge and science pedagogical content knowledge. Levering the recommendations of the principals provided an avenue for collaboration amongst multiple stakeholders within his organization and allowed them to work together to align their support for new teachers. Furthermore, Otto's strategic implementation of science professional development using Nearpod demonstrated adept management of curriculum. With Otto's knowledge of the tool and science content knowledge, he was able to confront the external barrier of time allocation for science based on standardized testing pressures with ELA and math. In navigating these challenges, Otto demonstrated proactive collaboration and innovative strategies, ensuring that science education received the attention and support it needed despite the barriers encountered with science education; specifically, he focused on developing people and managing curriculum. With his focus on developing people and managing curriculum, Otto worked diligently to ensure that science had a place in daily instruction and that his teachers felt supported and comfortable teaching and learning science with their students.

Levi - Creating Retention and Continuity

Levi, who served as a district-level STL, was keenly aware of the challenges surrounding retention among administrators and teachers, which often resulted in educators feeling overwhelmed. When educators feel overwhelmed, daily instruction and functions of classrooms and schools present challenges. Recognizing his pivotal role in shaping the development and practices of both teachers and administrators, Levi prioritized addressing the internal and external barriers contributing to this sense of overwhelm. Among the most significant external barriers was the issue of system constraints, particularly concerning the retention of administrators and teachers. The lack of consistency in personnel posed challenges in maintaining cohesive goals for enhancing elementary science education. In response, Levi worked diligently to address these systemic constraints and establish greater consistency in goals. Concurrently, he focused on addressing internal barriers such as improving teacher science content knowledge and reshaping beliefs about science among teachers and administrators. Levi's efforts were aimed at creating an environment that eased feelings of overwhelm and fostered sustained engagement and growth in science education practices among both teachers and administrators.

To address the internal and external barriers within his organization, Levi began by recognizing the prevalence of overwhelm among educators. Levi took on the role of a coach, providing support and guidance to help alleviate these feelings. Through coaching sessions and collaborative discussions, he empowered teachers and administrators to navigate challenges effectively and develop strategies to overcome obstacles in science teaching and learning. Furthermore, Levi cultivated a culture of "failing forward" within his organization, where mistakes were viewed as opportunities for reflection and growth rather than being viewed as setbacks. By creating a safe space for teachers to experiment, reflect, and refine their practices, Levi encouraged continuous improvement and innovation in science education. In managing curriculum, Levi adopted a strategic approach to aligning goals and objectives across different levels of the organization. By ensuring coherence and consistency in curriculum implementation, Levi facilitated a shared vision for science education that enhanced student learning outcomes and fostered a collaborative learning environment. Through his leadership approach, Levi focused his efforts in developing administrators and teachers while also managing science curriculum to help his organization to feel less overwhelmed.

Internal and External Barriers

Levi focused his efforts to create retention and continuity within his district. In particular, his work sought to attend to the external barrier of systems constraints, particularly working on the retention of administrators and teachers. He stated,

> I work with five administrators. Next year, four of them will be brand new. And the one who has been there, this will only be year two. So that gets me thinking, look at how much continuity we're losing in districts. (Levi, Year 2 Final Interview).

When working within reform efforts, consistency is key as it provides stability and predictability for teachers, students, and administrators, allowing them to develop a clear understanding of expectations and goals over time. This consistency helps establish a foundation for effective teaching and learning practices in science.

Creating consistency is imperative as Levi is tasked with addressing internal barriers regarding teachers' science content knowledge, confidence, and beliefs about science. In particular, “teachers are still demonstrating a fear of doing labs” (Levi, Year 2 Final Interview), and therefore, Levi is meeting his teachers and administrators where they are to become more confident with science education. In particular, he shared,

> We didn't create a specific focus on, it has to be this curriculum where you have to do this much. I think we started with just, "We want you to feel engaged with your kids." Once you start to feel engaged, then you can start to think through, how can I help them to build some skill? (Levi, Year 1 Midpoint Interview).

In navigating the challenges of turnover and building continuity within his district, Levi underscores the critical importance of consistency in educational reform efforts. By fostering stability and predictability, Levi's approach enables teachers, students, and administrators to establish a solid foundation for effective science education practices. His emphasis on meeting teachers and administrators where they are, coupled with a focus on engagement and skill-building, reflects a nuanced understanding of the complexities inherent in promoting confidence and proficiency in science instruction.

Leveraging Distributed Leadership

When working within reforms, the work must be consistent, specific, clear, and strategic. Therefore, Levi worked to create retention in his organization with administration and teachers so there could be continuity and consistency in the work for NGSS efforts. Levi shared,

> One example, and this is we're talking about science education, I work with five administrators. Next year, four of them will be brand new. And the one who has been there, this will only be year two. So that gets me thinking, look at how much continuity we're losing in districts (Levi, Year 2 Final Interview).

Not only is continuity lost due to lack of retention, but administrators are trying to implement new initiatives and “don’t have the background or practice to be able to speak with authority and model with authority” (Levi, Year 2 Final Interview). Specifically, Levi feels that one of the major challenges with retention and vague rollouts stems from being overwhelmed and lack of alignment with goals and initiatives across the system. In order to create alignment and coherence, Levi recognized that he needed to develop the administrators he worked with and coach them in a manner that allowed them to connect science goals and efforts... Levi elaborated,

> And I think this speaks to one of the challenges I see, which is I think our administrators are overwhelmed to a point where they're not able to put in the thought beforehand that leads to more effective conversations (Levi, Year 2 Final Interview).

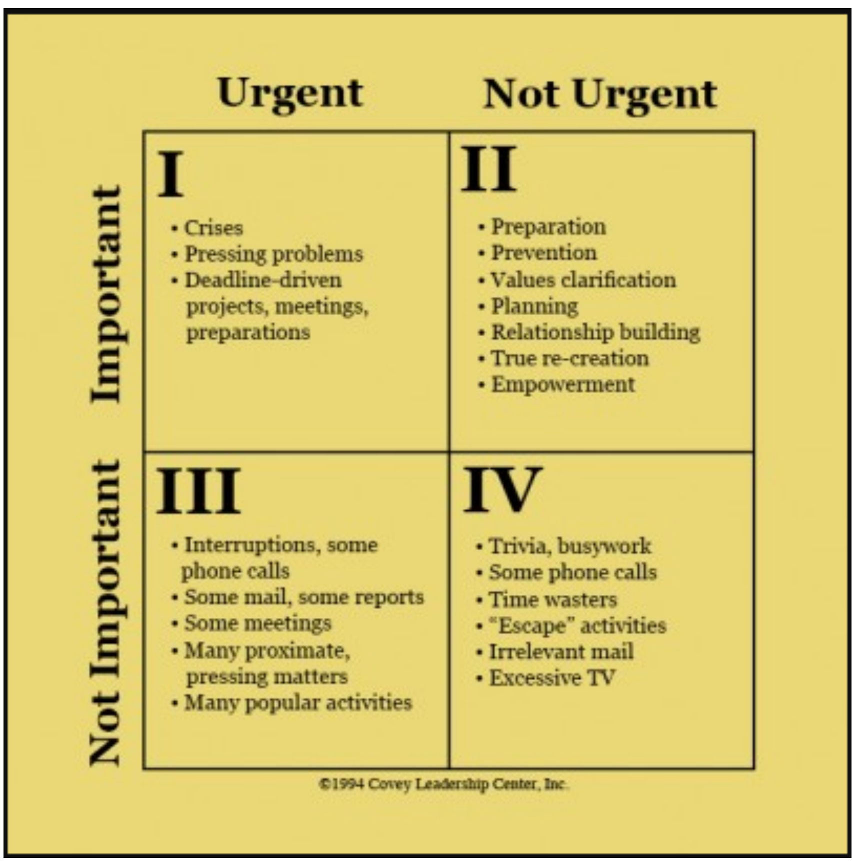
Within working to develop administrators, Levi saw it as his duty to carefully listen and interpret district initiatives, with the goal of reducing the overwhelming feeling experienced by both teachers and administrators. Specifically, he was working to develop alignment for the goals within the organization that he supported. Levi conveyed this sentiment, stating,

> I feel like a translator to me, I'm trying to be a glue. I don't want this system to fall apart, but I can see that it is. I'm going to spend a lot of my time trying to translate that (Levi, year 2 Final Interview).

To support his work, Levi noted on a few monthly PL trackers that he was supporting teachers with curriculum design, and administrators to align goals. On the PL tracker he specifically shared, "Helping teachers examine data, help administration align site, district, and teacher goals as well as a feedback system for teachers' ' (10/08/2020 PL tracker, Year 1). As a district STL, Levi emphasized and demonstrated the importance of translating visions into clear actions, ensuring that the implementation and support of initiatives were not ambiguous. Translating visions into clear actions allowed Levi to develop both administrators and teachers within his organization around a shared idea of enhancing science. Levi developed administrators and teachers by coaching them to align goals within their contexts and across the district so there was no room for interpretation to lead to ambiguity. Ambiguity, Levi recognized, led to frustration among teachers and administrators, potentially resulting in individuals leaving the profession. Levi's work was centered around providing clarity to mixed messaging, continuity, and retention of administration and teachers. Through efforts to align goals, Levi leveraged curriculum to help focus and manage the work within science teaching and learning.

Science education plays a crucial role in shaping the future of our society by nurturing students and equipping them with the skills needed to thrive in an increasingly competitive global economy. However, Levi found that looking at the four quadrants of leadership (Covey, 2004), administrators were often pulled to quadrant one where they were left putting out fires, which meant they did not make it over to quadrant two where they could begin to focus on the improvements necessary for an organization to move forward. Below is a chart from Stephen Covey (2004), that Levi was referencing.

Figure 6. Stephen Covey's Time Management Matrix



Note. Retrieved from "The 7 Habits of Highly Effective People: Restoring the Character Ethic," by Covey, S.,R., 2004, Free Press.

Specifically in Levi's organization science work was located in quadrant two, which required planning, preparation, value clarification, re-creation, and empowerment which was not always attended to. Levi shared his visions to support the development of administration in hopes of moving out of quadrant one (putting out fires) which was very overwhelming and exhausting. Levi shared,

> Oftentimes in a school day, we're left in quadrant one, things are urgent and they're important, so we're constantly putting out fires, we thought. But you can't ever get to improving practice unless you're in quadrant two. It has to be strategic. It has to be thought out. I'd love for us to look at the coach admin relationship as a quadrant two relationship (Levi, Year 1 Midpoint Interview).

Levi recognized that if he could retain his administrators and develop and coach them to recognize when to remain in quadrant one and when to move into quadrant two, he believed that they could begin getting into science classrooms and looking at where instruction was and where it needed to go. Levi elaborated by saying,

> This process is being able to look, to observe teachers with these descriptors, and put it where we've always known it should have been. What is the student doing as opposed to what the teachers do? Is the student asking questions? Are the students making connections? I feel like moving ahead, the more we can change the conversation with teachers from, "Here's what I saw you do." To, "Here's what I saw students doing. What do you think caused that?" The more successful we can be (Levi, Year 1 Midpoint Interview).

Levi acknowledged that developing administrators and teachers through coaching could lead to retention and continuity within the organization. The ultimate goal of coaching is to increase the level of effectiveness which increases outcomes for students, and in this case specifically for elementary science. In order to increase effectiveness, each context, administrator, and teachers must be looked at individually before they can be looked at collectively as all they are uniquely different, develop at different paces, and develop differently as they learn. In order to engage his organization and sustain engagement, Levi knew he must meet his teachers and administrators where they were and guide them through the creation of goals, implementation of new practices, reflection, and openly discuss next moves. Levi determined where his varying contexts were, through a survey that was sent out at the beginning of the year. Levi stated,

> In other words, when we start next year, do we give people the opportunity to reflect on where they are and where they'd like to move? And then use that reflection to have them choose what they want to learn. How are they going to show their success, how are they going to show they grew in that area, and specifically, how are they going to show it impacted kids […] And they have to come back and report on that (Levi, Year 2 Final Interview).

Levi wanted his organization to feel supported and at ease. He was hopeful that the responses from this survey would provide a chance for his administrators and teachers to reflect so he could meet them where they were and support them as they described goals for instruction and future successes they wanted for their students. Leveraging this survey, Levi wanted these responses to set the direction and guide the planning for curriculum and organizational goals. He stated,

> I feel like my role as a coach is not September to June, it's not as intense when the school year starts, but it is more work in the summer. And so today I have a meeting and one of our goals is to think, where did we go wrong? And I don't mean that we're the worst

> people in the world, but what can we fix? And one of the things I personally would like to improve on is I think people feel, whether it's true or not, their feelings are what's reality (Levi, Year 2 Final Interview).

Reflecting on "where did we go wrong", was not meant to be negative, but rather as an opportunity to look ahead and to begin planning for improvements. In Levi's role as a coach, taking these next steps allows him to create new directions for his organizations. In particular, this also provided support for his vision to retain administrators and teachers to continue building on the previous year's successes while planning for next steps. In particular, Levi wanted continuity so he could work with teachers to feel safe to try new things with science curriculum and instruction. Levi described his idea of "fail forward" and growing together. He stated,

> I definitely always have to fail forward. I enjoy the opportunity to teach and fail forward with teachers and just say, "Yeah, I'm happy to come in and we'll try this together and we'll see how it goes." I think that to me is a really valuable thing because I've even noticed with some coaching colleagues, the minute you step out of the room, it's really easy to quickly detach from the challenge of teaching. Then you start to tell people, "Hey, you should do this." But you're not necessarily living that. The minute they think you're not living that, then I think they stop listening. So then the more you can live it and say, "Oh, I did that and it failed terribly, but here's what I learned." I think you keep your credibility that way (Levi, Year 1 Midpoint Interview).

Levi leveraged developing people and managing curriculum to find a way to retain administrators and teachers to create continuity to see NGSS reform efforts through. Levi recognized that he was working against the external barriers of systemic constraints, specifically with the retention of administration and teachers. Due to the barrier of retention, Levi also needed to develop his organization to increase their science content knowledge and their beliefs about science. To address these barriers, he leveraged his ability to coach teachers and administrators to remember the WHY of the reform and not the compliance. Ultimately, Levi worked with his organizations to move from always putting out fires with various in-the-moment issues to moving more into a quadrant two perspective of enhancing and moving the organization to attend to next steps to enhance teaching and learning. With a “fail forward” attitude; together an organization can work together to try new strategies and methods to determine what works best for their contexts through shared visions for science education. In navigating the challenges posed by systemic constraints and administrative priorities, Levi's commitment to coaching for deeper understanding and shifting organizational perspectives reflects his dedication to advancing NGSS reform for the betterment of science education.

Dawn - Sense-Making Leads to Equity

Dawn served as a district-level STL and was dedicated to ensuring all students had opportunities to receive equitable science. While her district focus was centered around equity, science was not always considered a priority or a part of daily instruction. Recognizing the importance of equitable sense-making strategies in science instruction, Dawn specifically targeted her efforts towards supporting new teachers in this endeavor. However, she encountered external barriers in the form of system constraints and administration and policy priorities, due to science not being seen as a priority in elementary schools. Despite this, science education was not always prioritized within the district, posing challenges to implementing equitable instructional practices. Internally, Dawn also identified barriers related to teachers' understanding of science content knowledge and pedagogical content knowledge. Addressing these internal barriers was crucial to promoting effective and equitable science instruction across classrooms.

Through her leadership and strategic initiatives, Dawn aimed to overcome these barriers and foster a more equitable learning environment for students in science education.

To address internal and external barriers, Dawn strategically utilized the dimensions of managing curriculum and developing people within her district. Dawn recognized the need to promote equitable sense-making strategies in science instruction and planning documents with a list of sense-making tools to support teachers in planning and implementing equitable science lessons. These tools aimed to provide teachers with practical guidance and resources to integrate equity-focused practices into their science instruction. Additionally, Dawn focused on developing people by coaching educators on the effective use of sense-making tools and strategies in science teaching. Through coaching sessions, she supported teachers in implementing evidence-based instructional practices while enhancing their science content knowledge and science pedagogical content knowledge. By leveraging these dimensions of distributed leadership, Dawn worked to address both internal barriers related to teachers' skills and knowledge gaps and external barriers such as the need for equitable instructional practices in science education. Through her efforts, Dawn aimed to create a supportive science environment that promoted equitable teaching practices that aligned with her districts' vision for equitable teaching.

Internal and External Barriers

Dawn's district had an overarching direction for equitable practices to be present in all teaching and learning for students. Dawn learned that equity was a large umbrella and there were several barriers in regard to elementary science that she needed to break down to ensure all students were provided an equitable education, specifically for elementary science. Externally, Dawn and her boss were left to attend to the system constraints where teachers felt like science was yet another thing. For example, Dawn shared,

> I think people sometimes feel like you want us to do this, you want us to do this, you want us to do that, and it's all separated. And trying to help people understand like no, it's all connected under this umbrella of equity. We want to have this. So that's kind of I think where I see this kind of going next for me (Dawn, Year 1 Final Interview).

Working within this constraint, several internal barriers surfaced, including teacher content knowledge, teacher science pedagogical content knowledge, and beliefs. Many teachers were feeling overwhelmed with the new curriculum adoption as well as how to approach equitable teaching in all facets of the organization. To attend to this, Dawn and her boss attempted to make science more approachable by,

> To help make it (science) more manageable for them, and make it more doable, which sadly means sometimes going through and kind of really narrowing down which science lessons to teach, because otherwise they're like you expect me to teach science 3 hours a week like that's not happening. So, then they just don't teach science at all. So, trying to make it a little bit more like, okay, teach it for an hour, and if you have more time, you could also do this. (Dawn, Year 2 Final Interview).

Despite the battle for science to be a priority, Dawn did her best to attend to the overarching vision of her district to provide equitable learning opportunities for all students. One way she did this was by providing accessible science lessons for teachers to use and implement in their classrooms. While Dawn might have narrowed down some of the lessons to make science more manageable for teachers, she remained committed to ensuring that these lessons still offered rich learning experiences that leveraged sense-making strategies for students and teachers.

Leveraging Distributed Leadership

The overarching direction in Dawn's district was centered around equity in education. In order to attend to this, Dawn supported science education by setting the direction for her organization to promote equity through sensemaking strategies. She shared,

> I would say that previously when thinking of student sense making, I was looking at it more through the angle of like that's just good practice for how people learn[…]not only is it a good teaching practice, but it attends to the equity piece too, that's a way that we can make sure that those voices are all being heard and that students feel valued and all of that (Dawn, Year 1 Final Interview).

In order to ensure that equity was being attended to, Dawn knew she needed to ensure that the materials and instructional strategies being used by teachers allowed for sense-making to happen. Therefore, she needed to make sure that she was supporting teachers to relinquish power and leverage sense-making strategies that allowed students to figure things out. Specifically, she stated,

> The sense-making piece for students, sometimes is getting lost. It's very focused on what the teacher is doing, and too, wanting to have that sense of control, maybe, a little bit more, and having a hard time letting go and letting students figure things out (Dawn, Midpoint Year 1 Interview).

While science instruction does present high level concepts that require explanation, Dawn wanted to ensure practices began to shift from what the teacher was doing and saying, to more of what the students were doing and saying. In NGSS, student sense-making is an important component and one that needs to be recognized, because students come with different experiences, ideas, and knowledge (NASEM, 2015; NGSS, 2013). Allowing them space to sense-make on their own or with peers allows them to work on their critical thinking skills (NASEM, 2015; NGSS, 2013).

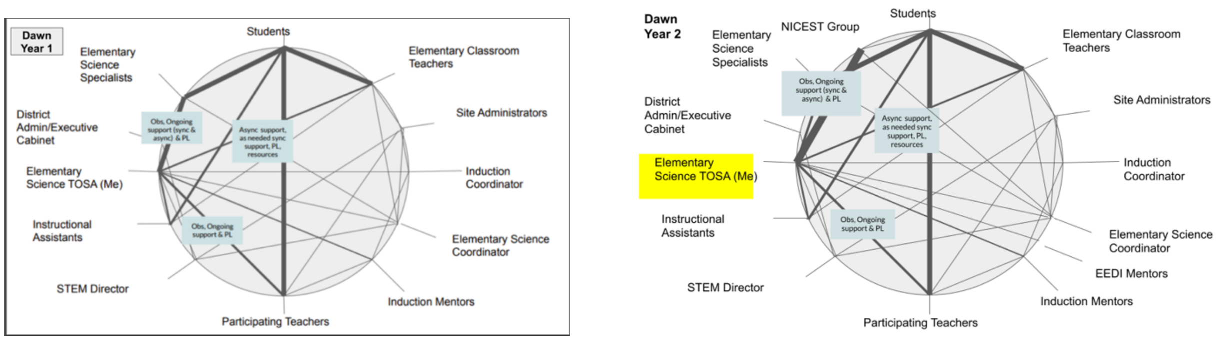
Dawn also knew that she needed to coach teachers to implement proper sense-making strategies in their science classrooms based on the new graduation requirements for science. The new graduation requirements required high school students to take three more science classes than previous years to graduate. Therefore, Dawn recognized that sense-making needed to begin in elementary schools to lay a foundation for students to build upon. Dawn specifically shared the mindset shift that needed to happen for elementary science in hope of working to support the new graduation requirements,

> So, I know my boss has been working on a plan, and so I'm supposed to start helping her with it. If we're going to have students be able to do that in high school, we need to start all the way back in elementary school. So, we need to change this mindset that science is in the same category as PE, or art, or music, or whatever, which are also all wonderful things. Science needs to be considered core. It can't just be, "Oh, just if you have time for it (Dawn, Year 1 Midpoint Interview).

Recognizing that shifts needed to be made and support needed to be in place, Dawn knew she needed to manage curriculum and develop people and attend to the shifts for science education.

In order to ensure that she was supporting elementary teachers to incorporate sensemaking strategies that provided an equitable education for students, she needed to ensure that she was coaching, using the right strategies, and targeting the right people. Leveraging her Actor Network Map (ANM), she mapped out her context and determined where she had the most influence; and that was working with the new teachers in her district.

Figure 7. Dawn's Actor Network Maps (Year 1 Left, Year 2 Right)



Note. Both ANMs identify new teachers as an area of focus, however, year 2 (right side) the line is thicker.

After identifying her target group, she recognized her coaching methods needed to meet them where they were. Meeting teachers where they are allows coaches to embrace their teachers' strengths and next steps. Coaching is a delicate process as coaches are seeking to grow and support individuals. In the realm of elementary science education, it is essential that STLs meet their teachers where they are. Dawn emphasized the idea of meeting teachers where they are by stating,

> Another thing that really has kind of evolved is that you know as much as I might see areas of growth or things that I think are important for them to work on like I need to meet them where they're at like it needs to be something that we're going to make progress with (Dawn, year 2 Final Interview).

Despite seeing other areas of growth, Dawn truly focused on understanding where her teachers' comfort levels with science were and from there worked to plan, coteach, and problem solve lessons and units together. By recognizing and respecting the starting points of her teachers, Dawn was able to build trust and rapport, creating a supportive environment for professional growth and development.

Dawn got to lead new teachers in their professional learning through various methods of coaching and managing curriculum. Together, Dawn and her boss pulled resources and created templates that teachers could use to pick equitable sense-making strategies to include in their lessons. Dawn described the planning document that was created.

> We basically provided the research, some of the tools and strategies they could use for their science talk. And then we had kind of a graphic organizer for them to think and play it out like. Okay. So when I'm doing my instruction here's the talk activity, and I'm choosing it because of this reason…because I'm trying to elicit student ideas, I'm choosing it because I'm wanting them to come to consensus, or I'm choosing it because we're trying to develop a model or whatever, and then they pick the strategy that they're using to support sensemaking (Dawn, Year 2 Final Interview).

While providing a variety of strategies for teachers to use was a great idea, tools are not useful unless teachers understand how to use them and implement them effectively. In this process of managing curriculum and providing a variety of tools, Dawn learned that she had to also develop her teachers to understand how to use these tools and why they supported sense-making for students. She expressed,

> I learned that tools need explanation, and I think they were more effective when there was conversation going on ahead of time. I think it was more effective if we were able to have a pre meeting before doing the lesson, because then it helps you kind of talk things out more beforehand versus after. You're just kind of deconstructing things so I think that was definitely valuable (Dawn, Final Interview Year 2).

This highlights the importance of coaching teachers in using instructional tools effectively, emphasizing the value of pre-meetings to facilitate better preparation and comprehension before lesson delivery. Creating opportunities for teachers to plan their lessons and talk through them with coaches is especially important so that teachers do not feel like they are being done to and left with the feeling of frustration trying to figure out things on their own.

Dawn also emphasized to her teachers that shifting their mindsets to new tools and working to enhance sense-making in their classrooms was something that might not go well the first time. She shared trying things for the first time,

> It just feels clunky when you're trying something for the first time. So really just trying to encourage people like you know don't give up on it like just because it didn't go well the first time (Dawn, Year 2 Final Interview).

Knowing that teachers were working through this, Dawn recognized the importance of her coaching. She knew that in order to develop her teachers, she could not be evaluative. Dawn shared her reflection,

> So, I think you know, kind of going back to what I was talking about before is like really trying to not be evaluative when meeting with the teachers to discuss either before or after, like really trying to work on just asking them questions, and maybe guiding or facilitating their thinking in certain ways. But you know, kind of letting them do the mind work and so that they're feeling they're building their capacity in their tool set (Dawn, Year 2 Final Interview).

When teachers feel like they are being evaluated, they are less likely to try things out as they do not want to fail or let people down. Therefore, Dawn knew she needed to coach and develop her new teachers, but she also needed to be a thought partner for her teachers.

Leveraging the distributed leadership dimensions of developing people and managing curriculum, to address internal barriers to the implementation of sense-making strategies in science education. Dawn coached teachers to understand the tools provided for them and how they could implement them into their science lessons. She provided time for teachers to discuss their lessons before being taught and time to reflect after teaching them. Externally, Dawn and her team confronted systemic barriers to science education, such as graduation requirements and the need for science to be a priority beginning in elementary school. Dawn recognized that the changing landscape of graduation requirements, to include more science classes, necessitated proper support for both teachers and students to incorporate sense-making practices from elementary school onwards. In other words, Dawn prioritized equitable science teaching and learning and worked to make science accessible and present in daily instruction.

Brad - All Science, All Students

Brad served as a county level STL, and much of his work mirrored the work of the state and allowed him to act as a liaison for communicating initiatives and goals regarding elementary science education. With his work, Brad faced external barriers due to system constraints that hindered smooth communication and dissemination of reform initiatives and messages from higher administrative levels to the classroom level. This lack of effective communication left teachers uninformed potentially resulting in disconnect with implementation and what the state and county were looking for. Due to the external barriers, Brad directed his efforts towards overcoming internal barriers by enhancing educators' science content knowledge and science pedagogical content knowledge (PCK). By empowering teachers with greater expertise in these areas, Brad aimed to equip elementary schools with the necessary tools for delivering impactful science instruction. Through his endeavors, Brad sought to bridge the divide between systemic hurdles and classroom practices, striving to cultivate a more conducive environment for science education across the county.

Brad effectively leveraged various aspects of distributed leadership to drive positive change in science education within the county. Firstly, he demonstrated strong leadership in setting direction for his county and the districts he served to work towards creating equitable and student-centered science education for all students. By prioritizing student-focused approaches, Brad ensured that the county's science education initiatives were aligned with the needs and interests of the student population they served. Additionally, Brad engaged in organizational redesign by creating a network for teacher leaders and administrators. This network served as a bridge between different levels of the organization, facilitating communication, collaboration, and shared decision-making to enhance overall science reform efforts. Furthermore, Brad was committed to developing people by establishing networks for teacher leaders and administrators, fostering a culture of professional growth and collaboration. Through these networks, Brad facilitated the exchange of ideas and best practices, ensuring that educators had the support and resources needed to effectively implement science curriculum initiatives. Finally, in managing curriculum, Brad introduced an innovative approach called "name it, verb it, finish it," which integrated science into literacy instruction. This curriculum framework aimed to ensure that science was seamlessly woven into literacy lessons, enhancing students' understanding and engagement in science concepts. Brad's proactive approach to curriculum development and his plans to pilot and share this curriculum model exemplify his dedication to advancing science education practices within the county.

Internal and External Barriers

Brad’s work at the county level entailed prioritizing student-focused and student-centered approaches for science teaching and learning. For this to happen, Brad needed to make sure that science education initiatives were aligned, and goals were properly communicated. With this work, one external barrier that Brad uncovered was working against system constraints. He found that oftentimes, information from the state was only making headway to the county and district levels, but it was not making it into the classrooms. Here is how Brad came to this realization.

Working at the county level, Brad had the opportunity to initiate very similar if not the same initiatives as the state. With the same or similar initiatives, Brad and his team started, "going to these communities of practice meetings at the state level, we'd go to about four or five a year, something like that (Brad, Year 1 Midpoint). These meetings enticed Brad which prompted him to think,

> Well, wouldn't it be great to get information here? We can get it into our leaders by going through our distinct leadership meetings, but how are we getting it into the classroom (Brad, Year 1 Midpoint Interview).

After attending these state communities of practice meetings, the team realized they were getting important information that they needed to share and filter throughout the different levels of their organization (county, districts, schools, and classrooms). However, there was a problem. Brad stated, "We soon realized we had a problem, that a classroom teacher just wasn't getting this information or almost all of them," (Brad Year 1 Midpoint).

This messaging was particularly important as instructional and curriculum moves were being made to ensure NGSS was being taught and taught well. Brad shared,

> And the teachers, the classroom teachers as well, this year we're moving and we're moving from just information about NGSS and so forth to implementation. So, it's all about implementation now. It's like this has been lost since 2013. It's time to move (Brad, Year 1 Final Interview).

Big shifts needed to happen in order to attend to overarching direction to prioritize student-centered and student-focused learning, Therefore, to ensure that students received an equitable science education, Brad committed to addressing system constraints head on to ensure that his teachers had sound science content knowledge and science pedagogical skills to provide equitable instruction to the students that they served.

Leveraging Distributed Leadership

Brad worked in the Instructional and Curriculum (IS) department of the county office. He set a direction for his county, and the districts and schools he served for all students to receive equitable science that was student centered and student focused. Brad likened the direction he set for his county to NGSS' call by stating,

> As a matter of fact, the vision of the next generation science standards is all science, all students. And so elementary kids not getting equitable access to science education and critical thinking skills, not being able to do hands on, and actually learn while they're doing, is kind of non-existent. So, the low hanging fruit would just be to bring it into the classroom (Brad, Year 1 Final Interview).

In particular, Brad was pushing his county, districts, and schools to move from just information about NGSS to actually implementing instruction. However, getting science into the classroom and implementing effective instruction takes time, support, and actually relaying the information to the classroom teachers. In response to this problem, Brad and his team worked on a plan to create their own teacher leader network for their county not only to filter the information, but to also gather data from the classroom to share and provide insight regarding how the initiatives were going.

> So, we developed a teacher leader meeting and we started with the secondary group for middle school and high school [added in elementary 2020-2021 more to come]. And it was fun. So, we brought these teachers together in a network meeting. And really what it was, is because of our NIG, our network improvement group, with the science leaders, coordinators, TOSAs, whatever, from the larger districts around us. They actually then provided the teachers to bring and work with them as a group so they could work with them outside of the meetings and be able to have this kind of a throughput; come in, coordinate, go back to the district, work with them, do whatever they do in their district stuff, bring it back (Brad, Year 1 Midpoint Interview).

Leveraging the concept of redesigning his organization, Brad created this teacher leader network within the county, across districts and schools allowing for multiple perspectives and input to be shared and discussed amongst multiple stakeholders within the system at varying organizational levels. This teacher leader network created space for teachers to implement initiatives, collect data, and share their success and shortcomings with the ones at the top.

While Brad and his team began this work with their secondary teacher leaders, there was more work to be done in regard to elementary education. Brad shared, "We thought that was a tremendous success and we really enjoyed doing that, but then we were asked over and over again, 'what about elementary?" (Brad Year 1 Final Interview). To respond to this, in 2020-2021, Brad and his team created teacher leaders for the elementary level. Based on the ways in which NGSS scaffolds learning, the team created two teacher leader teams one for TK-2 and one for 3rd-5th. With the creation of the teacher leader groups for elementary and the already up and running secondary teacher leader group, the state level all the way down to the classrooms were leveraging one another's expertise to determine successes and next moves for science reform efforts. Brad stated,

> In essence, what we've done is created a throughput from the state through the county into the districts and then directly into the classroom. But the biggest part was now we're getting data and information from the classroom back, so we can take it back up to our meetings […] we now have a process for the very first time of actually getting that input all the way from the state into the classroom and then back so that we can inform what we're doing as far as projects and things that we're working on (Brad, Year 1 Midpoint Interview).

Creating these teacher leader networks exemplifies the transformative impact of distributed leadership in driving organizational change and fostering collaboration at both the local, classroom level and all the way back up to the state level, ultimately enhancing the quality of science education for students statewide. On the monthly PL trackers, Brad diligently worked with his TK-12 District Science Teacher Community of Practice network and District Science Leadership Community of Practice network to support the "throughput" from the state all the way to the classroom and back. For example, on 11/10/2020 Brad held Administrative and Elementary Network meetings, and on 2/09/2021 he held meetings for Grades TK-12 District Science Teacher Community of Practice network meetings, District Science Leadership Community of Practice network meeting for District level science leaders, and an Office Hours meeting that helped with TK-5 literacy in the science curriculum (PL Tracker, Year 1). These activities show the emphasis and necessity Brad saw with ensuring that classroom teachers received information and were able to share their successes and next steps leveraging data with those at the top who created directions and initiatives. Below, figure 4.5 illustrates the typical organizational system of how initiatives and information are filtered from top down, and figure 4.6 illustrates the organizational redesign that Brad and his team effectively implemented with TK-2, 3rd-5th and secondary teacher leader networks within their county.

Figure 8. Traditional Organizational System

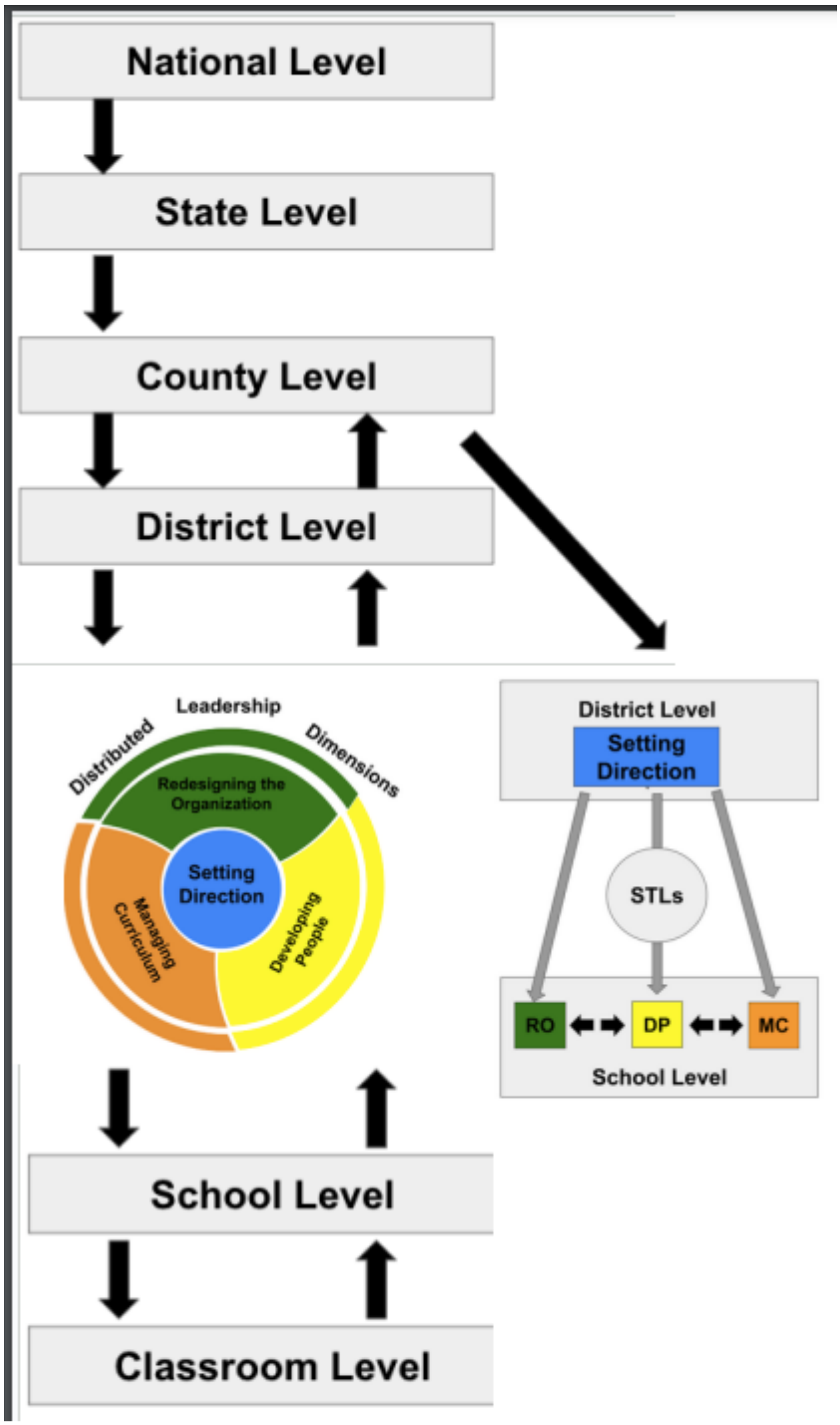
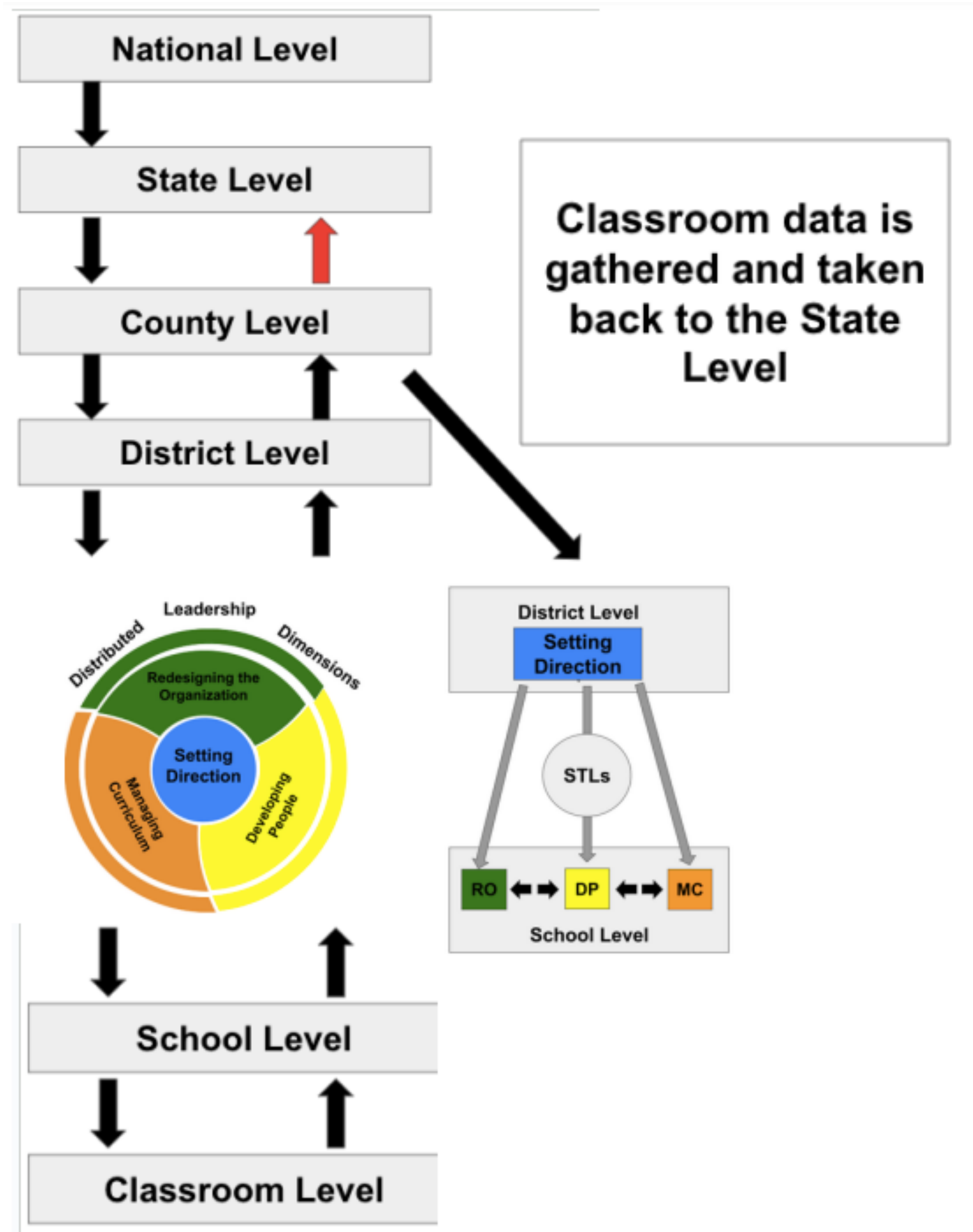


Figure 9. Brad's Organizational Redesign



While both teacher leader networks at elementary and secondary levels were a success, Brad knew there was another piece of network that was needed. He needed to address the administration and policy priority external barriers because he knew that all initiatives “roll downhill” (Brad Year 1 Midpoint Interview) at both elementary and secondary levels. Due to this, Brad recognized that teachers needed more administration support to see efforts moving in the right direction and for teachers to feel supported to implement science in their classrooms. His teachers shared things with him such as,

> Hey, listen, we would love this, but our administration doesn't know anything about it and they don't know what it should look like and therefore it's not important to them and they're concentrating on math and ELA. And so if we could have them see what NGSS is all about and be able to get a little more support. “So, we actually did that, and that's been pretty revealing as well (Brad, Year 1 Midpoint Interview).

Based on what teachers were sharing, Brad added another component to their network. “We called it administrative rounds and it's a network meeting for site level administration, assistant principals and principals” (Brad, Year 1 Midpoint Interview). Brad and his team hoped that by creating administrative rounds, they would be able to work with administration to prioritize science and collaborate with teachers to support and implement equitable science for all students.

Reflecting on his previous district work and classroom teaching experiences, Brad recognized that at the county level there was a “30,000-foot view… and there are a lot of moving pieces and logistics at the county level” (Brad, Year 1 Midpoint Interview). Brad had an idea that he believed would support science teaching and learning in elementary schools. So, he found a title-one school in a migrant farm area that was willing to pilot an integrated approach with ELA and science called “name it, verb it, finish it.” Brad described this approach as:

> I'm trying to kind of go back door into the elementaries. And we have a writing specialist that has joined our science team, and we're using the name it, verb it, finish it, strategy of writing (Brad, Year 1 Midpoint Interview).

Brad and his team recognized that due to many external barriers for science time allocation and standardized test pressures that one way to get science in classrooms was through the integration of other core subjects. Using a common instructional framework and the goals of NGSS, Brad and his team leveraged ELA and science to create a continuous learning cycle that supported both core subjects. Brad explained how he managed the curriculum roll out for name it, verb it, finish it as the following,

> So, our engagement piece would be like some sort of natural phenomenon, and it could be anything, it could be a video, it could be a picture, it could be a hands-on demonstration. It could be whatever. And then they would have to do a name it, verb it, finish it and start to draw a model to try to explain the phenomenon. And then we use the explore, explain as a continuous learning cycle. So, you would do an explore. And from what you found out, you would revise your model and do another name it, verb it, finish it, and then do another one (Brad, Year 1 Midpoint Interview).

He went on to explain that teachers would have the autonomy to "interject readings, videos, social science, or PE" (Brad, Year 1 Midpoint Interview) and anything else they believed would support the students to explore new learning and revise their models to show their understanding.

One thing Brad emphasized was every time students explored and learned something new, they had to complete a new name it, verb it, finish it, model that showed a revision of their new learning and thinking. With these multiple models, this would allow students to show their thinking and learning in a three-paragraph essay (attending to the ELA piece) that would then support them to apply their learning to an evaluative performance task that mirrored NGSS. Going in back door to elementary schools leveraging ELA to provide space for science Brad stated,

> Just putting all of those name it, verb it, finish it together from different sources, the learning level up to a DOK-3 alone. So just being able to do that, and all kids would be able to have access. There's really no floor, there's no ceiling either. So, it really allows those kids access, but also allows other kids that maybe get it a little bit quicker to be able to expand faster (Brad, Year 1 Midpoint Interview).

Leveraging the teacher leader networks, administrative network, and name it, verb it, finish it, Brad was able to attend to many barriers. Internally, he was able to support his pilot school with science content knowledge and science pedagogical content knowledge to effectively integrate ELA and science. However, working in the county office and mirroring state initiatives, Brad's work was mostly centered around addressing external barriers. Brad specifically addressed system constraints by creating teacher leader networks to ensure that information was getting to the classroom teachers. To add to this, he also worked to create a throughput to gather data from teachers to share with the state to ensure initiatives supported science teachers and their efforts. Ultimately, Brad redesigned his organization to begin a process where hopefully all organizational levels could work collaboratively to ensure decisions and initiatives were supporting the overall vision of NGSS, specifically, "all science, all students."

Stephanie - Funding Science Professional Learning

Stephanie, in her role as a county-level STL, advocated for elevating the status of science education to be on par with ELA and math. However, she encountered external obstacles in this endeavor, particularly in resource allocation. Securing funding for science professional learning initiatives proved to be a significant challenge. Without adequate financial support, teachers in the county faced limitations in accessing essential resources and opportunities for professional learning in science education. Internally, Stephanie focused on addressing the internal barriers related to teachers' confidence in teaching science. Recognizing that many educators lacked the necessary confidence or expertise in this area, she prioritized initiatives aimed at enhancing teacher confidence and competence in science instruction. By investing in teacher development, Stephanie aimed to foster a more equitable learning environment for students, ensuring that science education received the attention and support it deserved.

Stephanie leveraged the dimensions of distributed leadership to strategically address both internal and external barriers to science education in her county. Through her efforts in redesigning the organization, she successfully secured funding for the first time in a decade at the county level. This achievement ensured that each district within the county had allocated funds specifically for science professional learning initiatives. By proactively addressing the external barrier of resource allocations, Stephanie laid the groundwork for enhancing teacher capacity and competence in science education. She demonstrated a commitment to developing people by recognizing and understanding the barriers educators faced with teaching science. With the secured funding for science professional learning, Stephanie aimed to provide teachers with the necessary support and resources to overcome these challenges and cultivate confidence in their ability to deliver effective science instruction.

Internal and External Barriers

Stephanie worked at the county level and wanted elementary science education to be at the same level as ELA and math. Specifically, Stephanie wanted to provide proper professional learning to support teachers. She asked,

> How can we support districts with equity in their classrooms and with science instruction, and making sure that everyone is getting access to highly quality instruction and what that would look like (Stephanie Year 2 Finale Interview).

Within her county, she described her team as, “the go to resource if people needed more information about NGSS implementation or just NGSS in general” (Stephanie Year 2 Final Interview). Stephanie and her team recognized that they had the ability to support elementary teachers to implement science within their classrooms and even to troubleshoot some of the reasons science might not be taking place. She stated their work was sometimes, “just understanding that there were barriers that we needed to help remove and help teachers with. And that they didn't have to be content experts to be able to teach science” (Stephanie Year 2 Final Interview). To help support and break down these barriers, Stephanie and her team provided professional learning opportunities that, “supported them with their new curriculum, how to implement, how to get comfortable with materials and the books,” but there needed to be more than that. Stephanie really wanted to focus on,

> Helping, especially elementary teachers understand their own identity as a science instructor. I think that's a key piece in understanding what their background is, and maybe how they were taught science, and making sure that if there are any barriers there that we work on those barriers and have them feel comfortable with it (Stephanie, Year 2 Final Interview).

However, Stephanie and her team needed funding to implement professional learning that supported this work. So, not only was science not prioritized in her county, but there was also a stark difference in funding that was dispersed for science in comparison to ELA and math. Stephanie highlighted this misconception regarding funding.

> So, there's a misunderstanding, I don't know where you are, but a lot of people think that the county office has a lot of money, and we don't. We get a chunk of money from the state that covers the cost of the staffing. But beyond that, we don't have the money, but people go, "Oh you're flushed with cash." I'm like, "Where? I wish I was (Stephanie, Year 2 Final Interview).

Due to funding that only supported staffing, Stephanie made it her mission to locate funding to support teacher professional learning that helped address specific barriers in developing teachers to confidently implement science. Stephanie and her team advocated hard for science. They in fact drafted a letter and sent it out to entities such as the Exploratorium and CASE (California Association of Science Educators) to name a few, to ask for professional learning funding. Specifically, she shared,

> We sent a letter to the state saying that […] They've never designated actual funding for science, they've always done it for math, and language arts and all that, and so we've really pushed for that and advocated for it. So at least every county office and district could have specific funding to support teachers with NGSS even though it's been around almost 10 years (Stephanie, Year 2 Final Interview).

Leveraging Distributed Leadership

Despite the challenges posed by limited funding, Stephanie remained steadfast in her commitment to advancing science instruction in elementary schools, advocating for equitable access to quality professional learning opportunities for teachers as they navigated the reform efforts of NGSS. Stephanie's efforts focused on redesigning her organization to ensure equitable resource allocation, particularly in terms of funding. Her aim was to provide all districts in her county with the necessary financial support to prioritize science education on par with ELA and math. By expanding resources allocation in this way, Stephanie sought to support elementary science teachers in implementing effective instruction. Contrary to prevailing perceptions, Stephanie emphasized the significance of science education, stating, "I think when science, the CAST, the state science test is actually more like 'okay it counts now. We probably will be doing more of that work" (Stephanie, Year 2 Final). In essence, Stephanie aimed to underscore the importance of viewing science education with the same level of importance as ELA and math.

Cross Case Analysis

Commonalities and Differences with Internal and External Barriers

Each of the six STLs worked in suburban and urban districts across a large NGSS state and served at multiple levels within the system. For example, Brad and Stephanie served as county level STLs and Maxine, Otto, Levi, and Dawn served as district level STLs. Despite the variation in their contexts and organizational levels, the data analysis revealed striking similarities in the internal and external barriers they encountered. For instance, across all contexts, STLs grappled with external barriers such as time constraints for science instruction, conflicting administration and policy priorities, and systemic constraints. These external barriers, in turn, contributed to internal barriers named by the STLs, including gaps in science content knowledge, deficiencies in science pedagogical skills, and varied teacher beliefs about science teaching and learning. This convergence of barriers underscores the systemic nature of the challenges facing elementary science education and highlights the need for comprehensive strategies to address these barriers effectively. The ways in which the STLs addressed the challenges to these internal and external barriers leveraging the dimension of distributed leadership is elaborated on in the following case studies followed by a cross analysis of the cases.

Addressing Internal and External Barriers with Distributed Leadership

While there were many commonalities within the barriers that STLs surfaced for both internal and external barriers, the approaches they took to address them varied. District level STLs, for instance, focused more on internal barriers such as enhancing science content knowledge, pedagogical content knowledge (PCK), and fostering positive teacher beliefs toward science to ultimately create confident science teachers. While they also acknowledged external barriers like administrative priorities and system constraints, they employed diverse professional learning opportunities to support their efforts in overcoming these challenges.

In contrast, county-level STLs adopted a more overarching perspective, often referred to as having a "30,000-foot view." They tackled internal and external barriers through a broader lens that was less localized and more directed towards systemic change. For example, Stephanie, a county-level STL, embarked on a funding initiative after a decade to secure funding for professional learning opportunities for science across the districts she served. Meanwhile, Greg and his team created a network of teacher leaders and an administrator network to create a "throughput" from the state level all the way to the classrooms and back up to ensure proper messaging regarding initiatives from all levels was being communicated.

This study uncovered that both district and county-level STLs encountered similar internal and external barriers that required innovative solutions and strategic planning to attend to. However, the variations in the methods used to address these barriers while leveraging the distributed leadership framework proved to vary and provided insight into the complex challenges and opportunities faced by district/county level elementary STLs. The following section offers a cross case analysis of the ways STLs leveraged distributed leadership dimension to support science reform efforts at the elementary level.

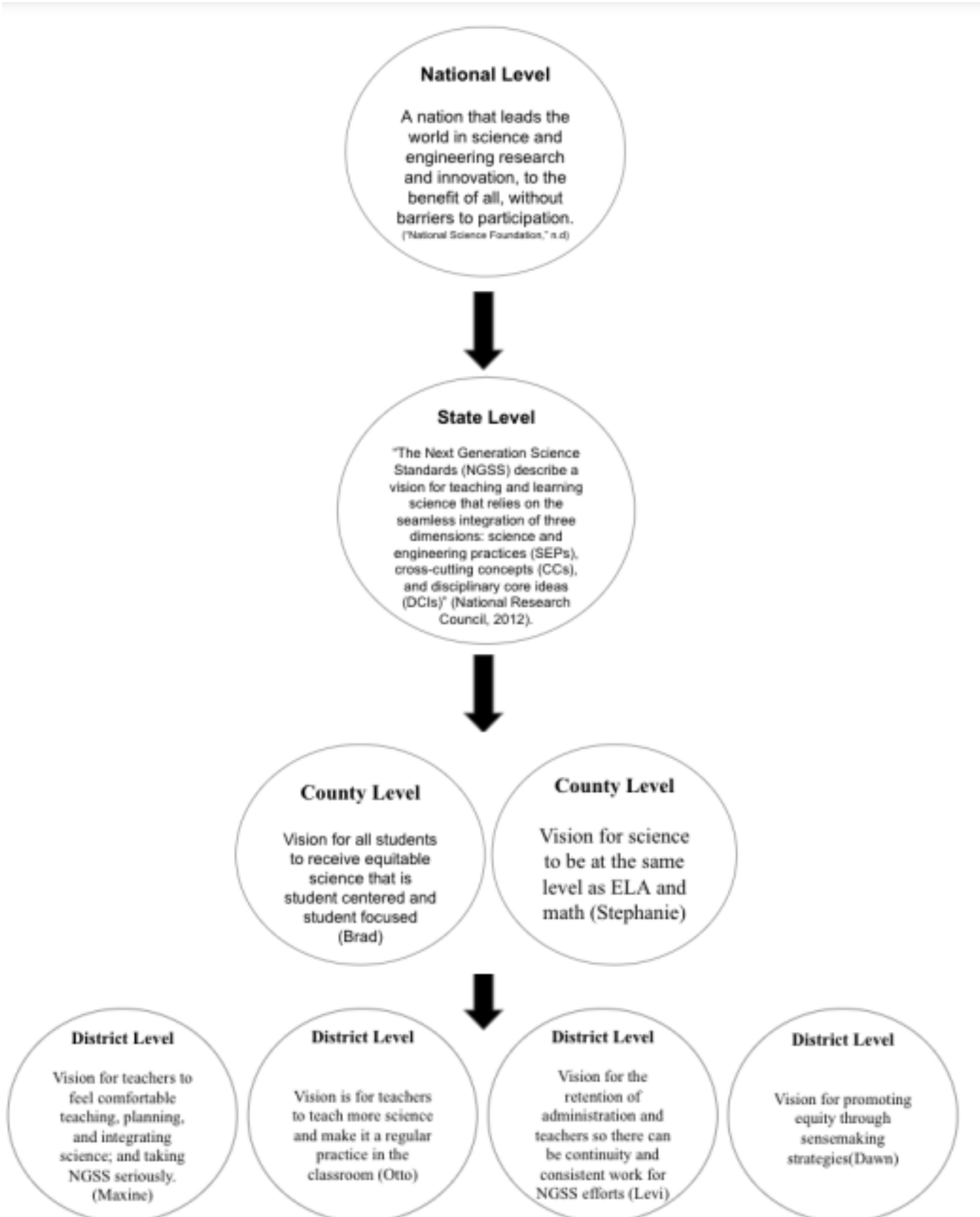
Distributed Leadership Variation

The distinct contextual influences molding each STL's context prompted a range of strategies in utilizing the four dimensions of distributed leadership to overcome internal and external barriers in elementary science reform. The following section explores the themes that emerged from the case studies, shedding light on the diverse strategies STLs used to navigate elementary science education reform.

The Glue to Reform Begins with a Direction

Setting a direction is the most important dimension of distributed leadership, as it lays the foundation for effective strategies to support the redesigning of an organization to promote science, the development of people to implement high-quality science instruction, and management of science curriculum. Without a clear direction, STLs lack the framework to guide their efforts towards successful science reform. The theme: Glue to Reform Begins with a Direction, emphasizes the importance of defining a unified direction with strategic goals to guide stakeholders towards common objectives to address science reform initiatives. STLs acted as liaisons, facilitating the establishment and support of directions for science education, promoting collaboration, communication, and shared vision among stakeholders. The following table details the directions that each STL set for their localized contexts.

Figure 10. Setting Direction Vision Findings



Across these directions, I was able to compare the overarching goals and objectives related to science education reform at both the district and county levels. Maxine, Otto, Levi, Dawn, Brad, and Stephanie all express a commitment to improving science education in their respective roles. While their specific language and focus areas vary, they share common themes such as promoting teacher comfort and competency in teaching science, integrating NGSS, increasing retention of teachers and administrators, promoting equity, and elevating the status of science education to be on par with other core subjects like English Language Arts (ELA) and mathematics. These directions collectively reflect a broad spectrum of priorities aimed at enhancing the quality and accessibility of science education for students across different educational settings. However, the specifics of these directions varied based on the STL's organizational level, necessitating STLs to leverage their expertise and understanding to effectively address elementary science reform efforts. Once the STLs had a direction in place, they were able to develop people and manage the curriculum to see the direction through, or at least make strides to attend to it.

Zoom OUT, Zoom IN

In this embedded comparative case study, there were two county-level STLs and four district-level STLs. From my analysis, I uncovered that the organization level in which the STLs worked played a role in the direction STLs were setting for their localized contexts. For example, Figure 10 supports us to understand that the county level is just below the state and therefore the county level STLs had a zoomed-out vision for science to simply be taught and viewed in the same capacity as ELA and math in elementary schools. For example, “the county level provides a broader perspective because so much of the county work is also state work” (Brad, Year 1 Final). Therefore, Brad and Stephanie understood their roles to look at the bigger picture and how their efforts could impact science teaching and learning at a larger capacity. Brad in particular did this by working to ensure that all messaging in regard to science education truly made it to teachers and that the teachers' voices were heard based on their successes and next steps. Stephanie wanted to ensure that science teaching and learning was viewed the same as ELA and math. In order for this to happen she recognized she needed to secure funding at the county level and disperse it to districts to focus on science professional learning. Stepping back and looking at the big pictures allowed the county-level STLs to leverage the initiatives of the state to help determine their work. Ultimately, the directions county-level STLs set for elementary science education had the ability to redesign their organizations to support the work they were seeking to address.

On the other hand, the district-level STLs zoomed in and set directions on specific needs of organizations and the contexts in which they served. Dawn stated, "I know what it is that my district is wanting to work on because I'm at the district office, so I work with my boss to translate that into what that means for us in elementary science" (Dawn, Year 2 Final Interview). Understanding this, district level STLs honed in on the specifics and inner workings of their organizations to attend to the direct needs of their contexts. For example, Maxine, Otto, Levi, and Dawn supported teachers by meeting them where they were to collaboratively plan, scaffold, and understand science concepts related to NGSS. Therefore, the district STLs had specific areas in which they focused their visions and efforts to ensure that they encompassed the vision of their districts and the directions they set out to reach within their organizations.

Regardless of their organizational level, all six participants expressed directions that aligned to supporting elementary science reform efforts. However, the extent of their influence in determining the direction varied depending on their organizational level. County-level STLs, whose work mirrored that of the state level, often played a role in setting the direction. In contrast, district-level STLs focused on selecting specific components to support and scaffold based on localized needs, contributing to the overall vision for elementary science reform efforts.

Developing People and Managing the Curriculum

When analyzing data, the two dimensions of developing people and managing curriculum were found to work in tandem with one another. The dimension of developing people is centered around providing teachers and educators with the necessary knowledge, skills, and support needed to engage students in effective science instruction. In contrast, managing curriculum entails overseeing and supporting the design, implementation, and evaluation of science lessons, curriculum, and strategies. These dimensions complement each other by ensuring that educators are adequately prepared and supported to navigate changes in the curriculum effectively to ensure elementary science is taking place.

At the core of each STL's work was enhancing opportunities for student learning and outcomes, specifically in regard to elementary science. When teachers are supported to develop as science teachers and deliver effective instruction, they are likely to provide more meaningful experiences and opportunities for students to engage in high-quality science teaching and learning. To ensure that students were receiving adequate science instruction, STLs combined two distributed leadership dimensions of developing people and managing curriculum to support their teachers. Each district-level STL worked diligently within their organization to meet their teachers where they were to determine the proper supports needed to develop their teachers and manage curricular efforts. These were some of the following statements shared by district-level STLs:

> “Another thing that really has kind of evolved is that you know as much as I might see areas of growth or things that I think are important for them to work on like I need to meet them where they're at (Dawn Year 2 Final).

This quote emphasized that in order for teachers to feel comfortable and feel like they were developing, we have to truly meet them where they were so that when they made strides, they could celebrate their wins. If STLs jump into work with teachers that they did not understand, then they might get easily frustrated and overwhelmed. As an STL, it was important to ensure that teachers did not get overwhelmed and frustrated with science as they might shy away from it. To add to Dawn’s thoughts, Levi shared,

> “I feel the same way about trying to help science teachers move ahead. How can I meet them where they're at, give them some parameters, but also recognize that they just have to be met where they're at (Levi Year 2 Final Interview)

This reiterates that growing science teachers is important, but in order for this to happen, they must be met where they are. Otto shared his thoughts about meeting science teachers where they were which elaborated on Levi’s previous statement. Otto shared, “What are some incremental steps to get there? rather than just trying to do everything all at once” (Otto Year 2 Final Interview)

Maxine emphasized what all district STLs stated in regard to meeting science teachers where they are by starting, “continuing to listen, trying to meet the needs of folks where they're at. I think that can't be emphasized enough” (Maxine Year 2 Final). Meeting people where they are and leveraging the dimensions of developing people and managing curriculum required specific knowledge, practices, skills, and experience to iterate and make changes as teachers developed or if they needed different support.

Implementation of Developing People and Managing Curriculum

STLs recognized the importance of meeting science teachers where they were and aligned their supports to move teachers forward through efforts such as coaching, planning, co-teaching, piloting curriculum, and providing necessary professional learning opportunities. While each of the six STLs supported the development of science teachers, the ways in which they enacted their work differed dramatically depending on the number of teachers they supported and the level in which they worked within their organization.

Organizational Level of STL

In this analysis, the level in which the STL worked determined their scope of influence within reforms. District-level STLs had a narrower scope of influence within their own district, focusing on supporting teachers and administrators within their immediate localized contexts served. In contrast, the county-level STLs had a broader scope, working across multiple districts within their county. This difference in scope had a direct impact on the ways in which STLs developed people and managed curriculum within their organizations.

County-Level STLs

Brad, a county-level STL first worked to ensure that the varying levels of his organization were working together to align and communicate efforts to support elementary science reform. Based on his broad scope of influence, Brad took managing curriculum a step further. He worked with a team of third grade teachers and a writing specialist to create and pilot a curriculum the team called; name it, verb it, finish it. This curriculum worked to integrate science into literacy to attend to the external barrier of time allocation. Due to Brad's level in his organization, he was able to pilot a curriculum with teachers in hopes of it turning into something larger. Working as a county STL, just under the state, allowed an STL to make broad decisions as well as space to try out new ideas and curriculum.

Stephanie, the other county level STL worked to secure funding to support professional learning for science teachers to break down the barriers they encountered to teaching and learning science. While she might not have been the one offering the professional development, her work entailed reaching out to various stakeholders to secure funding that would aid in developing teachers across her district to implement effective teaching and learning practices for science.

District-Level STLs

District-level STLs have a narrower scope of influence when it comes to supporting elementary science education. In fact, this analysis found that district level STLs provided professional development based on specific needs of science teachers, they provided coaching, and created tools to support planning and teaching science.

Otto worked in a very large district and due to this, he had to narrow his focus to new teachers to ensure he was able to effectively support science education within his district. Otto reported serving a range of 800-1,200 teachers. Therefore, he wanted to make sure he was supporting teachers who needed the most support. To narrow his focus, he chose to work with new teachers who needed support with science content, science pedagogical skills, and other various science work. Through coaching, office hours, and cadre meetings, he was able to provide specific support that teachers asked for, things he noticed when coaching, and items that administrators asked Otto to work on with their teachers. While focusing predominantly on new teachers, Otto was able to offer varying support to enhance their science and teaching abilities.

Levi worked with both administration and teachers to ensure that there was alignment within their organization that supported the development of people and science teaching and learning. Levi found that oftentimes, administrators did not understand the initiatives that their districts were asking them to implement. Due to this, it caused confusion and burnout. Therefore, Levi's work centered around translating district initiatives to be understood and implemented effectively. Through an idea of “failing forward,” Levi created opportunities for teachers and administrators to try out new strategies in a safe place. These opportunities allowed for coaching conversations to take place to determine successes and next steps. Ultimately, Levi modeled how to work together within a context to support one another to succeed and “fail forward,” to determine next steps.

Dawn focused on equitable teaching practices and created opportunities to plan, discuss, and try out new sense-making strategies that supported science teaching and learning. Dawn learned that while providing a plethora of tools for teachers was nice, they did not mean anything unless the teachers understood how to use them and why they needed to use them. Majority of Dawn’s work centered around managing curriculum to develop strong, confident science teachers to support the overarching direction of her district which was equitable teaching practices.

Maxine wanted to make science a normal teaching practice in classrooms. However, taking a pulse check within her district, she realized that teachers needed professional learning in specific areas to feel confident to implement science in their classrooms. Surveying her elementary teachers, she was able to determine the overall needs of her district and with the help of her science teacher leaders, they created and implemented a relaunch professional development that helped elementary teachers plan and understand their science curriculum.

Organization Level Influences Approaches

This section holds particular significance as it reveals that all STLs endeavored to tackle both internal and external barriers within their respective organizations. However, the level within the organization where the STL operated influenced how they approached supporting people's development and managing curriculum. By delving into the multifaceted roles of STLs across different organizational levels and their application of distributed leadership dimensions, this analysis sheds light on the diverse strategies employed by STLs in navigating the challenges of elementary science education. District-level STLs were noted for their hands-on, immediate support within their schools or districts, while county-level STLs took a broader, more overarching view of elementary science reform efforts. Despite these contrasting approaches, both district and county-level STLs effectively employed the dimensions of distributed leadership, encompassing setting direction, developing people, and managing curriculum. County level STLs, Brad and Stephanie were the only two who attended to the dimension of redesigning the organization. This broader scope of responsibility for county level STLs necessitates a more systemic approach to address challenges and implement reforms. County-level STLs at times might need to align policies, programs, and resources across various districts to ensure consistency and coherence in their science education initiatives. In contrast, district-level STLs may primarily focus on implementing reforms within their own district, with less emphasis on coordinating efforts across multiple districts or schools and more emphasis on developing the teachers they work with as well as managing curriculum and instruction.

CHAPTER V: CONCLUSION

Introduction

In this dissertation, a case study methodology (Merriam & Tisdell, 2016) was employed to examine a diverse group of district/county science teacher leaders (STLs) across different district and county contexts within a large state on the west coast. This case study aimed to unravel the organizational dynamics of elementary STLs' leadership, relationships, professional practices, skills, and knowledge in various contexts that differed geographically. The specific focus was seeking to understand how these distinct/county STLs understand their roles as science leaders to navigate the internal and external barriers inherent in science reform efforts. The research questions that guided this dissertation were:

Overarching Question: How do district/county level elementary STLs who participated in this study understand their role utilizing the four dimensions of distributed leadership to address internal and external barriers to science reform?

a) What are the commonalities and differences in the internal and external barriers attended to by district/county level elementary STLs within the four dimensions of distributed leadership?

b) What variations exist among district/county level elementary STLs in the enactment of distributed leadership specifically focusing on the four dimensions; setting direction, developing people, redesigning the organization, and managing curriculum to attend to elementary science reform efforts?

In this chapter, I summarize the main findings of this dissertation and their connection to the literature. I end the chapter with the limitations of the study and recommendations for future scholarship and efforts to understand and support science teacher leaders to enact distributed leadership to attend to internal and external barriers within varying contexts.

Contributions to the Literature

Distributed Leadership as a Framework

This study contributes to the literature by defining and describing the work of STLs within the framework of distributed leadership as they navigated internal and external barriers in science reform efforts across different contexts. The complexity of conceptualizing teacher leadership and science teacher leadership has been highlighted by scholars such as York-Barr and Duke (2004) and Wenner and Campbell (2017), who have noted the absence of comprehensive conceptual frameworks in this area of research. While past studies have yielded valuable insights, there is a recognized need for a robust framework to guide empirical investigations (Bae et al., 2016; York-Barr & Duke, 2004; Wenner & Campbell, 2017).

Many frameworks have been utilized in previous research to understand the roles of STLs, but the conceptual framework of distributed leadership stands out as crucial for comprehending the work of STLs in supporting elementary educators and addressing various barriers (Bolden, 2011; Gronn, 2002; Harris, 2008; Leithwood, 2004; Timperley, 2005). This approach allows organizations to leverage the expertise of STLs at different levels to drive improvement (Harris, 2007; Spillane et al., 2004). In this study, the focus was on county and district-level STLs, examining how distributed leadership manifests in setting direction, developing people, redesigning the organization, and managing instruction (Firestone & Martinez, 2007; Leithwood et al., 2007).

Implementing distributed leadership in elementary schools fosters a culture of shared responsibility, facilitating decision-making processes and promoting innovation and professional growth (Bolden, 2011; Gronn, 2002; Harris, 2008; Leithwood, 2004; Timperley, 2005). STLs play a critical role by providing insights based on their experiences and expertise, contributing to reform efforts in elementary science education (Reiser, 2013; Stein & Nelson, 2003; Wenner & Campbell, 2017; Whitworth et al., 2021; York-Barr & Duke, 2004). In particular, this study provides insights into the ways STLs at different organizational levels leveraged distributed leadership dimensions to attend to barriers within their localized contexts. For example, Otto partnered with administrators in his district to support new teachers and their needs to effectively teach science. Together, Otto, administration, and new teachers were able to get on the same page as they were able to collaboratively discuss successes and next steps for new teachers regarding science. Otto leveraged his own personal experience as a new teacher to support these teachers through a means of support he wished he had received when he was a new teacher. Specifically, Otto shared, “Now that I have the perspective of looking back and seeing how I struggled as a new teacher, it took some time to get good at being a teacher, and being a science teacher, so I’ve increased my empathy over time” (Otto, Year 2 Final Interview). Therefore, Otto provided multiple supports that new teachers could take advantage of spanning from office hours, zoom sessions, co-teaching opportunities, and cadre meetings.

Embracing distributed leadership also empowers organizations to decentralize leadership, allowing multiple stakeholders to contribute to reform efforts (Bolden, 2011; Gronn, 2000; Leithwood et al., 2007; Spillane et al., 2004). Brad, a county level STL, found an opportunity for classroom teachers to step into teacher leadership roles within a network he created with his team. Brad uncovered, "...that a classroom teacher just wasn't getting this information or almost all of them,” (Brad Year 1 Midpoint) in regard to curriculum, updates, and reform efforts for science education. Therefore, the purpose of creating this teacher leadership team was to enhance the overall messaging and initiatives within the organization to leverage the voices of individuals at all levels of the system. By doing this, Brad was able to leverage the voices from the state level, district level, school level, classroom level, and all the way back to the top. In essence, he redesigned his organization to leverage a top down, bottom-up system as opposed to the traditional hierarchy of schools with the top-down narrative. Overall, distributed leadership offers several advantages for understanding the work of elementary STLs, enabling a more comprehensive approach to advancing science education goals.

This examination of the distinct strategies of STLs at different organizational levels provided valuable insights into the diverse leadership approaches in a large state that has adopted NGSS. Specifically, county level STLs approached science reform efforts with a broad perspective that leveraged building coherence across multiple levels of an organization. In contrast, district level STLs had a narrower scope of reform efforts and used the district direction to help guide their efforts to support teachers in the realm of science. Distributed leadership as a framework emphasized the significance of considering contextual factors and organizational dynamics in reform initiatives and highlighted the adaptability that distributed leadership offers in addressing various educational challenges. For example, the ways in which STLs responded to challenges within their localized contexts differed. The STLs at the district level responded with more instructional support through methods such as coaching, providing targeted professional learning, or partnering with administration to support the organization. For example, Dawn worked closely with her teachers on sense-making strategies. Specifically, Dawn stated, “We basically provided the research, some of the tools and strategies they could use for their science talk. And then we had kind of a graphic organizer for them to think and play it out” (Dawn Year 2 Final Interview). On the other hand, county level STLs leveraged their roles and responded to more of the systemic challenges such as securing funding for science professional learning or ensuring a coherent messaging and initiatives. Overall, the dimensions of distributed leadership served as guiding principles for STLs as they navigated the complexities of their localized contexts and organizations to enhance science education in elementary schools.

Studying Science Teacher Leaders

Various studies have researched and explored the variance in STL's roles, school level, titles, and how they influence science education (Bae et al., 2016; Wenner, 2017; Whitworth et al., 2017). However, previous studies are considered monolithic as they do not consider the diversity and differentiation that exist within science teacher leadership (Bae et al., 2016; Wenner & Campbell, 2017). For example, Wenner (2017) explored the roles of elementary STLs in a high-achieving urban district and worked to understand what STLs named as responsibilities and supports within their work, the sample only included coaches and specialists (Wenner, 2017). Five different participants were involved in the study, there was little variation amongst the work as all schools were in the high-achieving urban district and STLs held similar positions and they were all females.

Whitworth and colleagues (2017) conducted a study that explored district science coordinators from a national sample. Members from the National Science Education Leadership Association (NSELA) were requested to complete a survey where potential participants were asked about their demographics, how they understood their responsibilities as a science coordinator, and ways they could grow professionally (Whitworth et al., 2017). After careful consideration of the survey responses, 16 participants were chosen, all were science coordinators, almost all of them were Caucasian females, all were members of NSELA, and all had served less than a decade in the science coordinator position (Whitworth et al., 2017). While this study gathered information at a national level, participants all held the same position, all participants were females, and almost all participants identified themselves as Caucasian.

Bae and colleagues (2016) attempted to address the monolithic practices in regard to science teacher leadership as they conducted a mixed methods study that attempted to gather data from STLs across multiple low-income, urban middle school districts. While this study was able to apply a typology, different characteristics, pathways, and targets of influence at the same school level, geographic location and socio-economic level of the schools were studied.

While these previous studies of science teacher leadership can be considered monolithic, they did provide a reference point to leverage the work of science teacher leadership. This study addresses the need for research to move beyond monolithic studies to consider the diversity and differentiation that exists within science teacher leadership. By focusing on district-level STLs and county-level STLs this research contributes to the literature by offering insights into how these leaders in varying geographic areas, varying districts, and genders leveraged the dimensions of distributed leadership to address internal and external barriers within their localized contexts. By examining the roles and practices of STLs at both the district and county levels within elementary education reform, my research provides a more nuanced understanding of how leadership operates within the varying organizational structures.

The participants in this study included three participants who identified as women and three who identified as men. Of the six participants, five participants self-reported their race/ethnicity as Caucasian, and one self-identified as East American Indian. Two STLs were county level STLs (One male, one female), and four were district level STLs (two women, and two men). Four STLs reported serving urban districts and two reported serving suburban districts. Based on the data provided, the participants in this study provide a more diverse population in regard to geographic location and gender in comparison to other studies.

Specifically, examining county-level STLs sheds light on the role of leadership at the level just under the state. The county level work is very similar to the work at the state level, therefore analysis revealed that oftentimes, these STLs had a hand in creating the direction in which their organizations were set to go. These leaders were also responsible for disseminating information and collaborating with districts and schools to support their needs within science education reform. County-level STLs faced unique challenges related to leveraging funding for professional learning and ensuring messaging was filtering from the state, through their county level, into the district, into schools, and most importantly into classrooms. Stephanie and her district for example drafted a letter to the state advocating for science funding. They were successful and she was able to report that "at least every county office and district could have specific funding to support teachers with NGSS" (Stephanie, Year 2 Final Interview) for the first time in a decade. Brad on the other hand created a "throughput; come in, coordinate, go back to the district, work with them, do whatever they do in their district stuff, bring it back" (Brad, Year 1 Midpoint Interview) where all levels of the organization were included, especially classroom teachers. Therefore, the county-level STLs worked to ensure funding, messaging, and proper support were in place, which provided insight into the ways they leveraged their knowledge, skills, experiences, and managed their complex networks to attend to external barriers within elementary science reform efforts.

Similarly, investigating district-level STLs allowed for an in-depth exploration of how these leaders navigate systemic challenges and policy priorities to support science education reform efforts. Specifically, District-level STLs often play a crucial role in aligning the direction for their organizations based priorities and initiatives provided by their districts. The district level STLs listened to their K-6 teachers and educators to implement strategies that addressed the internal and external barriers that presented themselves in their localized contexts. For example, Maxine and Dawn supported teachers with tools, resources, and time to discuss science teaching and learning. Maxine created a Relaunch Science professional development and planning sessions to support teachers to feel more comfortable to teach science, and Dawn vetted tools and research to support sense-making strategies. On the other hand, Otto and Levi acted as liaisons for administrators and teachers to better understand the initiatives for science education in hopes of decreasing overwhelming feelings. The approaches used by district-level STLs contribute to a deeper understanding and guide strategies for systemic change and policy implementation in science education. This study revealed how district-level STLs addressed specific and collective needs, aligning their efforts with their organization's vision for elementary science reform.

Overall, this study adds to the literature base by offering insights into the diverse strategies and approaches employed by diverse district-level and county-level STLs to address internal and external barriers in science education reform leveraging the dimensions of distributed leadership. By examining leadership practices at multiple levels of an organization, my research contributes to a more comprehensive understanding of how leadership influences elementary science reform efforts.

Commonalities and Difference in Internal and External Barriers

In elementary school classrooms, research has found that there are many factors that contribute to the obstacles faced when attempting to engage in science teaching and learning that can be categorized as either an internal or external barrier (Southerland et al., 2007). Internal barriers include the beliefs teachers have in regard to science and students, their understanding of the curriculum and content, and personal experiences and opportunities to engage in authentic science; whereas external barriers correlate directly to the availability of school resources and systemic obligations centered around learning and assessment (Southerland et al., 2007).

Specifically in this study, the work that elementary STLs supported surfaced internal barriers such as science content knowledge, science pedagogical skills, teacher beliefs, teacher experiences, which ultimately led to or hindered overall teacher confidence. These internal barriers directly impacted the work centered around teaching, learning, and view that ultimately impacted the instruction in the classroom. On the other hand, the external barriers that surfaced the most in this study included time allocation for science, resource allocation, professional learning opportunities, and administration and policy priorities, specifically around performance measures with ELA and math. All of these external barriers centered around systemic, organizational and policy challenges. Both internal and external barriers that surfaced in this study were similar to the barriers that Southerland and colleagues (2007) found to be prevalent.

One gap in the literature regarding internal and external barriers to elementary science reform efforts is the need for a deeper understanding of the interconnectedness and dynamic nature of these barriers (Aldridge & McLure, 2023). Specifically looking at how external barriers (broader, organizational challenges) impact the internal barriers and work at the classroom levels. While existing research often identifies internal and external barriers separately (Southerland et al., 2007), there is a lack of comprehensive analysis that explores how these barriers interact and influence each other within the context of elementary science education reform.

When conducting data analysis for this study, it was very difficult to tease out internal and external barriers. Therefore, in order to truly understand each STL and their work within their localized contexts, I looked at how the external barriers impacted the internal barriers. I found that the external barriers such as limited professional development opportunities contributed to the internal barriers related to science content knowledge and science pedagogical content knowledge. Otto and Levi found that if teachers were not provided opportunities in their districts to attend professional learning that enhanced their science content knowledge and science pedagogical content knowledge, they were often left feeling overwhelmed and less confident to teach science. Contrary to this, collaboration time for science also served as a support for teachers to enhance their science content knowledge and science pedagogical content knowledge. Through coaching, specific professional developments, planning sessions, and tools STLs worked to find ways to incorporate professional learning centered around science to support their localized contexts. Another example of an external barrier to that was prevalent in this study and impacted the internal work was administration and policy priorities. In particular, due to school performance measures and initiatives, many administrators did not prioritize science. Due to this, STLs were left finding ways to innovatively coach, provide professional learning, and create opportunities to plan, discuss, and share resources with their teachers. Ultimately, STLs worked within the confines of their localized contexts to address barriers to elementary science education to the best of their ability.

This study highlights the importance of examining the interconnectedness of external and internal barriers and how addressing one aspect may affect the other (Aldridge & McLure, 2023). A critical aspect of this understanding is that solely focusing on internal barriers can lead to blaming teachers (Allen & Heredia, 2021). By considering internal and external barriers together, there is a shift from viewing teachers through a deficit lens to understanding how systemic limitations restrict their opportunities and access to resources for effective science teaching (Allen & Heredia, 2021). Understanding this intricate interplay between barriers is essential for devising comprehensive strategies that truly support efforts to reform science education.

Variations Among STLs Enactment of Distributed Leadership

Distributed leadership encompasses a range of practices aimed at enhancing the overall effectiveness of an organization (Bennett et al., 2003; Gronn, 2002; Spillane, 2006; Spillane et al., 2004). In particular, focusing on the four dimensions of leadership; setting direction, redesigning the organization, developing people, and managing curriculum all vary in the ways they are enacted based on the organization in which STLs serve (Firestone & Martinez, 2007; Leithwood et al., 2007). This study uncovered that the organizational level in which the STL worked provided variation in the ways that distributed leadership was enacted to address internal and external barriers.

Setting Direction

Setting a direction includes ensuring that all members in the organization understand the direction in which the organization is set to go through strategic goals in order to align their work with these guiding principles (Jenkins, 2009; McBrayer et al., 2020; Mercer, 2016; NCSSE, 2013). While many organizations have set directions and strategic goals in place, oftentimes they are overarching and may not include science. In this particular study, district level STLs found themselves working within the confines of the overarching district's vision. For example, Dawn stated, "I know what it is that my district is wanting to work on because I'm at the district office, so I work with my boss to translate that into what that means for us in elementary science" (Dawn, Year 2 Final Interview). Therefore, Dawn had to set a direction for what this looked like for elementary science education and became the liaison to communicate and lead this direction.

Dawn and her boss worked to provide research and tools to support the direction of science that was set by their district and county level. However, through this process Dawn learned that "tools need explanation" and "deconstructing" these tools and how they can support science teaching and learning were very valuable. Similarly, the four-district level STLs Maxine, Otto, Levi, and Dawn communicated the direction for science by meeting teachers where they were to collaboratively plan, scaffold, and understand science concepts related to NGSS.

STLs are a necessity in setting direction for elementary science education as they can help bring NGSS to life by leveraging their knowledge and expertise to ensure elementary students are receiving opportunities to engage in high-quality science instruction that calls on their critical thinking skills and creativity to solve problems (NASEM, 2015; NGSS, 2013). While district level STLs worked within the confines of district directions, county-level STLs in this study whose work mirrored that of the state level, often played a role in setting the direction for science. Brad and Stephanie who were county level STLs understood their roles through a "zoomed out" perspective that looked at the bigger picture and how their efforts could impact science teaching and learning at a larger capacity. Therefore, Brad designed his work to ensure that the direction of elementary science was understood through effective communication and Stephanie secured funding that worked to elevate science to the same capacity as ELA and Math. When considering how to address science within reform efforts, this study recognized the importance that STLs play to coordinate and manage the logistics and ensure that there is space for collaboration, proper implementation of science mandates, as well as opportunities to monitor the organization's work and how it aligns to their direction (Heredia et al., 2023b).

Redesigning the Organization

Redesigning the organization within the dimensions of distributed leadership involves restructuring and realigning existing systems, processes, and structures to better support the goals and objectives of the organization (Bolden, 2011; Devos et al., 2014; Leithwood et al., 2007; Spillane, 2005). However, in order to effectively redesign an organization, it must reflect the direction that has been set. Within this study, I found that the organizational level in which STLs worked played a significant role in whether or not they enacted this dimension of leadership. The two county-level STLs (Brad and Stephanie), were the only ones that took on the responsibility of redesigning their organization to attend to needs that would help promote science to effectively address reform efforts. Brad created a “throughput” for his district by creating a teacher leader network to ensure proper messaging was filtered through every organizational level and back up. With Brad’s work, he shared, “...we now have a process for the very first time of actually getting that input all the way from the state into the classroom and then back so that we can inform what we're doing as far as projects and things that we're working on” (Brad, Year 1 Midpoint Interview). Brad redesigned his organization to leverage the voices of teachers who were implementing the reform initiatives and heard their insights on the success and next steps. Stephanie on the other hand made it her mission for science, ELA, and math to merit the same attention. Therefore, she worked to secure funding for science professional learning at the county level for the first time in a decade. This study details the ways in which STLs in particular organization levels (county-level) created an environment that enabled multiple stakeholders to contribute meaningfully to the organization's direction, while also facilitating the effective implementation of initiatives and reforms within elementary science (Leithwood, 2021).

Developing People and Managing Curriculum

The last two dimensions of distributed leadership were developing people and managing the curriculum. Developing people refers to the process of nurturing and enhancing the skills, knowledge, and capacities of individuals within the organization (Brolund, 2016; Leithwood et al., 2007; NCSSE, 2013). Managing curriculum entails supervising, evaluating, coordinating and monitoring instruction through a variety of tasks supports one of the most crucial functions of schools (Printy & Liu, 2021). Developing people and managing curriculum are interconnected within distributed leadership, as they both focus on fostering growth and improvement (Leithwood et al., 2007). Similar to the literature, developing people and managing the curriculum were found to be tightly connected within this study. STLs specifically at the distinct level tailored their efforts to support the development of science teachers and other elementary educators by managing and assisting with strategies that supported teachers' science content knowledge, science content pedagogical knowledge, and beliefs to implement effective science instruction by meeting the teachers where they were. While the two county levels implemented overarching efforts to support these two dimensions, such as picking out curriculum to pilot, the on the ground, specific work to develop teaching practices and engage in best teaching practices was done by the district STLs. These findings highlight the importance of aligning efforts to nurture science teachers' skills and knowledge with effective curriculum management practices to promote continuous improvement in elementary science education.

This study highlights the variations observed among STLs in their enactment of distributed leadership dimensions (setting direction, redesigning the organization, developing people, and managing curriculum) within their organization levels and localized contexts. This study highlights the dynamic nature of leadership within elementary science education. By recognizing and embracing these variations, educators, administrators, and policymakers can gain deeper insights into the diverse approaches and leveraging multiple actors to address limitations of the organization to foster excellence in science education (Bennett, 2003; Bolden, 2011; Gronn, 2000, 2002, 2008; Harris, 2008; Leithwood et al., 2004; Spillane, 2005, 2006; Spillane et al., 2004). Leveraging county and district STLs knowledge and expertise allows them to develop and tailor strategies and interventions that address the unique needs and challenges presented within different organizational contexts (Whitworth et al., 2021). As found in this study, the STLs organizational level provided insight into the limitations and next steps needed to best support elementary science reform efforts. Moreover, this study promotes the need to create a culture of collaboration, innovation, and continuous improvement, throughout the entirety of an organization to ultimately lead to effective science education outcomes for elementary students (Gronn, 2000, 2002).

This examination of the distinct roles and strategies of STLs at different organizational levels provided valuable insights into the diverse leadership approaches in science education. It emphasized the significance of considering contextual factors and organizational dynamics in reform initiatives and highlighted the adaptability of distributed leadership in addressing various educational challenges. Overall, the dimensions of distributed leadership served as guiding principles for STLs as they navigated the complexities of their localized contexts and organizations to enhance science education in elementary schools.

Limitations

One constraint of this study is the small sample size of STLs, which can make the findings difficult to generalize to a larger population. Despite the small sample size, I used multiple sources of data to triangulate findings through semi-structured interviews, PL trackers, and artifacts to draw rich conclusions (Merriam & Tisdell, 2016).

The second constraint to consider in this study was the nature of the sampled STLs and their participation in a research practice partnership between a university and a teacher leader network within a museum context. Due to their self-selection to participate in a science teacher leader network, this may not represent all the variations in STLs and their work within elementary science reform efforts. Additionally, the selected STLs may not fully represent the diversity of perspectives and experiences within the larger population of STLs, potentially leading to limited insights. Despite this limitation, I did my best as the researcher to accurately portray the internal and external barriers STLs named, how they leveraged distributed leadership within their organizations, and most importantly how they worked to support and attend to the needs of their teachers through rich descriptions from multiple data sources (Merriam & Tisdell, 2016).

Furthermore, the findings may be highly context-specific to the particular settings and circumstances of the six STLs involved, limiting the transferability of the results to other contexts. This study however did include three female and three male STLs, two of which were county-level STLs and four who were district-level STLs in an attempt to compare and contrast across the six participants and their organizations. To enhance the generalizability of these findings and further address some of the limitations, conducting future studies with larger and more diverse samples could help corroborate and extend upon the initial conclusions drawn in this dissertation.

Future Research

As elementary science education continues to evolve and undergo changes, there is a significant need for future research to understand the role of STLs in supporting this work. It is critical for future research to explore continuous and ongoing PD for science teachers, nurturing science specific practices for teachers to engage in effective science instruction, science focused collaborative learning environments for STLs, integrating science into core subjects, creating support and buy-in from administration, and building future STLs. By exploring these complex dimensions, researchers have the opportunity to discover effective methods for improving science learning outcomes for elementary students and equipping teachers, STLs, and administrators with the necessary knowledge and skills to attend to elementary science reform efforts. This section presents prospective research directions in elementary science education, highlighting the significance of attending to both internal and external barriers while addressing gaps in the current literature.

Continuous and Ongoing Professional Development for Science Teachers

Professional development needs to be continuous and ongoing to support the range of skills and activities needed for an organization to contribute to successful science teaching and learning (Klein et al., 2018; Wenner, 2018). Oftentimes, PD is delivered in a quick, one day course, or through a variety of documents with strategies and tools centered around policy or district agendas (Klein et al., 2018; Little, 1993). Dawn learned that even when supporting policy or district initiatives, teachers needed training on what they were being asked to implement. Dawn and her boss worked together to provide the research, tools, and planning documents that highlighted best practices to implement sense-making strategies into their classroom, but teachers needed more than that. Dawn found that while it was nice to have tools and strategies, teachers needed support to understand what the strategies were used for, how to use, and why. Therefore, Dawn worked to coach her teachers to use the tools over the span of a year through co-teaching, planning, and reflections directions. She learned that simply providing resources or one-day PDs are not enough to support science reform efforts.

Similarly, Maxine recognized that to get buy-in from her teachers to implement their new science curriculum, she needed to meet the teachers where they were at. In order to do this, she surveyed her teachers to determine curriculum support they were asking for so she could tailor PD sessions to attend to those needs. At the conclusion of the PD, Maxine collected feedback to determine the next level of support teachers were asking for. Maxine recognized that for teachers to be successful, they needed more than one professional development opportunity. Research also indicates, single day/single session PDs are not beneficial as they are typically not context dependent and there is not a lot of variety provided to support the differing needs of teachers (Little, 1993). Based on previous research and findings from this study, it is evident that continuous and on-going professional development is necessary to support teachers to implement reform efforts and something that needs to be researched further. Beginning with a needs-based assessment similar to Maxine in this study provides a starting point to determine what is needed for science teachers to feel successful.

Nurturing Specific Practices

The NGSS standards seek to address the call for high-quality science education by providing a framework that emphasizes hands-on learning, critical thinking, and real-world application of scientific concepts for all students (NASEM, 2015; NGSS, 2013). In order to attend to this call, elementary teachers need support with specific practices such as hands-on learning, using science tools and resources, supporting students with conceptual understanding and reasoning of topics, integrating science into other subjects, inquiry based learning, and teacher understanding of the content and standards (NASEM, 2015). By working with teachers to nurture these skills it provides access for students to receive high-quality science education that is aligned with curriculum standards and best instructional practices (NASEM, 2015; NGSS, 2013). Dawn, a district level STL created tools and resources centered around equitable sense-making that her teachers could use to plan with and implement in their classrooms. While Dawn's efforts to create these resources were necessary and useful, she found that without explaining the tools and nurturing her teacher to use them, they did nothing. Dawn's work emphasized the importance in fostering science-specific practices among educators to help build their confidence and competence in teaching science.

Maxine, another district level STL recognized that science professional development was necessary to support her teachers to engage their students in hands-on learning, sense-making and inquiry, and integration to best implement their new science curriculum. Using a survey, she was able to identify the specific needs of the teachers in her organization Dawn and Maxine employed two different approaches to cultivate and support their teachers' practices, yet both contributed to the overarching objectives of science education reform by fostering equity, accessibility, and inclusivity within science classrooms.

This study was framed within the framework of distributed leadership, which enabled an exploration of the diverse approaches STLs employed in supporting elementary science reform. Distributed leadership focuses on the activities that leaders engage in versus the actions of leaders themselves (Gronn, 2000, 2002; Spillane, 2005; Spillane et al., 2004). Utilizing methods such as coaching, developing and implementing professional learning, as well as creating and providing resources the STLs in this study were able to support growth within their organizations. By employing different strategies, these leaders navigated the complexities of supporting leadership development and fostering opportunities for learning and growth (Little, 1995; Harris, 2003; Klein et al., 2018). In this study, the STLs did not use one method to develop science teachers and instruction in their organizations. In fact, each STL used a variety of methods to enhance science teaching and learning. Therefore, this study motivates the need for nurturing science specific practices for both STLs and science teachers. To further enhance coordination efforts across organizations and promote effective science teaching and learning, science professional development emerges as a crucial necessity. Such initiatives support the cultivation of proficient mentors, observers, and coaches who collaborate to enhance and advocate for best practices in elementary science education (Harris, 2003). Thus, nurturing individual teacher needs, administrator needs, STL needs, and individual contextual support are implications to consider when working towards enacting distributed leadership through a variety of practices (Harris, 2003; Klein et al., 2018).

Science Focused Collaborative Learning Environments for STLs

Science focused Collaborative learning environments for STLs offer valuable opportunities for professional development, knowledge exchange, teamwork, problem-solving, networking, and leadership enhancement, which are all vital for promoting excellence in science education initiatives. Collaborative learning environments can be achieved and accessed through multiple avenues. For example, university and school practice partnerships, working relationships across schools, working across organizational levels, professional learning communities, and communities of practice [CoPs], (Mutch-Jones et al., 2022; Wenger et al., 2002; Whitworth et al., 2021). Ultimately, STLs and others who engage in collaborative participation such as communities of practice or networks share a passion towards solving problems and deepening understanding with teaching and learning (Wenger et al., 2002).

In this study, Otto and Levi collaboratively worked together using a coaching continuum to observe what students were doing and how they were responding to science instruction. The continuum also looked at what teachers were doing and how they were working with their students in regard to science teaching and learning. The STLs used the evidence they collected from the observations to create coaching conversations and plans to further support teachers. Collectively, both Otto and Levi became a source of support for one another to share ideas and strategies for coaching and developing teachers. While this study did not directly investigate the impact of science-focused collaborative learning environments for STLs, Otto and Levi's collaborative approach highlights the potential benefits of such environments.

Engaging in collaborative learning environments facilitates the growth of STLs by promoting shared norms, reflective practices, effective dialogue, and collaboration focused on student learning (Borko, 2004; Wenger et al., 2002; Whitworth et al., 2021). Consequently, they emerge as valuable sources of support, for introducing new teaching strategies, enhancing science content knowledge, and offering comprehensive coaching and assistance to their colleagues within the school community and beyond (Borko, 2004; Wenger et al., 2002; Whitworth et al., 2021). Research highlights STLs who participate in collaborative learning environments through structures such as professional learning communities, communities of practice, and networks help promote and encourage sustainable growth and refinement within their contexts and organizations (Harris, 2005). While this dissertation did not investigate science collaborative learning environments, there is a need for further research to look at how these

STLs could benefit from science specific collaborative environments as well as leveraging strengths of other STLs across organizations.

Integrating Science Into Core Subjects

An external barrier to science education is the time allocation to teach science, due to administration and policy priorities as well as accountability pressures for other core subjects (Smith & Southerland, 2007). In this study, all six STLs found science competing for a spot in the core subject line up. Research and STLs in this study identified one way to increase the amount of time that science is being taught is to integrate science into core subjects such as ELA and math (Kober et al., 2023). Integrating science with ELA and Math helps to maximize instructional time and provides an opportunity to cover multiple subject areas simultaneously without sacrificing depth of learning (Kober et al., 2023). Two of the STLs, one at the district and one at the county level worked on varying methods to support science integration. Maxine, a district level STL surveyed the teachers in her district to identify science supports they felt were needed. She found through this survey that elementary teachers wanted support to integrate science and ELA. Therefore, she created a session within her relaunch science PD for her district that provided strategies to integrate science and literacy specifically. However, it is important for subject integration to involve more than just passages. In order to truly integrate subjects, teachers need explicit training and coaching to ensure that integration is meaningful, relevant, and effective in enhancing student learning across disciplines. To support Maxine’s PD session, the table below supports some of the overlap that ELA and science share.

Table 12: Commonalities Between Science and ELA

Reading	Science
Use *observation* of textual elements to *predict* topic – format, pictures, cover and title pages	Use *observation* of materials and activities to *predict* causes
Identifying topic of the text	*Identifying* the problem that needs explanation
Use *background knowledge* to make *connections*	Use *background knowledge* to make *connections*
Make inferences about what is happening in the text	*Make inferences* about observations and interactions
Draw conclusions about what happened in the text and why	*Draw conclusions* about what is happening with the materials and why

Table I. Common elements between reading and science.

Note. Retrieved from "Building bridges: using science as a tool to teach reading and writing," by Nixon, D., Akerson, V., 2004, *Educational Action Research, 12*(2), 197–218.

Brad, a county level STL, worked closely with a team and writing specialist to integrate science and ELA through a writing curriculum he was piloting called name it, verb it, finish it. Both the PD session on integration and name it, verb it, finish it curriculum attend to the argument that hands-on science can be used as a way to support students' scientific ideas and knowledge development which could lead to opportunities for reading to support and enhance science understanding for students (Kober et al., 2023). Finding strategies to engage students in meaningful, context-rich activities that bridge science, ELA, writing, and Math, integration fosters a deeper understanding of concepts and promotes engagement and motivation in learning (Darling-Hammond et al., 2020; Kober et al., 2023). Overall, future research on integration strategies in elementary science education holds the potential to enhance student learning outcomes, support teachers in meeting curriculum requirements, and promote the development of essential 21st-century skills (Kober et al., 2023; NGSS, 2013).

While this study explored two different supports to leverage innovative approaches to integration, researchers can contribute valuable insights to the field and support the ongoing improvement of elementary science education practices with future research. Specifically future research could begin by looking at ELA curriculums to determine how science could be integrated into these lessons. Next, STLs could support teachers to pilot these integrative lessons across varying contexts to gather data on successes and next steps. Following the pilot, similar to Maxine's integration PD session, STLs could provide professional learning opportunities to support teachers with integration strategies using the piloted lessons and beyond. While this is only one potential integration strategy, science education could benefit from longitudinal research looking at student achievement, attitudes, and impacts on student's future that integrating science and literacy instruction could have.

Creating Support and Buy-in from Administration

Administrators play a crucial role in establishing a unified vision and mission that guides reform efforts and supports the endeavors of STLs within organizations. Administrators possess the capacity to facilitate a science vision and leverage STLs and their ability to support elementary science education within their contexts by providing space and opportunities to do so (Klein et al., 2019). However, it is argued, "Before they can lead and support changes in instruction and curriculum, their learning needs should be addressed, so they can then support the learning needs of all teachers" (NRC, 2015 p. 18). This study uncovered that teachers asked STLs to help with administrative support for science teaching and learning. Teachers recognized that their administrators did not understand science instruction and ELA and math took priority over science. In an effort to support this request, Brad, a county level STL created an administrator network to help administrators understand what science teaching and learning entailed. He also created this network so administrators could see that science was just as important as ELA and math. With Brad working at the county level in this study he knew that initiatives "rolled downhill" and therefore, he could help plan ways to potentially address external barriers, specifically in regard to administration and policy priorities. Wenner (2017), found that when administrators understood and valued science education, then the school culture was more likely to work collaboratively in their efforts to make effective science teaching a norm. Brad implemented the administrative network to support the Wenner's (2017) finding.

In order to support efforts for effective science teaching to become a norm within schools, professional development is necessary for STLs, teachers, and administrators. Including administrators in the professional development is imperative as they know the particular needs of their contexts and the goals, they have for STLs to support the success of the school as whole (Klein et al., 2019). Levi uncovered that administrators were a key driver within contextual support and change. Levi recognized that administrators were often overwhelmed with "quadrant one-putting out the fires" (Covey, 2004) and were unable to attend to quadrant two efforts where real change could occur. Acknowledging that administrators needed support, he worked to develop administrators to build their skills and understanding of initiatives to speak and promote them. Specifically, he leveraged his work to support administrators to align their contexts goals to district initiatives and from there he translated these goals and supported both teachers and administrators to attend to them.

While both county level and district level STLs were able to provide two different types of support to administrators, this study as well as previous research recognizes that future efforts need to include administrators in science professional development. Allen & Heredia (2021) found that when administrators participated in science professional developments, the school was on the same page, teachers felt more comfortable to take risks, and it allowed for more collaborative work across the organization between multiple leaders to take place (Firestone & Martinez, 2007; Gronn, 2000, 2002; Harris, 2007; Spillane et al., 2004).

Moving forward, it is crucial for future research to include administrators in professional learning opportunities that deepen their understanding of science practices and what this looks like in the classrooms. Professional development for administrators can and should closely resemble models designed for teachers, engaging them in active participation, alignment with school, district, and state policies, and foster collaborative engagement among participants (McNeil, 2018; NSAEM, 2015). Once administrators gain a better understanding of what science education within reform seeks to attend to, future research could explore strategies for enhancing administrators' prioritization of science education within their schools. This research could investigate the effectiveness of professional development programs aimed at building administrators' understanding of effective science instruction and their capacity to support science teaching and learning. Additionally, studies could examine the impact of school policies and organizational structures on the prioritization of science education, identifying barriers that facilitate or hinder administrators' efforts in this area.

Building Future Science Teacher Leaders

While my study did not directly investigate specific strategies to build STLs, it is essential to consider the implications for future research and practice. Building science teacher leaders is a complex process that requires time and tailored support to meet the individual needs of educators (Harris, 2003; York-Barr & Duke, 2004; Wenner & Campbell, 2017). However, it is also important to recognize and understand the challenges that STLs face within their role. STLs within research can serve as classroom teachers who also lead beyond their classroom, or they are no longer in the classroom and serve multiple schools within a district (Katzenmeyer & Moller, 2009). Despite being leading in and beyond a classroom, it is imperative to consider the challenges of this role. STLs effectiveness resides on the time they are allotted to support, resources, funding, professional development for science and leadership skills, and support from administration and higher ups (Allen & Heredia, 2021; Borko, 2004; Firestone & Martinez, 2007; Harris, 2007; Hickey & Harris, 2005; Klein et al., 2018; Spillane et al., 2004; Wenger et al., 2002; Wenner, 2018; Whitworth et al., 2021). While all participants in this study were not classroom teachers, it is important for future research to address the challenges that STLs face when they have their own classroom and students while also supporting and leading within their school. Brad's initiative to create a teacher leader network in his county aligns with the literature emphasizing the importance of providing opportunities for teachers to lead and collaborate (Hickey & Harris, 2005), but his efforts were more focused on ensuring proper messaging was being filtered through all levels. While teacher leaders in his network were successful in providing insight to collaboratively address efforts in regard to science teaching and learning with higher organizational levels, this study did not investigate how to build teacher leaders and support them to navigate challenges they may encounter in this role. However, future research could study how to build future STLs using the steps outlined by Hickey & Harris (2005), (1) identifying teacher strengths, (2) matching teacher strengths to professional development needs, (3) developing professional development programs with their strengths and needs in mind, (4) providing space for teachers to lead PD, and (5) providing chances for teachers to engage collaboratively with others (Hickey & Harris, 2005) and (6) how to navigate challenges of the role in general. Moving forward, further research should explore the effectiveness of these strategies in nurturing STLs and promoting positive outcomes in teaching and learning (Firestone

& Martinez, 2007). By examining different contexts, tasks, roles, and actors involved in leadership development, we can gain deeper insights into the factors that contribute to successful capacity building efforts among educators.

Conclusion

Reframing science teacher leadership through the distributed leadership framework places emphasis on the shared decision-making dynamics and relationships within the school, district, and organization, with direct implications for advancing research, practice, and leadership development (Gronn, 2000; Spillane, 2008; Spillane, 2010). Departing from the traditional notion of a single authoritative leader, distributed leadership encourages collaborative engagement among all stakeholders to drive organizational success (Gronn, 2000, 2002; Spillane, 2005; Spillane et al., 2004). This approach allows science teacher leaders to collaborate with administrators, fellow teachers, and other various stakeholders to collectively address challenges, set goals, and implement initiatives related to science education reform (Leithwood et al., 2007). By fostering a culture of shared decision making, distributed leadership enables science teacher leaders to leverage the diverse expertise and perspectives within their organization (school, district, and county) resulting in more effective and sustainable efforts to improve science teaching and learning (Bolden, 2011; Gronn, 2002; Harris, 2008; Leithwood, 2004; Timperley, 2005). STLs and teachers are at the core of distributed leadership as they reinforce organizational commitment (Mifsud, 2023). With a specific focus on developing teachers and creating opportunities for them to lead and engage within the shared decision making for their organization promotes efficacy, trust, satisfaction, and retention (Angelle, 2023, Misfud, 2023).

In the words of Wilson (1993);

> "I hope the school of the future will be a non-hierarchical system that nourishes informal arteries of influence, a place where the pulse and rhythm of good teaching and learning are driven by the capabilities of teacher leaders…. Only then will we genuinely begin the work of fashioning school environments within which it is possible for every student to achieve" (p. 27).

This quote emphasizes the importance of rethinking future educational structures to create a non-hierarchical system that supports informal channels of influence, driven by the capabilities of teacher leaders. By promoting distributed leadership, it highlights the need to empower teachers to take on leadership roles, using their insights and expertise in the classroom. This approach enhances collaboration and innovation among educators and ensures that teaching strategies are responsive to student needs. In elementary science education, this vision supports inquiry-based learning, encourages professional development, and fosters a collaborative learning environment. By prioritizing teacher leadership and flexible, informal influence, we can create school environments where every student has the opportunity to succeed.

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APPENDIX A: YEAR ONE MIDPOINT INTERVIEW

Spanning Boundaries
Mid-point Interviews of TLs
January/February 2021

Background for interviews
Dimensions of interest

- **Conceptions/shades of Teacher Leadership**. What are TLs doing as leading teachers right now? How has this changed over time and why? (Providing more moral and emotional support? Focused more on logistics of distance learning? Etc.)
- **The role of context** in their professional learning work (and their needs and supports.) Who are the actors in the TL's networks that influence the TLs and who are influenced by the TLs?
- **How TLs have distilled, filtered, and translated** Explo/TI resources for/in their contexts.
- **The role of the TI Communities of Practice** in their TL learning and work.
- **The role of the Exploratorium's resources (including Teacher Leader Network** more broadly than CoPs). Maybe ToC meetups, TL share-a-thons, sharing other offerings, online videos, etc.

Reminder for interviewer:
Spanning Boundaries: A Statewide Network to Support Science Teacher Leaders To Implement Science Standards will study a one-year online professional learning model for secondary teacher leaders supported by an informal science education institution. The research will focus on how teacher leaders translate that experience to support their colleagues in the implementation of the Next Generation Science Standards (NGSS) in their respective school districts. The study may contribute to increased understanding of the responsibilities and needs of science teacher leaders and the development of a framework to provide professional learning opportunities for science teacher leaders in the age of NGSS-based educational reform, and now, during a pandemic.
Intro for interviewee/TL:
We are talking with each Teacher Leader in the CoP (DRK12) project to learn more about their TL practice this year and how it might be influenced by various factors (e.g. individual contexts, by the Exploratorium and/or the Teacher Institute and/or other TLs in the network, and the pandemic!)
We would like for you to talk with us about a particular artifact from your TL work this year. Whatever you think would be useful to help us better understand your goals for and approaches to your teacher leadership work.

Mostly, we want this to be an opportunity for you to reflect on your leadership practice, especially this year. We are not evaluating your work and we are not looking for any particular answers. We simply want to better understand your work this year. If a question doesn't seem to apply to you, please feel free to say so. You may also pass on any question or ask for the recorder to be turned off.

I would like to read this language from our IRB:
These interviews with project staff will be audio recorded and transcribed by a third party. Because your voice will be potentially identifiable by anyone who hears the recording, your confidentiality for things you say on the recording cannot be guaranteed although the researcher will try to limit access to the recording. We will protect your confidentiality by keeping any recordings, images, or other records stored on password protected hard drives stored in locked cabinets in a secured office and on a password protected cloud database (Box).

Do you have any questions for me before we start?
Do you mind if I record this conversation?

Questions

1) I know that you are a [role] in [district/school].
How would you describe the context in which you work (district community, school, colleagues)?
   - What does a typical day or week look like for you?
   - What are you doing right now both formally and informally to support other teachers in your school or district?
   - Is your district more traditional or progressive?
     - District supportive of teacher professional learning, leadership, and professionalism? What resources do your school or district provide to support you in your role?
     - Stance toward NGSS? Toward Science?
   - Familiarity with/perception of Exploratorium - How does the district/school view your participation with the Exploratorium?
   - How do you define your sphere of influence within your role in your school or district?
2) Tell us about the artifact you would like to share
   - What inspired you to use and choose this artifact?
   - How does this represent your goals and approach to your TL work (particularly **in science)**?
   - How did you develop - or translate and adapt - this artifact for your particular context?
   - Tell us about how you used the artifact and how it went.
   - What did you learn from finding, developing, or trying this artifact?
   - What questions do you still have about your practice?
3) Your current work as a teacher leader
   - How would you define a teacher leader? How would you describe yourself as a teacher leader? What does it mean to you, to be a teacher leader?
   - How, if at all, do you think the landscape and conversation around teacher leadership has been different this year because of the pandemic?
   - How has your TL work evolved or changed this year?
   - How, if at all, has the conversation about NGSS been different this year?
   - What do you think the influence or impact of a teacher leader can be?

4) How if at all, have you drawn on Exploratorium resources, (including the TI Statewide Network) for your work?

- **How has your involvement with the Teacher Institute influenced your practice as a teacher leader?**
- What are you able to access through the Teacher Institute (and the TL Network) that is difficult or impossible for you to access through other means?
- **How, if at all, has the Teacher Institute's approach to professional learning influenced your TL practice (if not already described)?**
- Have you reached out through Lens or some other means to other TLs in the Explo network this year? And why?
- Have you drawn on other resources other than this program for your work?
- Are there any occasions where you used what you have learned through the program when working with other science education groups, such as BaySci etc
- **Do you feel like you have access to different colleagues (CoP Teacher leaders) than you usually do on a regular basis? Explain.**

5) Time permitting? How would you describe the work you've done in your CoP? How, if at all, has your CoP work influenced your teacher leadership (**in science**)?

- Have you used any of the tools you've learned about or tried in your CoP group (e.g. Actor Network map? Defining terms or defining Problem of Practice?) with other colleagues?
- If so, tell us how that went.
- How, if at all has interacting with the other TL's impacted your work?

6) What else is important for us to know?

APPENDIX B: YEAR ONE FINAL INTERVIEW

Spanning Boundaries
Final Interviews of TLs (Year 1)
May 2021

Intro for interviewee/TL:
We are talking with each Teacher Leader in the CoP (DRK12) project to learn more about their experiences in the CoP workshops during the 2020/2021 school year. Mostly, we want this to be an opportunity for you to reflect on your participation in the workshops this year. We are not evaluating your work and we are not looking for any particular answers. We simply want to better understand your participation and what you think you learned in the CoP groups this year. If a question doesn't seem to apply to you, please feel free to say so. You may also pass on any question or ask for the recorder to be turned off.

I would like to read this language from our IRB:
These interviews with project staff will be audio recorded and transcribed by a third party. Because your voice will be potentially identifiable by anyone who hears the recording, your confidentiality for things you say on the recording cannot be guaranteed although the researcher will try to limit access to the recording. We will protect your confidentiality by keeping any recordings, images, or other records stored on password protected hard drives stored in locked cabinets in a secured office and on a password protected cloud database (Box).

Do you have any questions for me before we start?
Do you mind if I record this conversation?

Questions

1. How would you describe your CoP group to someone outside of the Exploratorium?
2. Describe a memorable moment from your CoP? Why is this moment memorable?
3. What was the problem of practice that your group was working on?
    a. Why did you choose that problem of practice?
    b. Do you think that you were able to attend to or develop some solutions to that problem in your CoP? [ask for an example]
    c. How has your participation in the CoP impact how you understand your problem of practice?
4. What was your biggest takeaway from your work in your CoP?
    a. What were the elements of the CoP that led to that outcome?
    b. Were there particular moments, tools, structures that led to that?
5. What aspects of the CoP were especially impactful to your practice as a teacher leader? [seed - activities, people, resources, protocols, etc.]
6. Did you use any of the activities or protocols introduced in your CoP in your context?

a. If yes, what did they use and how?

7. How did salient aspects of your identity play out within the group dynamics?

a. If they struggle with this question you can seed some identity markers for them to consider - (race, gender, sexual orientation, ability, professional, etc)

8. What would you change or do differently with the CoPs next time?

9. Were you participating in any other virtual teacher groups this year? How did it compare to the work that you did in your CoP?

APPENDIX C: YEAR TWO FINAL INTERVIEW

STL final interview Y2
Background for interviews
Dimensions of interest

- **STL roles/profiles**. What are TLs doing as leading teachers right now? How has this changed over time and why? (Providing more moral and emotional support? Focused more on logistics of distance learning? Etc.)

- **The role of context** in their professional learning work (and their needs and supports.) Who are the actors in the TL's networks that influence the TLs and who are influenced by the TLs?

- **How TLs have distilled, filtered, and translated** Explo/TI resources for/in their contexts.

- **The role of the TI Communities of Practice** in their TL learning and work.

- **The role of the Exploratorium's resources (including Teacher Leader Network** more broadly than CoPs). Maybe ToC meetups, TL share-a-thons, sharing other offerings, online videos, etc.

Reminder for interviewer:

Spanning Boundaries: A Statewide Network to Support Science Teacher Leaders To Implement Science Standards will study a one-year online professional learning model for secondary teacher leaders supported by an informal science education institution. The research will focus on how teacher leaders translate that experience to support their colleagues in the implementation of the Next Generation Science Standards (NGSS) in their respective school districts. The study may contribute to increased understanding of the responsibilities and needs of science teacher leaders and the development of a framework to provide professional learning opportunities for science teacher leaders in the age of NGSS-based educational reform, and now, during a pandemic.

Intro for interviewee/TL:

We are talking with each Teacher Leader in the CoP (DRK12) project to learn more about their TL practice this year and how it might be influenced by various factors (e.g. individual contexts, by the Exploratorium and/or the Teacher Institute and/or other TLs in the network, and the pandemic!)

We would like for you to talk with us about a particular artifact from your TL work this year that was inspired by or you gained access to through your CoP. Whatever you think would be useful to help us better understand your approaches to your teacher leadership work and how the CoP supported that work.

Mostly, we want this to be an opportunity for you to reflect on your leadership practice, especially this year. We are not evaluating your work and we are not looking for any particular answers. We simply want to better understand your work this year. If a question doesn't seem to apply to you, please feel free to say so. You may also pass on any question or ask for the recorder to be turned off.

I would like to read this language from our IRB:
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Do you have any questions for me before we start?
Do you mind if I record this conversation?

Questions

1. Tell me about your work as a science teacher leader this year.
    - Returners
        - i. How has your leadership practice changed from last year?
        - ii. How has your sphere of influence changed (if at all) from last year?
    - If new to CoPs this year
        - i. How would you describe the context in which you work (district community, school, colleagues)?
        - ii. What does a typical day or week look like for you?
        - iii. What resources do your school or district provide to support you in your role?
        - iv. How do you define your sphere of influence within your role in your school or district?
2. Your current work as a teacher leader
    - If new to CoPs - ask them to define science teacher leadership.

- During the profile activity - you put stickers in the following categories [look up for each STL prior to interview]
    - Talk to me about why you chose these roles and what aspects of your leadership practice aligned with these roles.
    - You chose xxx to develop more. Why did you choose that/those roles? What supports do you need to be able to develop more in this leadership area?
    - Were there aspects of your leadership practice that were not captured in any of the roles?
- Show leadership journey map picture. Ask about these critical moments/experiences that lead them to where they are today?
- How has your thinking about TL changed or evolved over time?
- What do you think the influence or impact of a teacher leader can be?

3. Tell us about the artifact you would like to share
    - Why did you choose this artifact to share with us?
    - How does this represent your goals and approach to your TL work (particularly **in science)**?
    - How did you develop - or translate and adapt - this artifact for your particular context? How did your work in the CoP support your development of this artifact?
    - Tell us about how you used the artifact (or plan to use it) and how it went.
    - What did you learn from finding, developing, or trying this artifact?
    - What questions do you still have about your practice?
4. How would you describe your CoP group to someone outside of the Exploratorium?
5. Describe a memorable moment from your CoP this year? Why is this moment memorable?
6. What was the problem of practice that you were working on this year?
    - Why did you choose that problem of practice?
    - Do you think that you were able to attend to or develop some solutions to that problem in your CoP? [ask for an example]
    - How has your participation in the CoP impact how you understand your problem of practice?
7. What was your biggest takeaway from your work in your CoP?
    - What were the elements of the CoP that led to that outcome?
    - Were there particular moments or activities within the CoP that led to that?
8. What aspects of the CoP were especially impactful to your practice as a teacher leader? [seed - activities, people, resources, protocols, etc.]
9. Did you use any of the activities or protocols introduced in your CoP in your context?
    - If yes, what did they use and how?

Group 4 Returners ONLY

- Can we articulate how this CoP was created and what was created?
- What makes this group different? How is this experience different from others that you have had?
- What are some key aspects of the facilitation of the group or activities that we did that supported the development of our community?

- And how do you see yourself as an essential component of building that community?

- Which of the commitments do you feel was core to the foundation of our group and why?
- How has this group supported/modified/shifted your ideas/practices of teacher leadership?

For group 5 returners:

- How did their work shift from last year to this year, and why?
- What was their process for determining what they wanted to work on this year and how, if at all, was that different from year 1?

APPENDIX D: K-12 SCIENCE LEADER NETWORK AT THE EXPLORATORIUM

K–12 Science Leader Network

exploratorium®

Broad and Sustained Reach Across CA

Too few California students receive science education rich in real-world phenomena that prompts them to ask questions, gather evidence, and understand the world around them.

The Exploratorium has been a professional home for phenomena-based learning for over 40 years. Since 2016, we have partnered with county offices, district leads, and teacher leaders who serve as local advocates throughout the state, equipping educators with high-quality, NGSS-aligned science resources for relevant and responsive science teaching.

Through sustained and collaborative professional learning, The Exploratorium continues to expand a network of K–12 science leaders, investing in long-term, local capacity for inquiry-rich science education for *all* California students.

K–12 Science Leaders, 2016–2020

800+ Unique K–12 Science Leaders

2,300+ professional learning engagements

35+ hours of professional learning per leader

90% work in Title I schools or districts

Highly Leveraged Impact

As of 2020 ...

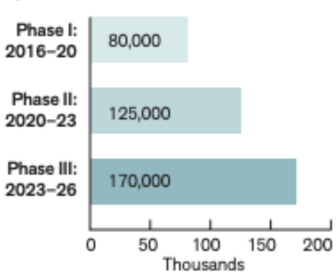
The Exploratorium has worked with over **800 K–12 science leaders**, representing every region in the state.

Collectively, these leaders provide professional learning to over **80,000 classroom teachers** in their home districts.

Millions of California students receive increased access to standards-aligned, phenomena-based science education.

By 2026 ...

Teachers receiving continuous support by K-12 Science Leader Network



A Trusted Resource with Enduring Value

98% of participants recommend the Exploratorium as a go-to resource for teaching science

97% say the Exploratorium is the best resource for NGSS

During training: **93%** say experience will contribute to their ability to support NGSS locally

One year later: **99%** say their experience has made them a better provider of science professional learning

(*Inverness Research*, 2018)

K–12 SCIENCE LEADER NETWORK	IMPACT REPORT, JULY 2020	EXPLORATORIUM

Leading in Equity-Oriented Science Learning in San Diego County

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Eric Cross serves in three formal science leadership roles; therefore, the scope of his influence is both deep and wide. For the last five years, he has been teaching 7th grade science to 200 students in a charter middle school in San Diego, where he is also on the leadership team. He is also an adjunct professor in the credential program at the University of San Diego, influencing dozens of future educators. He also works as a consultant, speaking at conferences and presenting to educators around the world on using technology in the classroom and the power of mentors, particularly for addressing equity issues. His most popular session is entitled Techquity.

Eric appreciates that the Exploratorium educators model how to effectively engage students in the science and engineering practices through observing, predicting, using evidence to respond to open-ended prompts, and mentoring.

"Being at the Exploratorium means watching what we think modern science teaching should look like in a classroom. The most useful thing is the modeling and the mentorship. The questions that are being asked, the questions that are being answered, the questions that are not being answered, the responses. All of those things are things that I get a lot of value out of seeing what it looks like to teach that. As teacher leaders we don't get a lot of opportunities for that."

Eric is passionate about the urgent need to address equity issues in education and make science culturally relevant to students, while aligning instruction to NGSS. **The Exploratorium adds value to Eric's leadership by modeling inspiring and culturally relevant pedagogy.** One of the things that really stands out for Eric is how proactive and progressive the Exploratorium is in facing issues of equity and representation in science, by talking about skin color, gender diversity, socioeconomic constraints, indigenous peoples, and contextualizing them in the history of science:

"And you only have that when you have people from multiple backgrounds having these conversations. If you're trying to draw a picture and you only have red, green, and yellow crayons, you're not going to get the best picture . . . . I don't think this happens in a lot of other places."

SAN DIEGO COUNTY

42 school districts
500,000 students
24,344 K–12 teachers

While at Exploratorium, he experienced the Decolonizing Science activities, through which learners explore the Eurocentric nature of maps and the physics of blowdarts. In turn, Eric collaborated with a colleague who works at the Juvenile Court Schools in the San Diego County Office of Education, and together, they engaged learners who are in juvenile hall in the Decolonizing Science activities.

For Eric, the Exploratorium's approach to NGSS and its high-quality resources coupled with the strong, inclusive relationships he has built with staff and other teacher leaders has helped tremendously:

"Nothing has created as much value as actually knowing what 'teaching along NGSS standards' looks like. I haven't got as much value out of anything outside the Exploratorium. Nothing's come close. It's one of the reasons why I keep coming back, not only because of the relationships, but also it makes me better for my kids and for my students. There isn't a training that's come close to it."

Since 2016, the Exploratorium has worked with science education leaders in every California county to support the implementation of the Next Generation Science Standards and the phenomena-based practices that engage student interest, elicit scientific thinking, and deepen student learning. Through the sponsorship of the **Exploratorium K–12 Science Leader Network,** the Exploratorium serves the state by equipping science leaders with resources, first-hand learning experiences, and ongoing connections that enable them to lead NGSS implementation in their local schools, districts, and counties.

exploratorium.edu/CAeducator/workshops

Prepared by Inverness Research, developmental evaluation partner for the Exploratorium K–12 Science Leader Network.

Inverness Research

Leveraging Exploratorium Resources to Lead Science Leaders Statewide

Maria Simani is Executive Director of the California Science Project (CSP), a network of 18 university-based sites that provide an infrastructure for quality professional science learning for Pre-K through 12th grade inservice and preservice teachers throughout the state. Each year, scholars and teachers from these sites work collaboratively to design, implement, evaluate, and refine professional learning programs, in an effort to enhance K–12 teacher's content knowledge and instructional strategies, with a special emphasis on English learners and high-needs schools. Experienced with a wide range of professional learning options, Maria says:

"The Exploratorium matches our view of how the best professional development should be done."

Maria is a leader of leaders in K–12 science in California, and is able to see how different county offices and regions tailor and disseminate the Exploratorium offerings for their own contexts. Forty-five professional learning providers attend an Exploratorium workshop at a time, engaging in the activities as learners, reflecting on their roles and practice as leaders, and then recreating the experience for the teachers who work in their own contexts. Regional science leaders are amplifying the magnitude of the Exploratorium's pedagogy and resources. For example, the Dissolving with Lifesavers activity, a hands-on investigation that helps teachers understand how the NGSS science practice of modeling supports the development of science concepts, has been used in every region that has participated in an Exploratorium workshop through the CSP, and one region took it a step further and developed a module for administrators.

The CSP retains a special focus on improving literacy among English learners as well as native speakers in high-needs schools; therefore, Maria appreciates the Exploratorium's approach, which encourages participants to analyze, reflect, discuss, and write about their observations and their models, thereby strengthening mathematics and literacy skills, while simultaneously addressing the Next Generation Science Standards (NGSS).

"With the Exploratorium activities, the engagement in the Science and Engineering Practices is really high. The activities really showcase the entire pathway from 'I'm engaging with a phenomenon' until 'I'm developing an explanation for this phenomenon' and in between you do all the talk, all the writing, all the math, and all the reading. Science requires a lot of talking and if your focus is language development, just giving people vocabulary doesn't really help. You have to have people talk."

Maria considers the Exploratorium educators to be leaders in professional learning for science teachers due to their early innovations and expertise in hands-on inquiry and investigation of phenomena, which are highly aligned to the Science and Engineering Practices of the NGSS.

"The Exploratorium educators have been pioneers and we have taken advantage of that. The California Science Project is always looking for other educators who are willing to engage in thinking critically about our practice and how to make it better."

California Science Project (CSP)

1,300 schools

4,200 teachers

heavier impact

lighter impact

csmp.ucop.edu/csp. The CSP is one of nine California Subject Matter Projects, which include mathematics, world language, reading, literature, writing, history-social sciences, global education, and art.

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exploratorium.edu/CAeducator/workshops

Prepared by Inverness Research, developmental evaluation partner for the Exploratorium K–12 Science Leader Network.

Inverness Research

Building a Long-Term Partnership to Support Regional Leadership

"If you could pick the best folks in the world to help you build skills around student-centered inquiry, well, oh my gosh, we are just so lucky that we live within striking distance of the Exploratorium."

—Kirk Brown

Kirk Brown is Division Director for STEM programs in the San Joaquin County Office of Education (SJCOE) and recognized as a leader in the region. He brought 22 professional learning providers from San Joaquin and Stanislaus counties to the Exploratorium K–12 Science Leader Network to increase support programming for Next Generation Science Standards (NGSS) in the region's 39 school districts.

Kirk and his team collaborated with the Exploratorium to develop an integrated science and math workshop for a 3-day summer institute for 50 cross-regional teacher leaders charged with supporting teachers in their districts.

A common NGSS starting point for many K–5 leaders across the state is the Exploratorium's Parachute activity involving force and motion. This activity was adapted to include the mathematical elements of ratio between weight and drop time, and was also successful in searching for patterns in data.

"Because NGSS and Common Core mathematics are all about student-centered sense-making, what better group to get involved with in the world really [than the Exploratorium], as they are experts in student-centered inquiry," according to Kirk.

SJCOE is responsible for supporting NGSS implementation across the county's 14 districts. **Lissa Gilmore**, a SJCOE science coordinator, delivers much of the NGSS early implementer professional development. **She anchors the professional learning to the Exploratorium's Dissolving with Lifesavers activity because it helps teachers apply the science practice of modeling to explain how temperature, size of particles, and movement influence the rate of the Lifesavers dissolving.**

Lissa explains, *"I do a lot of work with elementary teachers, and there's a disconnect [in how science used to be taught and what is being expected now] . . . . Helping teachers identify practices and using those to teach their kids science is the focus."*

Kirk sees the Exploratorium partnership as a win-win that helps the county promote equity across the region. *"The kids in the Central Valley are some of the most needy in the country. A lot of kids here are English language learners . . . whatever we can do to help support those kids . . . things that engage them, things that cross over so they can learn math and science at the same time . . . . We have just really enjoyed working with the Exploratorium. It is a true partnership."*

SAN JOAQUIN COUNTY

14 school districts
148,000 students
7,069 K–12 teachers

STANISLAUS COUNTY

25 school districts
110,405 students
5,234 K–12 teachers

Since 2016, the Exploratorium has worked with science education leaders in every California county to support the implementation of the Next Generation Science Standards and the phenomena-based practices that engage student interest, elicit scientific thinking, and deepen student learning. Through the sponsorship of the **Exploratorium K–12 Science Leader Network,** the Exploratorium serves the state by equipping science leaders with resources, first-hand learning experiences, and ongoing connections that enable them to lead NGSS implementation in their local schools, districts, and counties.

exploratorium.edu/CAeducator/workshops

Prepared by Inverness Research, developmental evaluation partner for the Exploratorium K–12 Science Leader Network.

Inverness Research

Leading a District in Life Sciences: Teacher-In-Residence to Teacher Leader

explOratorium®

"I feel so fortunate to have found a professional home at the Exploratorium that has supported me throughout every stage of my career."

During **Daisy Yeung**'s first two years in the biology classroom, she turned to the Exploratorium's Teacher Induction Program for one-on-one coaching and mentorship. Daisy returned often for workshops, and **in 2017–2018 she served as the Exploratorium's teacher-in-residence. That experience gave her the confidence to take on a new role: instructional coach in the Sequoia Union High School District,** where she is responsible for the design and implementation of professional development for all science teachers in the district.

Daisy's work with the Exploratorium helped her plan potential sequences of activities that engage learners in the Science and Engineering Practices (SEPs) inspired by their own observations of and interest in a phenomenon, and driven by learners' own questions.

"[Learners] are no longer learning about something, they are trying to figure out something. It is no longer a list of facts or 'Here is a hands-on activity.' It is, 'Which practice is each activity providing for the students to engage in?' And 'How is that activity going to help learners address something they are figuring out and prompt another step?'"

The NGSS are also language intensive; students must read, write, and visually represent their models and explanations of scientific phenomena, which can pose access issues for students:

"There are a lot of issues about equity, because this new model has the students talking to each other to figure something out. You have to create a classroom environment where the kids are comfortable not knowing something and they want to take academic risks. That is something even [native speaking] students are not comfortable with yet."

Daisy helps teachers address these issues by planning with them, observing their instruction, and debriefing with them. This approach is in line with the Exploratorium's discovery that teachers need tools and processes for changing their instruction.

To develop a professional learning program for the teachers she works with, Daisy drew on the Exploratorium's models and tools for providing phenomena-based, hands-on inquiry activities, for sequencing lessons, and for providing access to science with attention to equity.

SAN MATEO COUNTY

23 school districts
94,234 students
5,060 K–12 teachers

Since 2016, the Exploratorium has worked with science education leaders in every California county to support the implementation of the Next Generation Science Standards and the phenomena-based practices that engage student interest, elicit scientific thinking, and deepen student learning. Through the sponsorship of the **Exploratorium K–12 Science Leader Network,** the Exploratorium serves the state by equipping science leaders with resources, first-hand learning experiences, and ongoing connections that enable them to lead NGSS implementation in their local schools, districts, and counties.

exploratorium.edu/CAeducator/workshops

Prepared by Inverness Research, developmental evaluation partner for the Exploratorium K–12 Science Leader Network.

Inverness Research

A Science Leader Supports Novice, Non-Credentialed Teachers with Implementing NGSS

"Being a part of all of the workshops at the Exploratorium definitely has increased my confidence."

Katherine (Katie) Burns serves as a coordinator at the Teachers College of San Joaquin (TCSJ), an accredited institution of higher education within the San Joaquin County Office of Education. Katie brings more than 10 years of science teaching experience to her role as a teacher leader.

When Katie was assigned responsibility for teaching science content and pedagogy to 40 novice 6th–12th grade teachers hired on emergency permits, her greatest concern was the new teachers' lack of professional development:

"As brand new teachers, they have felt safest with old textbook lessons, which are not aligned with the NGSS."

Faced with the challenge of supporting underprepared teachers, Katie joined the Exploratorium K–12 Science Leader Network in March 2017. The Exploratorium equipped Katie with the professional development and resources she needed to help novice teachers incorporate phenomenon-based inquiry strategies of NGSS.

"Through what I have learned with the Exploratorium and shared, the new teachers have experienced subtle, very accessible changes in their practice that make science much more engaging for students."

SAN JOAQUIN COUNTY

14 school districts
148,000 students
7,069 K–12 teachers

The Exploratorium's pedagogy and resources drive Katie's leadership practice. **She now invites teachers into science inquiry and discourse by engaging them with phenomena and asking, "What do you notice?" and "What do you wonder?"** In a local summer professional learning program, Katie used Exploratorium resources to deepen teacher NGSS knowledge around sequencing student activities; graphing, modeling and incorporating visualizations; and designing experiences with phenomena in their schoolyards. She has also created professional learning modules based on local phenomena that other TCSJ faculty use to teach environmental literacy.

Through her work at the Exploratorium, Katie gained knowledge and confidence to lead others; as a result, her colleagues seek out her leadership.

Since 2016, the Exploratorium has worked with science education leaders in every California county to support the implementation of the Next Generation Science Standards and the phenomena-based practices that engage student interest, elicit scientific thinking, and deepen student learning. Through the sponsorship of the **Exploratorium K–12 Science Leader Network,** the Exploratorium serves the state by equipping science leaders with resources, first-hand learning experiences, and ongoing connections that enable them to lead NGSS implementation in their local schools, districts, and counties.

exploratorium.edu/CAeducator/workshops

Prepared by Inverness Research, developmental evaluation partner for the Exploratorium K–12 Science Leader Network.

Leading Next Generation Science Standards Implementation for Rural Educators

exploratorium®

Rural leaders are expected to support improvement in multiple subject areas and across grade levels. Yet they have access to fewer high-quality resources for their leadership. The **Exploratorium K–12 Science Leader Network** equips rural leaders with science knowledge, first-hand learning experiences, professional connections around the state, and practical materials they can use in their local science leadership.

SHASTA COUNTY

26 school districts

26,000 students

1,331 K–12 teachers

MODOC COUNTY

3 school districts

1,400 students

82 K–12 teachers

Mark Lewin is the Instructional Technology Coach for the Enterprise Elementary School District in Shasta County. With 20+ years of teaching under his belt, he leads the adoption process for the next generation science standards (NGSS) in his district and supports all of Shasta County.

The Exploratorium institute connected him with other science leaders: *"I have a rich network of people to rely on and ways I can continue my own professional learning."*

The Exploratorium provided Mark with core science activities that he has helped teachers use in classrooms and he has adapted for his own professional development workshops across Shasta County. Mark has also shared Exploratorium resources at statewide meetings of the California League of Schools.

Exploratorium activities are especially effective, according to Mark, because they embody the three-dimensional learning the NGSS calls for, and they are practical for classrooms: *"[A core Exploratorium activity] has a good anchoring phenomenon, clear cross-cutting concept, and an engaging practice—with inexpensive supplies and low material set-up."*

Liza Butler is an educational Renaissance woman, having taught high school English and served on the Modoc County instructional leadership team, where she led professional development in math, science, and language arts. Liza now serves as the elementary school principal in Tulelake Joint Unified District.

To help Modoc educators shift to NGSS, Liza sought out professional development for herself. Ultimately, it was the Exploratorium's leadership workshop that equipped her to help teachers grasp NGSS and begin to change their practice: *"Seeing how the team at the Exploratorium used an activity with parachutes as the anchor phenomenon to build a common base of knowledge among the participants in the workshop was something I'd never seen before. It was incredibly valuable."*

Liza adapted the parachutes activity and other Exploratorium resources to work with every K–6 teacher in Modoc county. Follow-up Exploratorium online workshops gave Liza additional ideas to share with teachers.

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exploratorium.edu/CAeducator/workshops

Prepared by Inverness Research, developmental evaluation partner for the Exploratorium K–12 Science Leader Network.

Inverness Research

Summary Findings from the External Evaluation

INVERNESS RESEARCH

The Exploratorium aims to strengthen leadership for science improvement in diverse local contexts across the state. Evidence gathered to date[1] affirms the consistent excellence of the Exploratorium's programs for developing K-12 science educators' leadership capacities. Over time, local science leaders are seeing positive results of their efforts to support teachers in implement NGSS. Still, large numbers of administrators and teachers lack the knowledge and resources they need to realize their goals of implementing NGSS. The combination of promising results and ongoing need suggests that the Exploratorium should continue—an even expand—its efforts to develop K-12 science leaders and support their local efforts to improve science.

1. The Exploratorium's institutes for K-12 science leaders earn consistently high ratings for quality and value.

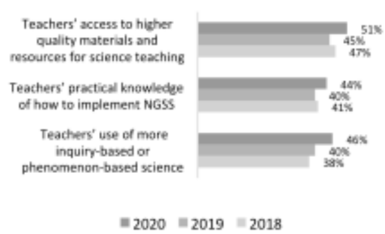
Exploratorium leadership institutes are—	**2020**	**2019**	**2018**
High in quality	98%	97%	100%
Higher in quality than other science professional development	*95%*	*92%*	*93%*
High in value	99%	95%	98%
Higher in value than other science professional development	*95%*	*90%*	*90%*

2. The Exploratorium leadership network helps K-12 science educators build multiple capacities for leadership.

Being part of the Exploratorium K-12 leadership network—	**2020**	**2019**	**2018**
Has made me a better provider of professional development	98%	95%	98%
Increases my confidence as a leader	94%	91%	91%
Provides an important professional community for me	91%	91%	95%
Gives me stronger ties to local science educators	89%	87%	91%
Increases access to opportunities for leadership	86%	85%	87%

3. Local improvements in classrooms are becoming more visible over time.

Changes in key areas*



Reported by K-12 science leaders.

4. The majority of administrators and teachers still require support to implement NGSS.

California's adoption of NGSS placed a heavy burden on under-equipped districts, schools and teachers. There are disparities between educators' goals and their capacities to meet them.

- While 60% of local administrators value science, only 26% understand NGSS*
- While 44% of teachers want to implement NGSS, only 36% are familiar with the standards.*

**Reported by K-12 science leaders May 2020.*

[1] **Sources of data**. Inverness Research (https://inverness-research.org/) has served as the external evaluator of the Exploratorium's initiative to contribute to science improvement statewide. Over four years, IR has conducted in-person observations and collected participants' ratings of leadership institutes, on-line workshops, and other core activities; engaged over 100 K-12 leaders in in-depth interviews; and measured network members' leadership activity and impact across the state through annual surveys.

Science Teacher Leader Profiles

May 21, 2022

Agenda

- Introduce activity
- Describe different leadership roles
- Place stickers on posters
- Conversations at posters about different roles
- Productive supports for science teacher leadership

Activity

Identify different roles that you identify in your leadership practice.

You have 12 dots each

- Put your initial on each dot
- Select leadership roles
    - weight your selections by using more dots on roles they mostly identify with and less dots on roles they only partially or sometimes identify with.
- Identify one or two roles you would like to develop more

Networker

Connects teachers, school, and/or district to social and material resources

- Knows what resources are available within the district and connects teachers with those resources.
- Connects with outside resources and then shares with others in their context.
- Identifies what teachers need.

Organizer

Coordinates the logistics of science reform initiatives dictated by their district and/or school

- Shares information and resources about district- or school-based decisions with teachers
- Makes space for teachers to collaboratively make sense of reform
- Plans professional learning resources to ensure that teachers are gaining the knowledge and support they need.

Innovator

Works to locate or develop new and innovative ideas and practices in their context to support science education reform

- Identifies problems of practice and develops solutions to those problems within their school or district context
- Tries out new and innovative practices in their classrooms
- Creates opportunities to disseminate their solutions to other science teachers

Activist

Actively takes steps to reduce and/or heal impacts of various forms of harm/violence/oppression in science education (including but not limited to inequities due to differences in race, gender, sexual orientation, religion, ethnicity, linguistic, ability)

- Reflects on their instructional practices to identify ways that they reproduce inequity
- Works to reduce the gaps in their instructional practice to make their teaching more equitable through connections with external organizations or through their own research
- Takes risks in their classrooms to attend to issues of harm and oppression in science learning spaces

Translator

Provides coherence across their organizations and acts as a liaison between administrators and teachers to translate policy to practice

- Has a vision of science education that “fits” with other district policies
- Develops systems of communication between administration and teachers to enact that vision.
- Collects and analyzes data on improvement efforts and seeks feedback from the teachers they work with on improvement efforts.

Ambassador

Is the "go-to" person for NGSS or equitable science instruction in their district or school.

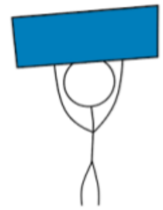
- Mentors student teachers and beginning teacher into the profession of science teacher and supports them to understand how to realize their vision for science education.
- Opens up their classroom to observation or models instruction during professional development.
- Is often the only science person at the table and make sure that science is attended to at the district and administrative levels.

Collaborator

Work with other teachers or district leaders to coordinate and implement reform efforts.

- Collaborates on developing or choosing curriculum for science reform
- Coaches teachers in their instructional practice, working side-by-side with teachers to modify and improve their instructional practice.
- Collaborates intentionally and strategically with administrators for extra leverage when necessary to further their work with teachers.

Activity - Place your dots



- Put your initials on each dot
- Select leadership roles
  - weight your selections by using more dots on roles you mostly identify with and less dots on roles you only partially or sometimes identify with.
- Identify one or two roles you would like to develop more

Conversation at posters

Go to one of the roles you identify strongly with and have a discussion with other STLs at that poster.

1. Why did you choose this role?
2. What aspects of your leadership work align with this role?
3. How do you think your leadership journey led you to this role? What critical events, people, or materials led you to this role?

Conversation about role you'd like to develop

1. Why did you choose this role to develop more?
2. What resources do you need to develop this role?
3. What has been constraining your ability to develop this aspect of your leadership practice?

Productive supports for STLs

- Communities of practice - reduces isolation and provides access to more resources; show up for each other joyfully
- Consensus around shared endeavor - supports talking across difference; understanding various perspectives; new/hybrid ideas and practices
- Understanding sphere influence - actor/network map; where they can have the greatest impact, leverage contextual resources (people, ideas, or materials); identify weak connections; areas of tension and challenge
- Time to work together - collaboration; translation into practice
- Modeled pedagogy - opportunities to experience activities as a learner; snacks, facilitator protocols
- Choice - provide multiple strategies to meet folks where they are in developing their leadership practice

APPENDIX F: PL PD TRACKER YEAR ONE AND YEAR 2

PL PD tracker

Start of Block: Default Question Block

Q1 What kind of professional learning support did you provide to other teachers in your organization this month? Check all that apply.

- mentoring new teachers (1)
- leading professional learning community (PLC) (2)
- workshop (3)
- online workshop (4)
- co-teaching (5)
- lesson study (6)
- curriculum development with teachers (7)
- none (8)

Q4 If you did some other type of professional learning activity this month, please write that here.

____

Q12 How much time did teachers spend engaged with your professional learning supports?

____

Q2 How many teachers participated in your professional development workshops this month?

____

Q8 Who participated in your professional learning activities? Check all that apply.

- K-5 teachers (1)
- middle grades science teachers (2)
- high school science teachers (3)

- other science teacher leaders (4)
- school administrators (5)
- community members (6)
- family members (7)

Q9 If others participated with your professional learning activities and they were not listed. Please write them here.

____

Q13
Did you use any of the following resources from the Exploratorium with teachers this month? Check all that apply.
- Snacks (1)
- NGSS Planning Tools (2)
- NGSS Sequencing Tool (3)
- Professional development videos (4)
- Other (5)

Q15 If you used an Exploratorium resource not listed, please write that here.

____

Page Break

Q3 Briefly describe how you engaged teacher learning in any of the activities you provided this month. If you did multiple, pick one that you think best represents how you provide professional learning opportunities.

____

Q5 How successful were these resources in supporting your vision for science instruction in your organization?
- o Very successful (1)

- Successful (2)
- Somewhat successful (3)
- A little successful (4)
- Not successful (5)

Q6 What did teachers learn from this experience? How did you measure their learning?

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Q7 What challenges emerged in your implementation of these resources?

____

Please submit a copy of what you provided teachers for their professional learning. This might include a facilitation guide for your workshop, teacher handouts, or sample activities. If you have questions about this step, please email Sara Heredia at scheredi@uncg.edu