STEM AND DATA: INSTRUCTIONAL DECISION MAKING OF SECONDARY SCIENCE AND MATHEMATICS TEACHERS

by

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ABSTRACT

This research is focused on the intersection of secondary teachers' data-use to inform instructional decisions and their teaching of STEM in STEM-focused high schools. Teaching STEM requires presenting more than just the content knowledge of the STEM domains. The methods of inquiry (e.g., scientific inquiry, engineering design) are skills that should be taught as part of STEM activities (e.g., science labs). However, under the data- and standards-based accountability focus of education, it is unclear how data from STEM activities is used in instructional decision-making. While teachers give tremendous weight to the data they collect directly from their observations of their classrooms, it is data from standardized testing that strongly influences practices through accountability mandates. STEM education alters this scenario because, while there is a growing focus on teaching STEM, important aspects of STEM education are not readily standardized. This mixed-methods study will examine the perspectives of 9th through 12th grade science and mathematics teachers, in STEM-focused schools, on data-use and STEM teaching. We developed a framework, adapted from existing frameworks of data-use, to categorize these perspectives and outline contexts influencing them. Through a concurrent triangulation design we will combine quantitative and qualitative data for a comprehensive synthesis of these perspectives.

CHAPTER 1: INTRODUCTION

Since the mid-1990s, two separate policy initiatives have been rising in the educational system. These initiatives are the *use of data to inform educational decisions* and a *focus on consolidating Science, Technology, Engineering, and Mathematics into a new instructional focal point known as STEM*.[1] Together, these data and STEM initiatives require a certain level of knowledge or literacy, on working with data and on teaching content within and across subject domains, to be effectively implemented in schools. In their preparation to be certified to teach, secondary education instructors learn both subject domain-specific content knowledge and pedagogical content knowledge appropriate for teaching their chosen subject domain. The growing use of data and the need to teach across multiple domains, as generally pushed in STEM initiatives, adds to the amount of foundational knowledge teachers need to have to function in the changing educational landscape. To understand the intersection of data-use and STEM, I will start by introducing the history that has led to the current state of these initiatives.

Policy Histories of Data-Use and STEM Initiatives in the U.S.

The use of data to inform educational decisions is closely tied to the idea of accountability in education. In 1965, the Elementary and Secondary Education Act (ESEA) was authorized to provide federal funds to help lower performing schools, which was followed by a push for accountability in identifying the schools that were not improving in performance (Jorgnsen & Hoffmann, 2003). ESEA was, legislatively, reauthorized several times throughout the latter half to of the 20th century to address educational trends of the time. However, the 2001 reauthorization of the bill titled the No Child Left Behind (NCLB) act marked a major change in the data focus of accountably in the United States.

[1] The discussion surrounding what constitutes STEM in education has greatly expanded the number of ways STEM can be conceptualized and implement in teaching. Later in this study I will discuss these conceptualizations from the literature and I will define how my research will characterize STEM education, including the distinction between STEM and Integrated STEM. However, at this point in this introduction I am using STEM as a generic term encapsulating all facets of this initiative.

The No Child Left Behind Act

The wording of the NCLB (2001) act focused on applying *scientifically based research* to gather empirical evidence to show school improvement. This mandate set the stage for changing the types of data used by schools. In the early days of this change, Ingram, Louis, and Schroeder (2004) used the phrases “systemic” and “systematically collected” data to distinguish this kind of “Data-Based Decision Making” from “the use of anecdotal information, experience, or intuition to make decisions” (p. 1267). Isaacs (2003) noted, in the context of school counselors’ growing need to use data, that there was an anticipation of programs moving towards being based on “data” over, “history, tradition, intuition, or personal preference” (p. 294). This focus on data brought with it a need for teachers and other educators to have the knowledge to understand how to work with data on a more sophisticated level than ever before. As this change in ideology surrounding accountability and the increased need for understanding data propagated through the school system, another initiative, STEM education, was also expanding in significance.

The Origins of STEM Education

A focus on STEM education, like the accountability and data-use initiatives, has its roots in events of the mid-twentieth century. The launch of Sputnik in 1957 presented a reality where the United States was not at the forefront of innovation and prompted a major refocus on science education, and by extension, engineering (Wissehr, Concannon & Barrow, 2011). Leading into the early 1990s, the National Science Foundation (NSF) advocated the importance of promoting the domains of Science, Mathematics, Engineering and Technology or SMET, a name that eventually morphed into the current moniker, STEM.

From this origin, I should distinguish STEM as an academic focus from STEM as a policy focus. While the academic questions of the nature of combining content from the STEM domains have been explored in detail (Bybee, 2013; Sanders, 2008), the larger policy discussions of STEM have tended to treat it as an umbrella term meant to convey the importance of making sure content from the four STEM domains is taught in schools (Breiner, Harkness, Johnson & Koehler, 2012). What exactly STEM is and how the domains of STEM can or should be taught are topics I will address in detail further in this study.

Mirroring the aftermath of the Sputnik launch, an interest in teaching STEM (or, more accurately, teaching the domains of STEM) began to take off in the mid-2000s amid fears of dwindling economic dominance. The National Research Council's (NRC, 2007) report titled *Rising Above The Gathering Storm* painted a picture of an impending shortage of scientists, engineers, mathematicians and technicians, laying the blame, in part, on the lack of focus on and support of these domains in K-12 education. While the report mentions each of the STEM domains, it gives special focus to science and mathematics:

> Laying a foundation for a scientifically literate workforce begins with developing outstanding K–12 teachers in science and mathematics. A highly qualified corps of teachers is a critical component of the No Child Left Behind initiative. Improvements in student achievement are solidly linked to teacher excellence, the hallmarks of which are thorough knowledge of content, solid pedagogical skills, motivational abilities, and career-long opportunities for continuing education. (NRC, 2007, p.113)

This passage highlights two important facets of an increased focus on teaching the STEM domains. The first facet is why educators should focus on the STEM domains. If the goal is an improved workforce as opposed to a more scientifically literate populace, then that has the potential to influence how education in the STEM domains is approached. The second facet is in the content and pedagogical knowledge needed to teach STEM domains. Teaching within just one of these subject domains requires teachers to have a considerable amount of knowledge related to both content and teaching practices of that domain.

Incorporating STEM domains into teaching, however, requires even more knowledge of content and practice. Discussion of education in STEM domains has revealed that some form of connection or integration should exist among the STEM domains in teaching (Nathan et al., 2013; Sanders, 2008; Stohlmann, Moore & Roehrig, 2012). Educational policy has also begun to espouse and acknowledge the interconnected nature of education in STEM (NRC, 2011; NRC, 2014). Following a path paralleling the growth of data-use, the wider implementation of integrated STEM education brings changes in the expectations for teachers' subject-matter or pedagogical content knowledge (NRC, 2014).

Every Student Succeeds Act and Current Policy

In December of 2015, the U.S. federal government passed the Every Student Succeeds Act (ESSA) as a reauthorization of ESEA to replace the NCLB Act. ESSA contains two provisions relevant to the interest of this study. First, ESSA relaxed national accountability standards by shifting accountability for student performance from the federal level back to the state level. States became responsible for developing and implementing plans for improving instruction and overcoming existing achievement gaps. This policy shift is important because this change in accountability structure may be a catalyst for changes in educators' data-use. Given the recentness of this act, there is currently no research on the long-term effects of this legislation. However, an examination of individual state's Department of Education websites and press releases reveals that many states have begun work towards implementing the new policy.

Second, the act placed an increased focus on STEM education, designating funding to support STEM professional development and teacher organizations. This change made STEM a topic of national education policy. A majority of states have advanced their own STEM policies in line with this push at the federal level (Carmichael, 2017). STEM and data-use initiatives have become intertwined into education, prompting the need to research and understand their implementation.

Statement of the Research Problem

With the growing data-use and STEM focus in education, questions arise as to what happens at the intersection of these two fronts. Separately, the implementation of either of these initiatives in a state or school district requires teachers to develop specific new knowledge and practices in their classrooms. Implementing both initiatives together necessitates an even larger pool of new knowledge that teachers need to adopt and understand. I am interested in looking at what happens in education environments where both initiatives are being implemented. An unanswered question in this scenario is in what way does data from STEM education get incorporated into the data-based decision-making process, if at all?

Teaching STEM involves more than understanding the content knowledge from the four domains; it includes having a working knowledge of the methods of inquiry associated with those domains (e.g., scientific inquiry or engineering design) (Eekels & Roozenburg, 1991;

Frykholm, & Glasson, 2005; NRC, 2012). While aspects of these methods can be standardized (e.g., the Three Dimensions of Science Learning found in the Next Generation Science Standards), standardizing assessment of inquiry learning activities, as found in STEM, can be difficult (Ruiz-Primo & Furtak, 2006). Judging a student's understanding of a laboratory procedure or design activity is more complex then ascertaining their content knowledge since the former relies on a teachers' subjective observations and interpretations of a student thoughts or actions while the latter can be, to some degree, objectively tracked through quantitative assessments (Halonen et al., 2003).

In general, it has been observed that teachers place more weight on their personal observations for instructional decision-making while administrators, further from the classroom, focus more on psychometrically verified scores from standardized assessments (Coburn & Talbert, 2006). Standardized assessment has been the predominate data source for the comparison and judgment of student performance sought by accountability mandates (Ewell, 2008). However, in a STEM focused education setting, either an isolated STEM lesson or a dedicated STEM school, a large component of the students' performance in STEM activities (i.e., everything that is not content knowledge) can rely on the observations made by the teachers. The growing focus on STEM education raises questions about the sources of data considered relevant for assessing STEM and leads me to ask what role data from STEM educational settings have on the data-based decision-making process.

The past few decades have seen a marked increase in designated STEM schools (Eisenhart et al., 2015), mirroring the increased focus in STEM education overall. While research has looked into the structures of (Lynch, Behrend, Burton, & Means, 2013; Scott, 2012) and obstacles facing STEM schools (Eisenhart et al., 2015), no research has looked into data use in these schools. STEM schools situated under the current accountability focus domain provide an opportunity to look at the intersection of STEM and data-use in an educational setting.

Purpose of this Study

The purpose of this research is to examine how teachers working in secondary education (i.e., grades 7 through 12) in STEM focused schools use data to inform instructional decisions. Of interest is where data associated with STEM (e.g., assessments from STEM inquiry-based lessons, levels of participation in STEM outreach activities) fits into the overall decision-making process. For this study, I will examine these ideas through the following research questions.

- What are secondary educators' in STEM focused schools perspectives surrounding teaching and data-use in STEM education?
- What do secondary educators in STEM focused schools see as the role of STEM inquiry activities in informing educational decision-making?
- How do secondary educators, in STEM focused schools, describe their practices of implementing STEM education?

Definitions of Important Terms

STEM and Integrated STEM

Despite its prolific use, the term STEM does not have an agreed upon definition in the literature (Breiner et al., 2012). The depth of knowledge explored in each of the STEM domains, the ways the domains are connected in instruction, and the methods used to explore content in each domain (i.e., types of inquiry) can vary widely, leading to very different conceptualizations and implementations of STEM (Barakos, Lujan & Strang, 2012; Bybee, 2013). In this study, STEM refers to a wide range of educational plans, from the teaching of the four individually siloed domains to the integration of all of the domains into a seamless educational experience. Barakos, Lujan and Strang (2012) outlined how one may visualize a continuum of STEM education with the integration of subject domains determining the final arrangement of STEM (See Figure 1).

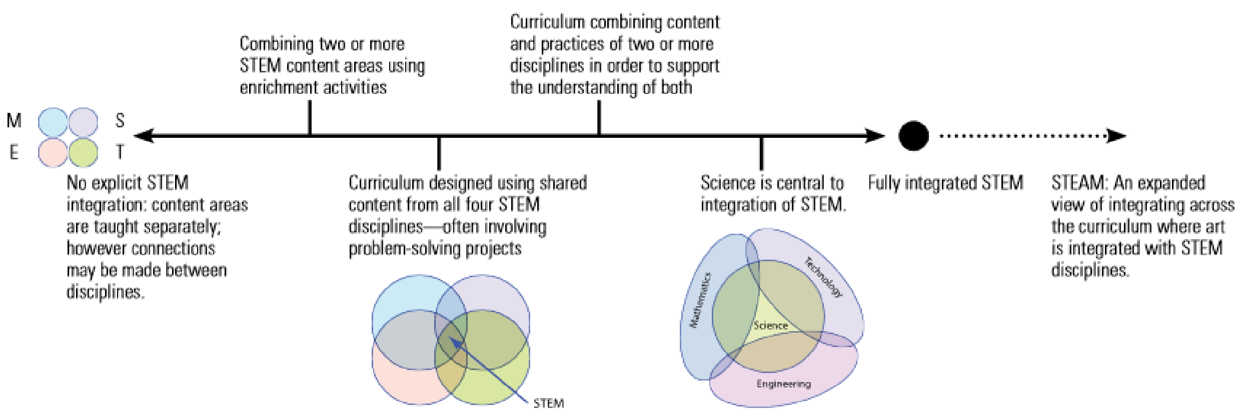

Figure 1. A continuum of conceptions of STEM (Barakos, Lujah & Strang, 2012).

With this view of STEM, what does integrated-STEM mean? As discussed by Breiner and colleagues (2012),

> From a policy perspective …or from an educational perspective like most K-12 agencies/school districts, STEM is often considered a traditional disciplinary coursework (science, mathematics, technology, and engineering) lacking an integrated approach. Thus, the most important modern conception of STEM education might be the notion of integration—meaning that STEM is the purposeful integration of the various disciplines as used in solving real-world problems. (p.5)

In this sense, *integrated*-STEM does not differ from STEM in an academic discussion. I can talk about STEM education that is more or less integrated or I can discuss integrated-STEM with differing levels of integration. I consider integration to be a fundamental part of STEM. The adjective, integrated, serves to limit the ambiguity surrounding STEM from policy or colloquial discussions, a point mirrored by Sanders (2008) in his reasoning for renaming their STEM education program to Integrative STEM education.

With this perspective in mind, I will use the terms STEM and STEM education as blanket terms to refer to all potential implementations and conceptualizations of teaching across the STEM domains. I do not consider versions of STEM as being better or worse than others, but I will rank them on levels of integration based on the number of domains present in participants' descriptions of lessons or curricula and the connections made between those domains.

Data Use

Data and Assessment Literacy

The discussion of data and data-use carries a broad set of meanings. To understand these terms, I need to distinguish *data* versus *assessment*. Assessment is a kind of data (Coburn & Turner, 2011). Assessment data, such as a test score, can be used to inform certain decisions just as other data, like socio-economic or ELL status, may inform decisions. However, assessment has taken on a prominent role in the discussion of data due to the focus on standards and standardized testing that has come out of accountability initiatives (Mandinach, Honey & Light, 2006). When I refer to data-use, I am referencing all forms of information a teacher may use in informing decisions. I will single out when assessment data is the primary focus of the data-use process.

Data literacy involves more than the mere existence or collection of data; it reflects an "ability to understand and use data effectively to inform decisions" (Mandinach & Gummer, 2013, p.30). Data literacy, in general, encompasses all forms of data. However, the prominent role of assessment in the K-12 system has led to specific discussions of understanding and effectively using assessments, labeled as *assessment literacy* (Popham, 2009; Volante & Fazir, 2007). Following my previous convention, I will use the term assessment literacy for specific assessment related discussions and use data literacy for discussions covering all forms of data.

Teachers' Perspectives of Data Use.

Next, I need to define how I am distinguishing teachers' perspectives in the context of my research questions. When looking at a teachers' perspective related to data, it is important to consider that their actions may tell a different story. Teachers may have certain beliefs about the usefulness or interpretation of some available data but respond to the data in a certain way based on policy initiatives they are tasked to follow (Apple, 2004). At the same time, how a teacher implements a policy may be influenced by the beliefs they have. Individual beliefs and chosen practices, in action, are intertwined with policy and implementation of policy to influence instructional decisions (Ingram, Louis, & Schroeder, 2004; Jacobs, Gregory, Hoppey, & Yendol-Hoppey, 2009). It is important to acknowledge this divergence that can exist between policy initiatives and internal beliefs in implementation since the perspectives obtained through this research will likely be a product of these internal and external influences. For this research, teachers' perspectives of data-use encompass the ideals *expressed* by teachers on engaging in data-use for educational decision-making and on the data-use practices they claim to engage in. I also apply this same structure when exploring teachers' perspectives on aspects of STEM.

Significance of this Study

Data has become a major driver of educational decision-making. The use of data for accountably purposes has had a particularly strong effect in shaping the course of schools' educational focus (Apple, 2004; Beaver & Wienbaum, 2015; Ingram, Louis, & Schroeder, 2004;

Jacobs el al., 2009; Jennings & Bearak, 2014). A focus on STEM education has the potential to influence this data-use scenario since the inquiry activities of the STEM are not easily assessed through standardized testing methods (Ruiz-Primo & Furtak, 2006). Assessment of these activities relies more heavily on the subjective interpretations of the teachers (Halonen et al., 2003), which was an aspect of data that the focus on standards was originally intended to eliminate.

The significance of this study is in beginning to understand how this data from STEM education is being used in the decision-making processes of teachers in STEM schools. If a school claims to be a STEM school but does not use STEM data in its decision-making, then this raises questions about what the "STEM school" description means in practice. Further, what effect does the way STEM inquiry activities are taught and assessed have on the STEM focused instruction? This study gives insight into the interplay of STEM education and the data-use that informs educational decision in such schools and into teachers' perspectives of their implementation of STEM education in a STEM school.

This research is of value to educators interested in focusing on STEM education in the current data-driven school environment. Specifically, for administrators, identifying how teachers' perspectives come together on both data and STEM initiatives gives insight into how these initiatives may be implemented by teachers and point to opportunities for targeted professional development to align teachers with desired data-use or STEM goals. Further, this study contributes to the research of data-driven decision-making through examining how data from STEM teaching may be used in and influence the educational decision-making process.

Summary of the Theoretical Framework

The theoretical framework for this study draws on three main ideas: the overall cycle of data-use from the collection of raw data to the outcomes of decisions, the decision-making process within the data-use cycle, and the different potential implementations of STEM education based on the different conceptions of STEM. The first two facets build on Schildkamp and Poortman's (2015) data-use theory of action framework. This framework is an expansion of numerous prior data-use frameworks (Coburn & Turner, 2011; Ikemoto & Marsh, 2007; Mandinach, Honey, Light, & Brunner, 2008). It provides a structure for understanding the cycle of the data-driven decision-making process while allowing discussion of how educators think about and make sense of data throughout this process.

The third facet of my framework categorizes diverse conceptualizations of STEM that have been articulated in the literature (Barakos, Lujan, & Strang, 2012; Bybee, 2013; NRC, 2013; Sanders, 2008) and which may be implemented in the teaching environment. Individual teachers may have different conceptions of how STEM curricula or lessons should be taught or how the STEM focus of the STEM school is organized. Building from the discussions in the literature of what constitutes STEM, I define levels of implementation of STEM, with more complex levels indicating the inclusion of more domains and the inclusion of inquiry activities and data from these activities, to categorize educators' perspectives of STEM. This categorization helps to clarify what individual teachers envision STEM to be to facilitate understanding of their perspectives relating to data-use and STEM.

Overview of this Study

In chapter two, I look at literature in the two main areas of data-use and STEM education. Under data-use, I will further examine the definitions of data, the influence of the accountability movement, the influence of leadership, and teachers' decision-making practices. I will expand on the still unclear nature of STEM and the conceptualizations of how STEM may function. From this literature, I construct a theoretical framework that combines educators' perspective on both data-use and STEM to explore to what extent aspects of STEM inform data-use.

In chapter three, I lay out the methodology for this concurrent triangulation mixed-methods work. Studying the intersection of STEM and data-use introduces several constraints on research sites, owing to the flexible nature of how these initiatives may be implemented in school environments. I use these constraints to justify focusing my research on a selection of teachers in STEM focused schools. I describe the process of how I collected quantitative data through surveys and qualitative data through semi-structured interviews and how I plan to complete my synthesis according to the mixed-methods design.

In chapters four and five I present the results and discussion of the qualitative findings of the study. Then, in chapters six and seven I present the results and findings from the quantitative portion of this study. Finally, in chapter eight I present the concluding synthesis of the study.

CHAPTER 2: LITERATURE REVIEW

In this chapter, I examine the literature on data-use and STEM and describe a theoretical framework to investigate the use of data in STEM educational environments. Many different contexts influence secondary educators' decisions with regards to data, including: role or proximity to the classroom (Coburn & Talbert, 2006; Young, 2006), subject domain taught (Datnow, Park,& Kennedy-Lewis, 2012; Grossman & Stodoksky, 1995; Siskin, 1991), influence of leadership (Halverson, Grigg, Prichett, & Thomas, 2007; Marsh, Bertrand, & Huguet; 2015; Park & Datnow, 2009; Young, 2006), participation in collaboration (Coburn & Talbert, 2006; Marsh, Bertrand & Huguet, 2015), and conceptions of valid data (Coburn & Talbert, 2006; Datnow, Park,& Kennedy-Lewis, 2012; Ingram, Louis, & Schroeder, 2004). A number of frameworks on data-use encapsulate the influence of these contexts (Coburn & Turner, 2011; Ikemoto & Marsh, 2007; Mandinach, Honey & Light, 2006, Marsh, Pane & Hamilton, 2006; Schildkamp, Poortman & Handelzalts, 2016). Highlighting these existing frameworks and the many influences on data-use reveal the complexity that may arise with adding STEM data to the educational decision-making process. This complexity is rooted in the fact that teaching in STEM education is not well defined (Breiner et al., 2012; Nathan et al., 2013). There are many views of the purpose of teaching STEM and on how the domains of STEM should be taught, but there is no one agreed upon goal or method (Brown, Brown, Reardon & Merrill, 2011; Pitt, 2009). Exploring the many conceptions of STEM allows me to identify and rank characteristics I can use to differentiate perceptions of STEM education as described by teachers. Combined, this information on data-use and STEM will form the basis of a new theoretical framework for exploring STEM data-use as a subset of all data use in a STEM education environment for the purpose of exploring the following research questions:

- What are secondary educators' in STEM focused schools perspectives surrounding teaching and data-use in STEM education?
- What do secondary educators in STEM focused schools see as the role of STEM inquiry activities in informing educational decision-making?
- How do secondary educators, in STEM focused schools, describe their practices of implementing STEM education?

Data-Use To Inform Educational Decisions

Teachers and administrators are situated in different educational contexts that inform the decisions they make on data. Teachers are in direct contact with the realities of the classroom but are held accountable to policies and mandates from school and central office administrators and state and federal standards. To understand teachers', specifically secondary education teachers', uses of data requires a discussion of both what the terms data and data-use entail and an understanding of the contextual influences that affect data-use.

Data & Assessment Literacy

Four related terms in the data-use literature are data, data literacy, assessment and assessment literacy. Literacy, in the educational context, relates to the use of either data or assessment to inform decisions about instruction. Jacobs and colleagues (2009) described data literacy in terms of the conceptions teachers have about using data to inform instruction, and Mandinach and Gummer (2013) defined it specifically as the "ability to understand and use data effectively to inform decisions" (p. 30). In a similar vein, assessment literacy refers the ability to properly choose, use, and interpret assessments to inform instruction (Popham, 2009; Volante & Fazir, 2007).

What distinguishes these two literacies is the definitions of data and assessments. Data can include the outcome of assessments but in principle encompasses many kinds of sources of information (e.g., attendance, ESL and SES status). Assessments serve to produce data. Assessment literacy is the understanding of what counts as a valid assessment to produce data for a given instructional method and what counts as valid interpretations of the data that comes from assessments (Popham, 2009).

The accountability focus in education has resulted in an increased focus on assessment, particularly in performance on standardized testing. As Mandinach and colleagues (2006) stated, the "use of data in meaningful ways assumes at least some level of facility with and knowledge about assessment information" (p. 5). Even though the act of assessment serves to provide data, assessment itself has a heightened importance in the discussion of data.

Incidentally, the differences surrounding data, assessment and their associated literacies obfuscate the meaning of data-use to inform instruction. As pointed out by Ikemoto and Marsh

(2007), educators who are involved in very different practices surrounding data-use may still use the same language of data-use to describe their practices as there is no "common understanding among educators of exactly what [data-use] entails, or a sufficiently nuanced vocabulary for them to describe various processes and activities sin which they are engaged" (p. 106-107). For research, ambiguity surrounding understanding educators' data-use is mitigated by the construction of data-use frameworks, which break down many potential facets surrounding how data may be used. I will discuss the role of these existing frameworks at the end of this chapter, as part of the discussion of the framework I have developed.

The Accountability Movement

The current focus on data-use arose from a national focus on having evidence to show improvements in instructional practice and student outcomes. The NCLB Act mandated the development of state level assessment test and standards to set a level of proficiency that all students must meet (Simpson, LaCava, & Graner, 2004). Accountability to meet these standards has been a driver for the use of standards-based data to inform educational decisions (Jacobs et al., 2009; Ingram, Louis, & Schroeder, 2004). However, this focus on standards-based data does not ensure a complete acceptance of the data. Both teachers and administrators may take a limited view of what data findings imply in terms of school improvement (Beaver & Weinbaum, 2015; Ingram, Louis, & Schroeder, 2004). When examining data, educators may not be certain of how to interpret the data to improve instruction (Farrell & Marsh, 2016; Beaver & Weinbaum, 2015). Further, the scope of curricula lessons taught by teachers, and in turn the data assessed, may be narrowed to meet the accountability focus (Ashby, 2009). In this way, accountability forms the backdrop of data-use. The policies that are established, the kinds of data that are focused on and the decisions that are made are all, ultimately, influenced by the need to meet the ever-present accountability requirements that schools are expected to achieve. All further discussion surrounding data-use stems from this base.

Leadership and Policy

Data leadership may influence teachers' data use through establishing an environment focused on data (Halverson, Grigg, Prichett, & Thomas, 2007; Park & Datnow, 2009) and support for improvements in data-use literacy (Marsh & Farrell, 2015). Young's (2006) case study to examine school leadership in the context of agendas (e.g., choices of data, plans for professional development and consideration for time for working with data) looked to identify the influence administrative leadership has on data-use. The school leadership's involvement with teachers resulted in greater alignment between how data was used for "instructional practices and leadership's exposed expectations for such use" (p. 544). The active role taken by administrators in establishing and guiding data-use helped maintain a coherent focus on data for meeting accountability measures. Leadership has also been observed to influence teachers' participation in collaborative efforts (e.g., professional learning communities (PLCs)) (Marsh, Bertrand & Huguet, 2015) through the implementation of policies that structure the social interactions surrounding data (Halverson et al., 2007).

Collaboration

In the same vein as agenda-setting actions of administrators, collaborative work sets a norm for guiding teacher data-use practices (Young, 2006). Collaboration takes many forms including work with individuals, such as instructional and data coaches, and organized time with working groups like professional learning communities (PLCs) (Marsh, Bertrand, & Huguet, 2015) and data teams (Schidkamp, Pootman & Handelzalts, 2016). However, establishing groups is not sufficient for promoting data-use; it is participation within the group that is important to changing teachers' practices (Marsh, Bertrand, & Huguet, 2015). Agreement on a unified focus, such as common assessments or specific standards, prompted by collaboration can push educators to more unitary positions regarding conceptions of what constitutes valid data and valid uses of data (Coburn & Talbert, 2006).

It is important to note that collaborative work does not, in general, exist independently of administrative oversight. Marsh, Bertrand, and Huguet (2015) observed that while participation in PLCs and work with coaches did change teachers' practices, school leadership was also found to be an important catalyst; principals had a role in influencing the organization of PLCs and teacher-coach interactions, and district administration exerted influence through policy and funding decisions. The allocation of responsibilities in collaborative work is tied to leadership in terms of specifically defined roles teachers may take in assisting the collaboration process. Work within explicit roles, compared with general participation, can vary with administrative engagement in the data culture (Young, 2006). The influence of leadership and collaborations serve to try to shape teachers' perspectives of data use.

Teachers' Decision-Making Practices

The NCLB act (2001), with its focus on 'scientifically based research', was a major piece of legislation regarding data-use in schools. The drive for empirically measurable data, through standardized testing, to show improvement in performance was a way to ensure schools were conforming to accountability standards (Wiliam, 2010). The advantages here are in the ease of mass deployment of assessment and the, arguably, objective nature of the standardized test score (McNeil, 2002). Objective here is not synonymous with accurate; it only means that the test is itself consistent across students for the purpose of comparison.

While standardized test data is mandated at the policy level, it is not the only kind of data that may be meaningful in the decision-making process. The use of "history, tradition, intuition, or personal preference" (Isaacs, 2003, p.294) and "anecdotal information [and] experience" (Ingram, Louis, & Schroeder, 2004, p. 1267) may have been data sources pushed aside by the NCLB act, but they encompass data given weight by teachers (Young, 2006). Alternative conceptions of the data focus of education, such as *Evidence-Based Instruction*, have sought to expand the view of data to incorporate not just the empirical but also subjective knowledge (e.g., professional wisdom) of instructors as an important part of the decision-making process (Smith, 2003; Zucker, 2004).

Teachers have both objectively measurable and subjectively elicited data available to inform their decisions, along with policy driven expectations, leadership interventions, and collaborative decisions on what data is considered important to act on. However, policy and the implementation policy do not always align and decisions surrounding data will, ultimately, be informed by the kinds of data teachers believe most accurately reflect their teaching and classroom.

Conceptions of Valid Data.

The school system consists of a hierarchy of levels, and groups at each level may use data as part of their decision-making processes. Due to unique contexts at each of these levels, how educators are situated and organized within the school system impacts their interpretations of data and considerations of what data is valid evidence of learning (Coburn & Talbert, 2006; Datnow, Park, & Kennedy-Lewis, 2012; Marsh, Bertrand, and Huguet, 2015; Schildkamp, Poortman, & Handelzalts, 2016; Young, 2006). Coburn and Talbert (2006) looked at educators' conceptions of what counts as valid evidence for making educational decisions, finding that an educator's role along with past involvement with educational reform efforts shaped her/his perspectives. Regarding the ability of systematically researched data to inform instruction, they observed that administrators had the strongest faith in research-based data claims, preferring to focus on psychometric properties and alignment with desired academic outcomes, while teachers had the weakest, giving more weight to data considered to provide "insight into student thinking and reasoning or was authentic and rooted in teacher judgment" (p.484). The idea of the hierarchy of the school system reveals itself here as the researchers observed that principals were positioned between the extremes of the teachers working directly with students and higher-level administrators' policy decisions.

The broad array of data sources available to educators, from benchmark assessments to personal intuition, can result in a diverse range of educational decisions (Datnow, Park, & Kennedy-Lewis's, 2012). Young (2006) observed that, for teachers, data "consist both of what teachers reveal of their classrooms, as in war stories and student work samples, and how *they* [emphasis added] measure progress" (p. 538). In this regard teachers have been observed to give increased weight to subjective data tied to their classroom experiences (Datnow, Park, & Kennedy-Lewis's, 2012; Ingram, Louis, & Schroeder, 2004). Teachers tend to find more direct value in their personal observations over standardized assessment data, or hold dual conceptions of data, treating assessment data as meaningful for certain tasks (e.g., grouping students and sorting, selecting content) but not as a good indicator of students' class performance (Beaver & Weinbaum, 2015). This is an important point to note as I move on to discussing STEM education. Inquiry activities advocated by STEM, such a science laboratory, are one place where class performance on the activities and standardized assessment of the surrounding content knowledge could lead to divergent claims around a student's achievement. A deeper look at STEM is needed to understand how aspects of STEM education entwine with how data-use policy and practice are implemented.

STEM Education

On the surface, STEM seems like it should be easy to conceptualize. It is an educational initiative that increases the focus on teaching content from the four STEM domains. However, looking at implementing STEM raises several pedagogical concerns. First, there is the idea that educational domains, in general, do not involve only content knowledge to learn but also require knowledge of how to use the methods of inquiry associated with the domain for thinking and deriving new knowledge within the domain (Eekels & Roozenburg, 1991; NGSS Lead States, 2013). Questions have been raised on how teachers can best instruct students in these ways of thinking, which is to say, on what pedagogical content knowledge (PCK) is needed by teachers (Stohlmann, More, & Roehrig, 2012).

Second, there is the idea that STEM domains can or should be integrated to combine content and methods of inquiry from the different domains (Breiner, Harkness, Johnson & Koehler, 2012; Sanders, 2008). This compounds the first issue above because a teacher now needs to know content, inquiry, and pedagogical content knowledge from multiple domains. The label *Integrated-STEM* is often used when discussing integration; however, the label is not universal as some research and policy discuss “STEM” or STEM education in terms of its integrated or interdisciplinary nature (Brown et al., 2011; Gerlach, 2012; State Educational Technology Directors Association, 2008). Following these examples, the reader should interpret references to STEM and STEM education, in this study, as including and encompassing any notion the reader may have of Integrated-STEM. Despite the interest in integration of the subject domains, there is currently no agreement on the form that this integration, and by extension STEM, should take (Breiner et al., 2012; Pitt, 2009).

The third issue is in the different ways the structure of STEM can be conceptualized and implemented (Barakos, Lujan & Strang, 2012; Bybee, 2013). The notion of integrating content across domains underlies this issue, but this issue focuses on the bigger question of how STEM is put together. What is the focus of teaching STEM? What domains or content from domains is covered? What connections are made across domains? Are some domains treated more importantly than others? These are all questions that reveal how STEM education programs, curriculum, or lessons may vary in their implementations. Understanding the different ways STEM may be conceptualized will be important to defining a framework that encompasses the possible implantations of STEM.

The Lack of Consensus on Implementing STEM Education

Since the early 2000s, United States economic policy has had a renewed focus on the importance of mathematics, science and engineering in response to worries of dwindling economic dominance due to the relatively small numbers, compared with the population size, of U.S. students who go into those fields (NRC, 2010). This added focus on science and engineering mirrors what happened in the 1950s when the government worried about falling behind on technological dominance following the Soviet Union's launch of Sputnik. The economic policy focus has seemingly become entangled with the educational interest in STEM education, due both to adjacency in desired educational outcomes[2] and timing of the renewed interest in teaching these subject domains. Following this, STEM has become a part of the national education policy focus (NRC, 2011; NRC, 2013; NRC, 2014).

However, despite the focus on teaching STEM, there is currently no agreement in the education research on what such teaching entails (Breiner et al., 2012). Pitt (2009) raises several issues noting,

> There is little consensus as to what it is, how it can be taught in schools, whether it needs to be taught as a discrete subject or whether it should be an approach to teaching the component subjects, what progression in STEM education is, and how STEM learning can be assessed. (p. 41)

Further, the concept of STEM is not fully understood or agreed upon among educators who consider it important (Brown, et al., 2011). Bruce-Davis and colleagues (2014) had observed that teacher and administrator collaboration in STEM schools could bring alignment in developing "curricular and instructional strategies … promoting the development of talent in STEM fields" (p. 294). However, this agreement on STEM was limited to the school level. An absence of consensus, higher within and across education, complicates both research on and implementations of STEM since there are no agreed upon standards from which to derive comparisons (Nathan et al., 2013).

[2] The call to increase the focus on science, mathematics and engineering differs from teaching STEM in that the former only looks for the domains to be taught without considering connections between them. STEM, in the educational capacity I am using in this study, implies some connection or integration among the domains. However, it is not unusual for individuals to use STEM as a proxy for naming all four domains. The language surrounding this is not standardized and context is necessary when identifying what is meant by the phase STEM when encountered in the education literature and in policy documents.

Different Mandates for Implementing STEM.

One of the hurdles in defining STEM is in the different reasons for focusing on STEM. As mentioned previously, STEM became a topic of U.S. national education policy in response to concerns surrounding the decreasing number of STEM professionals and possible dwindling economic dominance (NRC, 2010). However, the academic perceptions of STEM cover a wider array of potential outcomes. Bybee (2013) listed three goals that a STEM education focus can work towards: “a STEM-literate society, a general workforce with 21st-century competencies, and an advanced research and development workforce focused on innovation” (p. X). This implies STEM education may target a range of outcomes that include making society more STEM-literate, ensuring there are more STEM-literate workers entering the job market, and promoting the training of increased numbers of STEM professionals.

Using STEM to teach fundamental knowledge to form a STEM-literate society is a very different goal than using STEM to guide and train individuals into STEM-professions and implementing the desired policy outcome could influence how STEM curricula are structured. STEM[3] policies that focus on generating workers have been described as neoliberal, or highly capitalistic in focus, and lead to concerns of how this capitalist focus may shape or limit the scope of education (Carter, 2016). While the influence of the economic systems driving STEM policy are important for understanding the forces that shape STEM education, I forgo further discussion of those issues to focus on what shapes STEM education may take.

Components of Education Surrounding Integrated-STEM

Before outlining specific conceptions of the organization of STEM that may be implemented in schools, it is important to discuss the teaching knowledge that is intertwined with STEM education. This includes the knowledge of the methods of inquiry (and relevant pedagogical content knowledge) associated with teaching individual domains, the use of active learning pedagogies, and the general concept of STEM literacy.

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[3] Carter (2016) argued that STEM is just a renaming of science education, a point that is hard to dismiss given how much emphasis the STEM policy literature places on science. However, while she treats STEM as science education her arguments cover the general STEM policy literature. With this I argue that the concerns surrounding neoliberalism affecting STEM, as a proxy for science, are equally valid for examining a general conception of STEM.

Domain Knowledge: Inquiry and Subject.

The unique methods of inquiry associated with each domain are part of what define STEM. These methods of inquiry differ with the distinct philosophical underpinnings of each domain. For example, science and engineering can be viewed as having distinct objectives where science's aim is "to bring about a change in the realm of the mind: new or improved knowledge" while engineering's aim is to "bring about a change in the realm of the external material world" (Eekels & Roozenburg, 1991, p. 198). In turn, the methods of inquiry associated with these domains (i.e., scientific inquiry and engineering design, respectively) are distinctly organized to pursue these outcomes.

Focusing on methods of inquiry for integrating STEM domains involves more than just the inclusion of content for multiple domains. Frykholm and Glasson's (2005) study of preservice mathematics and science teachers revealed that, in an integrated mathematics and science lesson, the mathematics was only used as a tool in the activities. In considering mathematics as a domain with a unique purpose and method of inquiry, they note this tool use perspective "may fall short of how some in the mathematics community define mathematics and promote its study in the K-12 experience" (p.139).

Frykholm and Glasson's (2005) study leads to two different but equally important considerations. First, it is arguable that the integrated activities in the study did not actually portray mathematics as just a tool, and it was the perspectives of the participants that relegated it as such. This points to the issue of STEM literacy or the knowledge of teaching across subject domains. Teachers are trained within the content and pedagogical content knowledge of their own subject domain, but issues may arise when they try to integrate content from other domains in which they are not trained (Stohlmann, Morre, & Roehrig, 2012).

The second consideration is that if mathematics was just a tool in *that* activity, this raises questions about what constitutes integration in STEM, as it demonstrates that integration is not just the inclusion of domains, but also the inclusion of domains in a meaningful capacity. If a domain is being trivially used in an activity (e.g., mathematics for semi-relevant calculations, technology in the form of using computers for research), then to what extent can it be labeled an integrated STEM activity?

Defining Tool-Use of Subject Domains

Here I need to take a brief detour to clarify what I mean when I say content from one domain is being used as a tool to support learning content from another domain. Consider these two scenarios: (a) Mathematics calculations are being used to complete a science focused activity but nothing deeper is being learned about the math, and (b) science content is being used to give context to setup a mathematical calculation but nothing deeper is being learned about the science. In both cases one subject domain may be referenced or used extensively but is not the focus of learning. The tool-use language for describing this relationship between domains comes out of Frykholm and Glasson’s (2005) observation that “prospective science teachers often viewed mathematics as providing the tools for examining scientific phenomena.” (p.136).

Technology is the subject that is strongly affected by this mindset. The ITEEA (2007) defined technological literacy as the “ability to use, manage, assess, and understand technology” (p.7). Here understanding encompasses not just the how a technology works but understanding the role a technology plays in society and the decisions that should be made surrounding it. However, the implementation of technology in practice tends to focus more on the *use* aspect with students using computers, calculators and lab equipment to work on assignments for other subjects without any emphasis on the role of technology. The tool-use conception becomes just the literal use of technological tools in the classroom which is not really the role of technology envisioned by technology educators or by my understanding of STEM. This distinction of tool-use is relevant in my development of a framework that accounts for different possible implementations of STEM.

Pedagogies for Active Learning.

Another aspect of STEM education is the pedagogies that are used to teach a domain's methods of inquiry. A variety of active learning pedagogies (e.g., project, problem, discovery, and inquiry-based learning) are described in the literature as alternatives to traditional instruction. Using these pedagogies to teach gives students the opportunity to learn and apply a domain’s methods of inquiry. As an example, science assessment in the Next Generation Science Standards (NGSS) is envisioned such that “students not only ‘know’ science concepts; but also, can use their understanding to investigate the natural world through the practices of science inquiry" (NGSS Lead States, 2013, p. 1). Teaching science without inquiry activities that involve active learning (e.g., laboratory or research experiences) constitutes a very limited version of science education. A similar claim may be extended to other subject domains.

It is important to consider that while research has shown improved student performance in courses applying these active learning strategies (Freeman et al., 2014), there is also evidence that learning gains fall behind that of traditional instruction if too little guidance is given (Kirschner, Sweller & Clark, 2006). It should not be assumed that the content from STEM domains will be self-evident in a STEM lesson without proper scaffolding by teachers. Explicit guidance may be needed to steer students' attention to the relevant connections and content.

STEM Literacy and Pedagogical Content Knowledge.

STEM is not a content area in the traditional sense. The content of the separate domains may be present but what makes STEM integrative, or alternatively what makes STEM into Integrated-STEM, is the use of the conceptual tools from across each field to inform decisions (Kelley & Knowles, 2016). These conceptual tools form the basis of STEM literacy, which encompasses the use of "skills, abilities, factual knowledge, procedures, concepts, and metacognitive capacities ... to gain further learning" (Zollmen, 2012, p. 12). While STEM literacy often refers to the idea of STEM literate students (Katehi, Pearons & Feder, 2009; NRC, 2011), I will talk about STEM literacy as it applies to teachers.

Teachers, in their own subject domain, are taught strategies for presenting content, but in a STEM environment they may find themselves with content they may know, but not necessarily know how to properly teach (Stohlmann, Moore & Roehrig, 2012). In the context of preparing teachers for STEM education, Sanders (2008) noted that there is too much content knowledge and PCK for teachers to become effective educators in all the domains and we should instead focus on the importance of training to help educators "better understand and integrate complementary content and process from STEM disciplines other than their own" (p. 22). Along this line of thinking, Nathan and colleagues (2013) describe STEM education in terms of 'invariant relations' that serve as conceptual focal points for showing links between representations of ideas found in different domains. This mirrors Eekels and Roozenburg's (1991) point that there are both important differences and similarities when looking at the methods of inquiry across the domains of science and engineering. It is worth noting that the way

Sanders (2008) describes STEM literacy seems to reflect both the nominal idea of STEM literacy (i.e., the knowledge to work across multiple domains), and also the pedagogical knowledge to teach those domains. Nathan and colleagues (2013), on the other hand, talk of separate 'multidisciplinary content knowledge' needed to "recognize the many potential points of integration" (p. 111).

STEM literacy is one influence on conceptualizations of STEM that is mediated by teachers' understanding. Wang, Moore, Roehrig and Park (2011) observed that professional development in integrating STEM domains leads to teachers applying STEM "in the manner which is most comfortable to them and that this decision is highly correlated to their beliefs about the value and purpose of STEM integration" (p. 11). It is teachers' knowledge and perspectives that may influence how STEM is implemented.

Having looked at the issues surrounding the understandings and perspectives that may influence teaching STEM, I will discuss some of the ways STEM education has been conceptualized. This will serve to highlight the characteristics of implementations of STEM that need to be accounted for in defining my theoretical framework.

Conceptualizations and Implementations of STEM Education

There are two levels to discussing conceptualizations of STEM. First, I will discuss integration of the four STEM domains in terms of how many of those domains are present and the relative weight given to content from each domain. This will highlight some of the conceptual hurdles related to organizing STEM. Second, I will discuss integration in the context of content outside of the four domains, namely the humanities. This will lead into a discussion of how STEM may be organized in a STEM focused school.

Conceptualizations Across the Four STEM Domains.

Dominant Domains

The National Research Council's (2010b) report defined two concepts to describe potential ways to bring STEM domains together: infusion, or "the inclusion of learning goals from one discipline into another" (p. 23)), and mapping, or "drawing attention explicitly to how and 'where' core ideas from one discipline relate to the content of existing standards in another"

(p. 28). Choosing one domain to serve as the *dominant discipline* in the integration is a conceptualization based on the "inclusion of concepts or practices from other subjects … to support or deepen learning and understanding in the targeted subject" (NRC, 2014, p. 43).

The focus on mathematics and science standards in education can push these to be the dominant domains while the engineering and technology domains are relegated to the supporting role (Berland, 2013). The NRC's (2013) report, listing indicators of improvement in STEM education, held a similar focus on mathematics and science, specifying the importance of presenting content, availability of opportunities, and proper assessments of these domains. Engineering and technology are presented only as part of the general discussion of STEM. The way STEM is conceptualized in the NRC report puts a particular emphasis on the role of science. This emphasis mirrors an earlier NRC (2011) report that stated, "to make progress in improving STEM education … policy makers … should elevate science to the same level of importance as reading and mathematics" (p. 28). An important consideration to take away from this is that while, in theory, one could design STEM lessons or curricula to target learning in a chosen domain, the surrounding policy context can influence which domains are targeted.

Despite the name, the dominant domain or the target domain may be the weaker of the integrated domains. In their case study, Wang and colleagues (2011) observed that teachers of STEM lessons believed that "prior knowledge, such as science and mathematics content knowledge, is important for students to understand in order to be successful in STEM integration" (p. 10). This is a reflection of how teachers' perspectives of STEM may influence how STEM is implemented and the resulting data-use practices. If one teacher uses STEM lessons to teach domain content and another teaches domain content to prepare students for STEM lessons, how do these differences influence the decision-making practices in the classroom? Identifying these nuances that come out of conceptualizations of STEM are useful in shaping my theoretical framework to encapsulate perspectives teachers may have related to implementing STEM.

Combining Multiple Domains.

Sanders (2008) defines a conception of STEM[4] education which “includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (p. 19). This combination does not just mean content but also the domains’ methods of inquiry as indicated when the author defines, in a tech education context, a pedagogy that “combines technological design with scientific inquiry, engaging students … in scientific inquiry situated in the context of technological problem solving” (p. 19). What distinguishes this view of combining domains from the earlier conception is that here domains are combined to explore something in a new way while previously they were combined to specifically teach about a domain. In their summary of Sanders body of work, Nathan and colleagues (2013) noted that Sanders’ definition of integrated STEM requires bridging “the design and natural sciences” (p. 82), so a math and science *or* engineering and technology lesson, alone, cannot be considered combined or integrated.

The NRC’s (2014) report titled *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research* provides a more open definition of integration stating simply that,

> STEM...may bring together concepts from more than one discipline...; it may connect a concept from one subject to a practice of another ...; or it may combine two practices, such as science inquiry (e.g., doing an experiment) and engineering design (in which data from a science experiment can be applied). (p. 42)

From this perspective, any combination of two domains based on content *or* ways-of-knowing is technically a version of integrated STEM. Barakos, Lujan and Strang (2012) take the combination of domains further, using existing STEM education programs to construct a continuum of STEM conceptualizations ranging from isolated teaching of single domains to full integration of all domains including a focus on incorporating non-STEM domains, namely art or artistic expression.

In his book *The Case for STEM Education* (2013), Rodger Bybee outlined and provided visualizations of several separate perspectives of STEM (p. 74-79). Under these perspectives for STEM he lists,

[4] I should note again that I am using STEM in a way that covers integrative approaches to how STEM may be structured along with covering the phrase Integrated-STEM. Sanders (2008) uses the phrase integrated-STEM in his work.

- Equals Science (or Mathematics).
- Means Both Science and Mathematics
- Means Science and Incorporates Technology, Engineering, or Math
- Equals a Quartet of Separate Disciplines
- Means Science and Math or Connected by One Technology or Engineering Program
- Means Coordination Across Disciplines
- Means Combining Two or Three Disciplines
- Means Complementary Overlapping Across Disciplines
- Means a Transdisciplinary Course or Program

In introducing these perspectives, Bybee does not treat the different perspectives as forming a continuum or hierarchy. Instead, these are different forms of integration that should be defined to help educational reformers build on certain perspectives. That being said, Bybee does follow with a hierarchical view of implementations of STEM (exemplified as STEM 1.0 through STEM 4.0) that serves as a rubric for how many domains are integrated. This is a shift in defining integration in STEM. Instead of starting from a predefined perspective of STEM to create a program there are choices of integration (i.e., coordinating, complementing, correlating, connecting, combining) that create some implementation of STEM. It is clear that, while many conceptualizations of STEM exist, the implementation of those conceptualizations rest on a number of underlying decisions of choosing, presenting, and integrating domains. The potential presence of many conceptualizations is an important aspect of understanding how STEM is being implemented by teachers.

Conceptualizations of the Integration of Non-STEM Domains.

An interesting part of Sanders' (2008) definition of integrated STEM is that integration can be "between a STEM subject and one or more other school subjects" (p. 19). Brown and colleagues (2011) state that STEM education is "where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline specific content is not divided, but addressed and treated as one dynamic, fluid study" (p. 7). Notice how this says *especially* STEM teachers and not *specifically* STEM teachers.

There are a few ways this kind of integration can play out. One example is the intersection of, primarily, science and language literacy to support language skills (Lee, Quinn, & Valdes, 2013; Stoddart, Pinal, Latzke & Canaday, 2002). While this integrates a science and language component, the context for this is more focused on educational intervention in language arts skills and not sustained connections between science and language arts at the course level. Another example is in adding domains to STEM. Zollerman (2012) has noted that public conception of STEM has taken on a "broader meaning, and includes agriculture, environment, education, and medicine" (p. 12). Along with this broader meaning comes several modifications of STEM including the addition of agriculture (AG-STEM) (Stubbs & Myers, 2004), the arts or creative endeavors (STEAM) (Bequette & Bequette, 2012), religion & the arts (STREAM), reading and writing[5] (STREAM) (Root-Bernstein & Root-Bernstein, 2011), robotics (STREAM) (Stubbs & Yanco, 2009), and medicine (STEMM) (Miller & Benbow, 2012). These versions of STEM are in line with the dominant domain interpretation of STEM where some domains are utilized to support a target domain.

Consideration of the integration of non-STEM domains is important to the final topic of STEM schools. A school's designation as a STEM school does not remove education targeted at non-STEM domains. The state-level policy addressing STEM in the STEM schools in my study implicitly focuses on the integration of content from STEM and non-STEM domains. Characteristics of STEM schools will be discussed in the following section.

Conceptualization of STEM Schools

With the rising focus on STEM schools, research has begun to look at aspects of how these schools can or should function. One issue is in how STEM schools may support both gifted education (Cross & Frazier; 2009; Olszewski-Kubilius, 2009) and education targeted at underrepresented students (Peters-Burton, Lynch & Behrend, 2014; Spillane, Lynch & Ford, 2016). Another is in the observed improvements in standardized testing performance of students in STEM schools compared to traditional schools (Bicer et al., 2015; Erdogan & Stuessy, 2015; Scott, 2012). A final area of interest is in the potential structure and evaluation of STEM schools. In their report, Successful K-12 STEM Education (2011), the NRC detailed three potential

[5] Writing is used phonetically to give the R in this version of STREAM

criteria for judging STEM schools: (1) Student STEM Outcomes, (2) STEM-focused school types, and (3) STEM instruction & school practices. These criteria define facets of a STEM school's structure that need to be considered in defining research into these schools.

Student Outcomes

The report described moving beyond testing as a measure of success noting that, "entry into STEM-related majors and careers and making good choices as citizens and consumers … require applying and using STEM content knowledge in other settings besides tests" (NRC, 2011, p.6). The first part of this statement is again a reflection of the economic interest that drives a focus on education in the STEM domains (NRC, 2007; NRC, 2010). However, as noted in the report, additional research is needed to understand how to organize schools to attain these outcomes.

School Types

Next, the report defined three types of STEM school: (1) selective, (2) inclusive, and (3) career and technical education (CTE). One distinction between these schools is that the selective and inclusive schools are "organized around one or more STEM disciplines" (NRC, 2011, p. 8) while CTE is organized to "prepare students for STEM-related careers" (p. 13). Selective and inclusive schools are further divided by the extent to which STEM is a focus of the curriculum and are distinguished based on having criteria for admission or participation in the program. Peters-Burton and colleagues (2014) describe this difference as selective schools focusing on bringing in already identified, STEM gifted students while inclusive schools seek to "develop new sources of STEM talent among underrepresented students" (p. 65) and guide them into STEM professions.

STEM Instruction and School Practices

Finally, the report defined five key elements for promoting effective STEM instruction:

- A coherent set of standards and curriculum.
- Teachers with high capacity to teach in their discipline.
- A supportive system of assessment and accountability.

- Adequate instructional time.
- Equal access to high-quality stem learning opportunities.

Of these, the third element is most relevant in connecting STEM to data-use due to the concern that "current assessments limit teachers' ability to teach in ways that are known to promote learning of scientific and mathematical content and practices" (NRC, 2011, p.21). As noted in Rangel, Monroy and Bell's (2016) study of science teachers, it can be the case that teachers are exposing students to methods of inquiry (e.g., science labs) but have to focus on standards assessment for decision-making.

Now that I have introduced the many aspects surrounding conceptualizing STEM and data-use I will combine this information, along with a discussion of theoretical frameworks of data-use, to define a framework to encompass both STEM and data-use for the purpose of categorizing teachers' perspectives on these topics.

Theoretical Framework

Overview of Theoretical Frameworks of Data Use

Discussion of frameworks of data-use requires a short description of Data-Driven Decision Making (DDDM). DDDM is a way of discussing data-use that began to appear in education-focused literature shortly after NCLB (e.g., Isaacs, 2003; Mandinach, Honey, & Light, 2006; Wayman, 2005). The ideas covered under DDDM mirror phrases for discussing data such as *data-use*, *data-based* and *evidence based* (Honig & Coburn, 2008) all found in the literature. For this discussion, all of these terms are covered under my use of the phrase *data-use*.

Frameworks on data-use encompass the nature of the decision-making process associated with data. They involve identifying issues or contexts that may influence how data is used and also the connections between these contexts. A number of researchers have developed or expanded upon frameworks for how the data-use process functions (Coburn & Turner, 2011; Ikemoto & Marsh, 2007; Mandinach, Honey & Light, 2006; Marsh, Pane & Hamilton, 2006; Schildkamp & Poortman, 2015). Mandinach and colleague's (2006) framework, in particular, has served as the base framework for several of these extended models. They addressed three important facets of the overall cycle of data-use: (a) there is a difference between data that is collected and actual knowledge that can be acted upon, (b) the decision process surrounding data happens across levels of the school system (e.g., classroom, building, district) and, (c) the cycle of data-use is iterative where outcomes inform future implementations of the data-use process.

Schildkamp and Poortman (2015) built on this idea to construct a data-use, theory of action, framework that incorporates data-teams, one of the collaborative groups into which teachers and administrators may be organized for working with data. The authors describe their framework as linking “a broad view on data and data use to enablers and barriers that influence the use of data” (p.5). They share,

> The framework takes into account the process of data use …, the organizational context in which data use is taking place, and the characteristics of the data and data systems available, but also that individual data users … influence the process at a micro level (p.5).

As a theory of action, this framework focuses on how interactions and context drive “decisions with regard to what action to take” (p.5). The cycle of data-use produces “actionable knowledge” (p.6) which informs the decision-making process.

Schildkamp, Poortman, and Handelzalt (2016) tested the validity of their framework by comparing it to the observed function of a school data team. From the interconnectivity built into their framework, they could narrow down to specifics of where their framework was aligning with their observations. They found that their theory was “applicable in practice, but also that teachers and school leaders go through different feedback loops, and that some are able to reach the action and outcomes phase, whereas others are not” (p. 248). In other words, while the decision-making process had some coherent structure, the decisions being made were not uniform. This connects, in my study, to the observation that educators, in different levels of the education system, can have very different levels of accountability to and interpretations of data.

The framework from Mandinach and colleagues (2006) has been influential in articulating the iterative nature of the cycle of data-use and in highlighting how data-use varies based on educator’s level within the school system (i.e., district, building & classroom). One further aspect of this framework is the claim that decisions within these levels can influence decisions in others, of which they note that while there is “cross-level decision making, it is likely that there will be more top-down decisions than bottom-up decisions” (p.10). Schildkamp and Portman’s framework goes further by incorporating a structure for how the “school organizational characteristics interact with individual and team characteristics, data characteristics, and data use" (Shildkamp & Poortman, 2015, p.5). In this framework,

> Data-based decision making is embedded in the organizational context in which data use takes place (e.g., the extent to which a school-wide vision for data use exists, the role of the school leader with regard to facilitating data use, and being a role model for data use), individual and team characteristics that may influence data use (e.g., knowledge and skills for data use, knowledge about the data management system, attitude about data use), and data characteristics (e.g., the availability of data in a data system, reliability and validity of data, and data available on a timely basis). The way in which the several factors within the different layers are fulfilled, highly influences the way in which data use is implemented in schools. (Ebbeler, Poortman, Schildkamp & Pieters, 2016, p.20)

This framework's focus on contextual influences will be useful in this study for discussing context surrounding teachers' perspectives of data-use and STEM.

Schildkamp and Poortman's (2015) data-use theory of action framework incorporates the perceptions of educators related to various facets surrounding data-use. As Figure 2 illustrates, data-based decision-making is part of an iterative cycle that is embedded in the organizational context surround data-use. First, there is the level of a school's organizational characteristics. This is where perceptions of the implementation of state or school policies and interactions with school leaders (e.g., Principles and higher administration) may influence perspectives surrounding data. Second, there is the level of individuals and teams. Here, 'teams' is meant to refer to 'data teams'. As data teams encompass a wide array of organizational structures (Love, 2008) while maintaining a collaborative focus in working with data (Lachat & Smith, 2005), I argue that this term can apply to groups of teachers, working with data, even in instances where the group is not officially labeled as a data team. Wayman, Midgley, and Stringfield (2005) shared, regarding collaborative work on data,

> The goal of collaborative data teams is to form groups of educators that can work and learn together as they engage in the process of using student data to examine and improve their craft. These teams … can exist in a variety of forms: they can be made up entirely of teachers, or may also contain administrators, counselors, or

other building personnel. These teams may be formed within or across subjects and grade levels. (p.2)

This level is where perspectives may be influenced by the events or collaborations surrounding the teaching and learning environment. Finally, there is the level of data characteristics. This is the internalized view of data that can include ideas of what data can be considered important for decisions and what data sources can be considered reliable. It is within interactions in these levels that the cycle of data use is embedded.

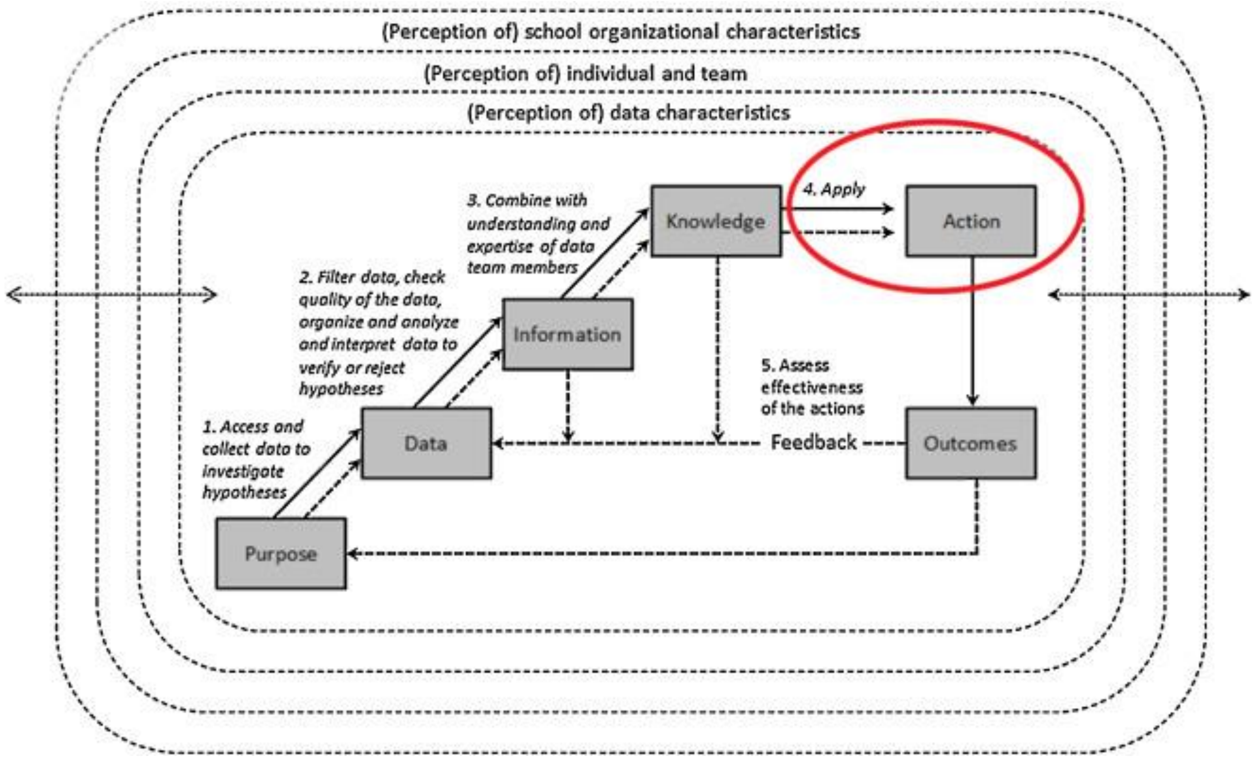

Figure 2. Effects of a data use intervention on educators' use of knowledge and skills (Ebbeler et al., 2015).

A cycle of data-use has been a hallmark of data use frameworks going back to Mandinach and colleague's (2006) work. It is through this cycle that data-use is broken into several stages: First, some issue or problem exists, which gives a purpose for collecting data. Second, raw data is collected to try to address this concern. Raw data, on its own is not useful so in the third step this data is organized into information to facilitate an understanding of what the data is stating. From this information, judgments are made on what information is accepted as useful, actionable knowledge to be applied in decisions. Once a course of action is chosen, steps must be taken either to track the outcome of the decisions that are made or to return to the start of the cycle informed by insights from the previous iteration.

A Modified Theoretical Framework for Data Use *and* STEM

Modeled on the structure of Schildkamp and Poortman's (2015) framework, I argue that the teaching of STEM in school is embedded in the contextual levels analogous to those which influence data-driven decisions. In a STEM school, there are organizational policies surrounding STEM, the teaching of STEM, and the collaboration with educators on STEM lessons and curricula (NRC, 2011), and the personal perceptions of what STEM is and how it should be taught (Frykholm & Glasson 2005; Wang et al., 2011). This generation of perceptions of context surrounding STEM runs in parallel to the generation of perceptions on data-use. Figure 3 illustrates where STEM is embedded in the organizational context of the school and should be envisioned to exist in parallel to the data-use components in Figure 2.

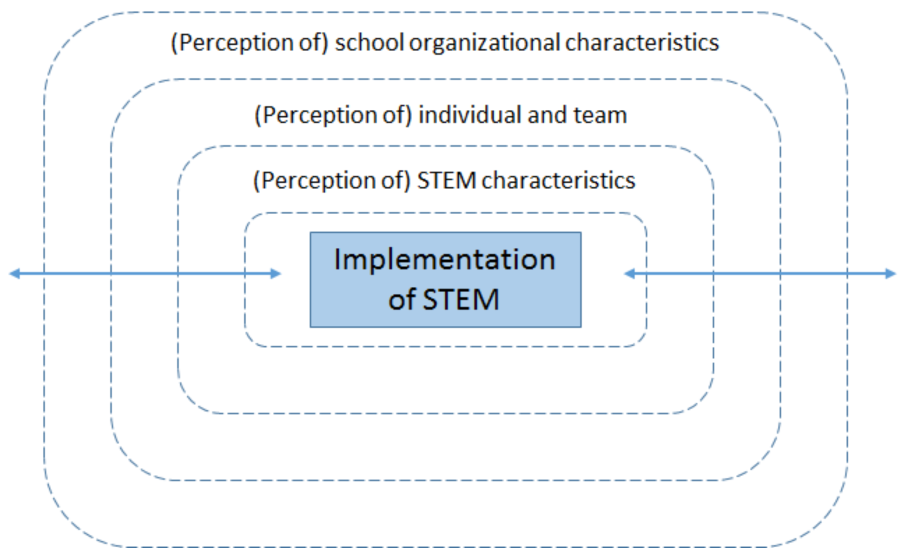

Figure 3. The implementation of STEM embedded in perceptions of the contexts surrounding STEM.

A notable difference between data-use and STEM is that while there is a cycle of data-use there is no cycle of STEM. Instead, there are the many potential implementations of STEM that may be present in the school. STEM may be conceptualized based on what domains of knowledge are present, the relative importance given to each domain, and the level of connection between them (i.e., integration) (Barakos, Lujan & Strang, 2012; Bybee, 2013; Sanders, 2008). In this framework, I assume that in a STEM environment there exist one or more ways that a teacher may conceptualize and implement STEM, which, in turn, influences the data that goes into the data-use cycle. A list and organization of these implementations of STEM is developed in the next section. Acknowledging that there are different conceptualizations of STEM and categorizing them serves to help capture the potentially nuanced and distinct versions of STEM that individual teachers may implement. Differences in conceptions and implementations could reasonably result in important differences in the data-use process based on the content and methods of inquiry that are focused on.

It can, of course, be argued that a limitless number of educational initiatives are implemented in parallel, however I am purposefully limiting this study to the intersection of data-use and STEM. In this work, I am extending Schildkamp and Poortman's (2016) framework to look at how data-use and STEM *could* be connected in the sense that data from the STEM learning environment may feed into the cycle of data-use which results in decisions related specifically to the STEM learning environment. The assumption that there *should* be a connection is implicit in the decision to look at STEM certified or focused schools. While they may be organized in many ways, a STEM school, by its very nature, has a curriculum oriented at teaching STEM (NRC, 2011) and use of data to inform instruction exist alongside this STEM context.

Based on many of the existing conceptions of STEM present in the literature, I have defined three levels of STEM implementation. One level is not considered better than any other. Instead, levels serve to denote the overall increasing complexity of certain conceptions. The categories defined within each level serve to highlight and separate: (a) Which domains are being taught, (b) Which domains serve as sources of data, and (c) Which domains are being taught or probed for data in terms of the higher order skills (i.e., methods of inquiry) associated with those domains. Some nested categories repeat or change wording slightly depending on the context.

Implementations of STEM

Level 0: Pre-STEM

This is a special case where only content from a single isolated domain (e.g., math or science) is presented. A Pre-STEM math class would be indistinguishable from a normal math class. In a STEM focused school there could be an instance where a teacher claims or believes they are teaching STEM but are really just teaching in the single domain. However, even when only a single domain is used in instruction there are still potential differences in the inquiry activities taught and data that is used (see Table 1).

Table 1

Level 1: Pre-STEM, Single Domain Focused

	Non-Inquiry Focused	Inquiry
Teaching	Active learning activities or methods of inquiry from this isolated domain are rarely or never implemented.	Active learning activities or methods of inquiry from this isolated domain are implemented.
Data	Data from active learning or methods of inquiry from this isolated domain are not included in the data-use process.	Data from active learning or methods of inquiry from this isolated domain are included in the data-use process.

Level 1: Dominant Domain STEM

In this conception of STEM, one domain dominates in instruction while one or more other domains may appear as tools or as context to teach the main domain. Domains can be either from STEM or the humanities. A science lesson that has a math component or a math lesson that incorporates language arts as a writing component would fall under this level.

Again, there are nested categories for identifying how STEM lessons are taught and the data that is taken from them. Level 1 can include both *Single Domain Focused* and *Multi-Domain Focused* lessons. With a single domain focus, the teacher treats the dominant domain as the primary source of data collection and assessment for informing instruction from the STEM lesson (see Table 2). With a multi-domain focus, the teacher treats data from each of the present domains as sources of data for informing instruction from the STEM lesson. Note that the categories in Table 3 are identical to those in the Single Domain Focused section with the modification that data from the non-dominate domain may now be incorporated into the data use process.

Table 2

Level 1: Dominant Domain of STEM, Single Domain Focused

	Non-Inquiry Focused	Dominant Inquiry
Teaching	Active learning activities or methods of inquiry from the dominant domain are rarely or never implemented	Active learning activities or methods of inquiry from this dominant domain are implemented
Data	Data from active learning or methods of inquiry from this dominant domain are not included in the data-use process.	Data from active learning or methods of inquiry from this dominant domain are included in the data-use process

Table 3

Level 1: Dominant Domain of STEM, Multi-Domain Focused

	Non-Inquiry Focused	Inquiry
Teaching	Active learning activities or methods of inquiry from the dominant domain are rarely or never implemented	Active learning activities or methods of inquiry from the dominant domain are implemented
Data	Data from active learning or methods of inquiry from the dominant and non-dominant domains are not included in the data-use process.	Data from active learning or methods of inquiry from the dominant and non-dominant domains are included in the data-use process

Level 2: Combined Domain STEM

In this conception of STEM at least two domains are combined on a roughly even level in instruction. If there are two domains, then there needs to be content or methods of inquiry from both. One domain cannot be just a context or tool for the other. If there are three domains, then one can be context or tool as long as the other two are strongly combined. While none of these domains should act as a dominant domain, it is possible for a domain to be favored. With a single domain focus the teacher treats a single domain as the primary sources of data for informing instruction from the STEM lesson even though the lesson itself combined multiple domains. With a multi-domain focus the teacher treats data from at least two of the present domains as sources of data for informing instruction from the STEM lesson. These two possibilities are combined in Table 4. This level includes sublevels analogues to those discussed previously.

Table 4

Level 2: Combined Domains of STEM, Single and Multi-Domain Focused

	Non-Inquiry Focused	Singe Inquiry	Multiple-Inquiry
Teaching	Active learning activities or methods of inquiry from all domains are rarely or never implemented.	Active learning activities or methods of inquiry from a single chosen domain are implemented.	Active learning activities or methods of inquiry from at least two domains are implemented. (Present in both single and multi-domain focused)
Data	Data from active learning or methods of inquiry from any domain are not included in the data-use process.	Data from active learning or methods of inquiry from a single chosen domain are included in the data-use process.	Data from active learning or methods of inquiry from at least two domains are included in the data-use process. (Present only in multi-domain focused)

Data and Implementations of STEM

These levels cover a wide range of potential STEM education implementations, contextualizing those environments in terms of the data that could potentially be or is claimed to come out of teaching in STEM. Returning to Figure 2 and Figure 3, this framework posits that both data-use to inform instruction and the implementation of STEM education exist in parallel. The surrounding organizational context informs the implementation of STEM curricula or lessons. Data from this STEM component of education, which is assumed to be data a STEM school would take into consideration, then becomes available to enter the cycle of data-use. The actions, if any, chosen by the decision-making process then may enact changes on how STEM is implemented, starting the cycle over again. The options in the tables of implementations of STEM are designed to distinguish teacher's individual implementations of STEM and clarify what kind of data is entering the decision-making process. STEM takes many forms and with no guidance on what STEM means the blanket question of how STEM intersects with data-use processes lacks the nuance necessary to fully explore this intersection.

My study aims to look at the contextual influences surrounding teachers to more fully understand how STEM teaching and data-use connect and overlap. The framework described here is developed to help understand teacher's responses in the context of my research questions. The layers of perception in this framework (i.e., school organizational characteristics, individual and team, data characteristics) give a structure to inquiring into the perspectives teachers have regarding their data-use and STEM teaching practices. The list of implementations of STEM categorize how teachers view their inquiry and class practices both in terms of the STEM and data content. The nuances sought by these categories may allow for deeper analysis of teachers' perspectives by narrowing down the characteristics of the STEM environment from which the perspectives are derived.

Chapter Summary

To look at the intersection of data-use and STEM requires an understanding of the policies and implementations surround both of these fields. The use of data to inform instruction is not simple since educators, in different roles and context, can interpret data differently. Interactions of teachers through collaboration or under leadership guidance further influences how educators may use data. STEM, too is a complex field as it has the potential to be conceptualized and implementing in many different, but simultaneously valid, ways. Everything from the policy decisions surrounding a school's STEM focus down to teacher's individual conceptions teaching the STEM domains can influence how STEM education manifest itself in the school. To understand how data from STEM educational activities enters and influences the data-use process, if at all, requires a thorough understanding of the traits of these two initiatives. In the next chapter I will define my methodology, study design and selection of participants that, ideally, represent the intersection of STEM and data-use in the STEM focused schools of this study.

CHAPTER 3: METHODOLOGY

In this chapter, I discuss my methods for this concurrent triangulation mixed-methods study. I provide an introduction and justification of the study design used, the choice of sites and participants, the data analysis procedures, and threats to reliability and validity. Furthermore, I discuss how my role as the researcher and background as a physics researcher may influence my analysis, particularly of the STEM components of this study.

Through this choice of methods and guided by the framework I have developed on STEM and data-use, I have constructed this study to explore the following research questions:

- What are secondary educators' in STEM focused schools perspectives surrounding teaching and data-use in STEM education?
- What do secondary educators in STEM focused schools see as the role of STEM inquiry activities in informing educational decision-making?
- How do secondary educators, in STEM focused schools, describe their practices of implementing STEM education?

Research Design

Mixed-methods design works to bring together the empirical evidence that can be gained from both qualitative and quantitative investigation. However, this combination is not simply for the purpose of having both kinds of data. Greene (2012) stated that the methodology chosen for research acts to "shape the knowledge generated from a study and the warrants for that knowledge" (p. 755). Mixed-methods approaches strengthen research by allowing exploration of questions that qualitative and quantitative research cannot effectively tackle in isolation (Creswell, Plano, Gutmann & Hanson, 2003; Mertens & Hesse-Biber, 2013). I chose this mixed-methods design based on an expectation that teacher participants would offer differing perspectives, on STEM and data-use, based on the qualitative and quantitative inquiry approaches (i.e., semi-structured interviews and survey) I used, and this design helps to capture as much of this variation as possible across these approaches.

The expectation for these differences was grounded in the disconnect between how policy initiatives surrounding data-use and STEM may be structured compared with how they are implemented. For data-use, teachers respond differently to data required by accountability standards and the data they obtain from their direct interactions in their classrooms (Apple, 2004; Beaver & Weinbaum, 2015). For STEM education, there is no agreement on what teaching STEM entails (Breiner, Harkness, Johnson & Koehler, 2012; Pitt, 2009). This leaves room for many potential conceptualizations of STEM, both at the administrative and classroom level, with regards to what domains of STEM are utilized, what content or methods for domains are used, and how the domains are combined (Barakos, Lujan & Strang, 2012; Bybee, 2013). Further, there is the influence of teachers' backgrounds and experiences with these initiatives and the personal beliefs they have developed surrounding their implementation.

The questions I used in both the survey and interview independently covered the full scope of teachers' unique perceptions to address the research questions, serving as insolated and, initially unconnected, data sources. More specifically, the quantitative and qualitative facets of this research, respectively, capture the board impressions teachers have surrounding STEM teaching and data-use and probe the nuanced views of how individual teachers define and implement these initiatives. I used a concurrent triangulation (CT) mixed-methods design (Creswell et al., 2003), which is also called parallel/simultaneous design (Tashakkori & Teddlie, 1998), to structure and integrate the quantitative and qualitative components of this study.

In the CT design, survey and interview data is collected and analyzed separately and then compared to identify both agreements and disagreements in conclusions (Creswell et al., 2003; Tashakkori & Teddlie, 1998). In this case, differing conclusions in analysis between data sources does not represent a failure of triangulation of the data but is rather a reflection of alternative perspectives that come out of the overall analysis. This view of data leading to alternative perspectives is in line with the expectation, in this study, that the analysis of the survey and interview data sources may reveal different perspectives, as shared by participants. The final analysis "either may note the convergence of the findings as a way to strengthen the knowledge claims of the study or must explain any lack of convergence that may result" (Creswell et al., 2003, p.229). The structure of this mixed-methods design is shown in Figure 4.

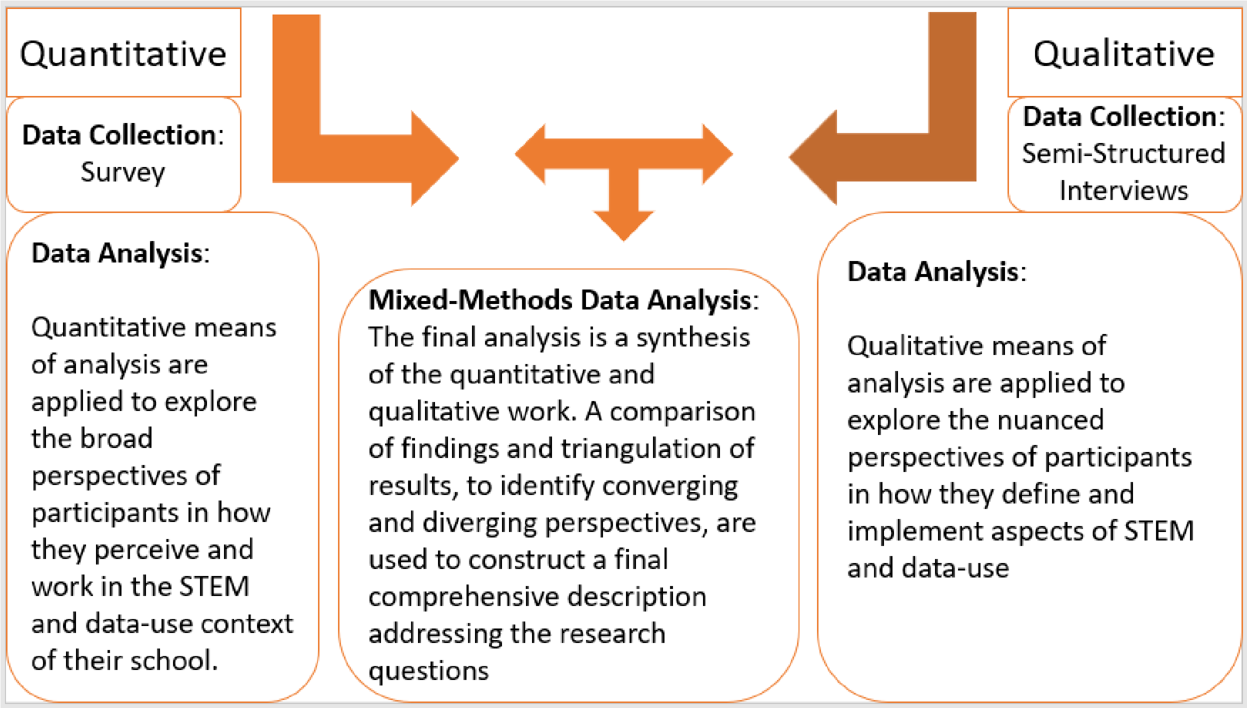

Figure 4. Concurrent triangulation design: The structure of data analysis and synthesis.

Site and Sample Selection

School Characteristics

For this study, I chose to work in one Midwestern state (referred to with the pseudonym MWS from here on) that has policies for both data-use and STEM school certification. Researching the intersection of data-use and STEM requires an educational environment with both a data-use and STEM education policy focus and, for the purposes of this study, it would not be meaningful to inquire about the use of STEM data from educators with no connection, or at least no expected connection, to STEM.

In MWS, data-use for the purpose of improving teaching and learning is one of several stated guiding principles for discussions around school improvement. Data-use is an explicit part of MWS school policy. Additionally, MWS began developing tiered criteria for accrediting STEM certified schools in the early 2010s. These schools follow an established framework and rubric to qualify for state recognition of implementing STEM. This framework, relating to a school's structure, defines tiered levels of STEM school immersion with each tier specifying guidelines for the categories of instruction, courses and curriculum, scheduling, partnerships (with universities and business), collaboration (among teachers) and extended opportunities (outside the classroom). While a school level STEM focus does not guarantee individual educators are engaging in STEM, it does ensure that STEM is, at least on some level, an influence on aspects of instruction or policy in the school.

During the time of this study the state has continued to expand the number of certified schools. I outlined the proposal for this dissertation study in early 2017 and at the start of the 2016-17 school year, roughly 30 schools spanning K-12 were STEM certified. As this study concludes in 2019 the number of certified schools is now close to 80.

At the time of this study, out of the 30 STEM schools, 10 could be described as secondary schools including students in the 7th through 12th grade. After contacting the respective school districts, five of these schools allowed me to distribute my survey and teachers from four of the schools consented to interviews. These five public schools are a high school, school-within-a-school STEM academy, three middle schools and a ninth-grade alternative school.

School A is a large suburban school that enrolls around 3400 students, overseen by roughly 160 teachers. Both the numbers of students and teachers have been fairly constant over the 2010s. Among these students 80.2% are White, 4.6% are African American, 4.5% are Hispanic and 5.9% are Asian. The gender breakdown is 48.9% female to 51.1% male. Free or reduced lunch recipients are 22.1% of the population. Students here perform above the state average on English and mathematics standardized testing. Performance has stayed above 80% over the past decade. In this instance, only part of the overall school is appropriate for this research. This school employs a school-within-a-school model. It is this internal school that forms a STEM academy. This academy has been STEM certified since 2016.

School B is a midsized, suburban school that enrolls around 500 students overseen by roughly 30 teachers. The number of students has remained consistent over the 2010s while the number of teachers has returned to around 30 after a steep spike a few years before. This is a Title I school. Among these students 79.8% are White, 5.4% are African American, and 6.5% are Hispanic. The gender breakdown is 50.2% female to 49.8% male. Free or reduced lunch recipients are 44.8% of the population. Students here perform above the state average on English, mathematics, and social studies standardized testing. Performance climbed from around 50% to above 80% over the past decade. This school has been STEM certified since 2017.

School C is a large, suburban school that enrolls around 1100 students overseen by roughly 60 teachers. The number of students has gradually shrunk from 1500 at the start of the 2010s while the number of teachers has come to 60 after recovering from a steep drop at the start of the decade. This is a Title I school. Among these students 22.8% are White, 50.4% are African American, and 18.7% are Hispanic. The gender breakdown is 47.0% female to 53.0% male. Free or reduced lunch recipients are 69.5% of the population. Students here perform below the state average on English, mathematics, and social studies standardized testing. Performance has stayed below 50% over the past decade. This school has been STEM certified since 2015.

School D is a midsized, rural school that enrolls around 500 students overseen by roughly 30 teachers. Both the numbers of students and teachers have been fairly constant over the 2010s. This is a Title I school. Among these students 86.3% are White, 3.0% are African American, and 5.2% are Hispanic. The gender breakdown is 51.1% female to 48.9% male. Free or reduced lunch recipients are 54.0% of the population. Students here perform below the state average on English, mathematics, and social studies standardized testing. Performance has gradually declined over the past decade. This school has been STEM certified since 2015.

School E is a large, urban, alternative school that enrolls around 1300 students, overseen by roughly 90 teachers. Both the numbers of students and teachers have been fairly constant over the 2010s. This is a Title I school. Among these students 35.6% are White, 33.0% are African American, and 25.3% are Hispanic. The gender breakdown is 49.2% female to 50.8% male. Free or reduced lunch recipients are 75.9% of the population. Students here perform below the state average on English and mathematics standardized testing. This school only enrolls 9th grade students and has, as part of its mission, a goal to prepare those students to pass state mandated end of course assessments. This school is geographically adjacent to the corresponding 10th through 12th grade school. This school has been STEM certified since 2017.

Participants

The participants in this study were the 7-12th grade mathematics and science teachers in these STEM certified schools. Mathematics and science are the two subjects that are placed at the forefront of STEM policy (NRC, 2011; 2013). The recommendations for improving STEM education advocate placing science at the same level of mathematics through the same accountability and standards focus already directed at reading and mathematics (NRC, 2011). I focus on these participants because they are situated in the evolving accountability context surrounding STEM education. Gathering the perspectives of non-mathematics or science teachers might further provide insight into the interactions of STEM and data-use, but collection of that data was not feasible within the scope of this study and is an avenue of future research. I focused on secondary school teachers as they are more likely to have their background training and teaching limited to a single subject domain and an interesting aspect of studying STEM education is in how teachers perceive and attempt to teach and assess the content outside of their subject domain.

There were approximately 65 potential participants among the schools included in this study. Among there were 35 mathematics teaches and 30 science teachers. This set of potential participants was the same for both the survey and interview. This potential participant pool was roughly half of the full population size (approximately 130) of the mathematics and science teacher at the, then, 10 secondary STEM schools.

The survey was directed to all of the potential participants to obtain the largest number of responses across the chosen schools and domains. A total of 34 opened the survey and 15 persisted to the end of the survey. For the interviews, the ideal participants were teachers that meet both of the following criteria. The first criterion was having at least five years of teaching experience or more. For context, the start of the 2010 marks the time when national education policy began focusing more heavily on STEM both in policy documents (i.e., Rising Above the Gathering Storm Energizing and Employing America for a Brighter Economic Future in 2007) and legislation (i.e., STEM Education Coordination Act of 2009). Both the data-use and STEM initiatives have been growing and evolving over time, and teachers with at least a few years of experience might be able to speak more extensively to the role of these initiatives in their teaching. The second criterion was for the teacher to have been at the school during the transition of the school to a STEM certified school. Such teachers would have direct experience with the differences that arose as part of the certification process.

I asked the school administration to initially direct me to teachers that meet these criteria of which seven out of eight interview participants did. For variation in perspectives, I planned to have at least two interviews per school (one mathematics and one science) for eight interviews total. Ultimately, 4 teachers from School A, 2 teachers from School B, 1 teacher from School C and 1 teacher from School D consented to be interviewed. No teachers from School E were interviewed but teachers from that school may have participated in the survey.

Data Collection

Quantitative Data Collection – Online Survey of Secondary Mathematics and Science Teachers

The survey component of this research was intended to capture the broad perspectives of teachers surrounding STEM and data-use. I developed the survey items around the STEM and data-use framework established for this study. Within this framework, there are layers of contextual influence on both data-use and STEM education in the form of the perceptions the school organization has, the perceptions of the individual and team collaborations teachers are involved in, and the direct perceptions of what data and STEM are. Within the context surrounding data, there is a cycle of data-use that seeks to explain how data informs educational decisions, and within the context surrounding STEM there is the array of potential implementations of STEM based on the choices of domains taught, connections made between those domains, and the inquiry activities teachers offer students.

While this framework defines the scope of the survey items, I did not explicitly define STEM and data-use in the survey as I desired the responses to be based on teacher's internalized perspectives of these initiatives. To facilitate this, I asked questions of the practices and perspectives surrounding STEM and data-use, without specifying what these mean, through a series of Likert-scale type, multiple-choice, multiple-answer and short response questions. In the survey I asked about (1) frequency of implementation of STEM and data-use actions, (2) agreement and disagreement with the need for certain STEM and data-use actions, and (3) support for implementing aspects of STEM and data-use. To limit the influence the wording of the items could have had on teaches perspectives of STEM and data-use, as they went through the survey, I used page breaks to separate key parts of the survey. The full survey had the following structure.

- Page one has a summary of the research and option for consent to participate in the survey. Indicating consent will be necessary to progress in the survey.
- Page two asks questions surrounding the participant's perspectives and practices of STEM and data-use in their teaching and school environment.

- Page three contains a series of questions that will help categorize the implementations of STEM a participant uses, based on their description.
- Page four contains demographic information including gender, years of experience teaching, years of experience in a STEM school, and domain taught.
- Page five contains a note of thanks to participants and offer to contact the researcher with any questions.

I designed the survey to take around 20 minutes to complete. I tested this length with the help of a former teacher with experience in one of the state's STEM schools. The appropriateness of survey items (including content of items to address the research questions, the format of items, and wording) was addressed based on input from content experts, both in STEM education and data-use, and the STEM teacher just mentioned. This teacher also provided feedback on the understandability of the survey.

Procedure for online survey.

I first prepared an email, summarizing this study, and sent it to the superintendents of the pre-determined districts explaining my interest in conducting both survey and interview research. In the email, I requested permission to contact the principal and teachers in the selected STEM schools. After permission was granted by the superintendent, I prepared a second email that I sent to the principal of each school to inform them of the research and to get their permission to conduct the study. Once the principals agreed, I asked them to help me distribute my survey to the appropriate teachers. I provided an email to be forwarded that explained the nature of the research and contained a link to the online survey delivered through Qualtrics®.

Qualtrics®, as with other online survey tools, offers flexibility in preparing and disseminating the survey instrument (Devlin, 2017) and is the survey software that was available to me, through my institution, at the time of this study. The survey was open for ten weeks and was closed two weeks after the final interview was completed. The survey and all interviews were completed in the Fall 2018 semester.

To incentivize participation in the survey and to help find interview participants, offered $5.00 electronic amazon gift cards to any teacher who completed the survey and advertised that I would offer a $15.00 electronic amazon gift card to teachers who would complete an interview.

Survey participants were instructed to send me an email, claiming they completed the survey, in order to be sent the gift card.

Qualitative Data Collection – Individual semi-structured Interviews

Case study design

I applied a collective or multi-case study design to the qualitative portion of this study. Case studies allow researchers to identify a "unit of social life" (Kumar, 2005, p.113) to serve as the focus of analysis that is bounded within the constraints of a study (Creswell, 2012). In this study, I defined a case as the individual STEM certified secondary schools located in MWS. This is a state STEM certification, so each case was inherently bounded to MWS. I did focus on only mathematics and science teachers however the cases were not organized around subject or individual teachers. Instead the case is centered in the administrative and policy environment that the teachers worked in.

As with the survey items, the interview questions were developed around the STEM and data-use framework established for this study. However, unlike the survey the interviews delved into much greater detail on the claims participants made to examine teachers' experiences with (1) implementing the schools STEM and data-use initiatives, (2) the contexts surrounding and influencing work with STEM and data-use, and (3) using data from their STEM instruction to inform educational decisions. These interviews followed a semi-structure protocol (see Appendix), a style of interview useful for investigating "predefined categories" while having "flexibility for … follow-up questions" (Devlin, 2017, p. 217).

Excluding introductory questions, the interview questions (see Appendix) were divided into five main categories.

- Kinds of things teachers do in their classroom related to data-use and STEM
- Personal perspectives around "data-use"
- Personal perspectives around "STEM education"
- School support for teachers' use of data and engagement in STEM
- Data from STEM

The first category delved into the specific actions participants claimed to engage in related to data-use and STEM. The second and third categories looked at the layers of perception at the personal level that give context to the actions stated previously. The fourth category looked at perceptions of the organizational context surrounding participants. Finally, the fifth category was explicitly on the connection between STEM education and data for instructional decision-making. Even with questions developed for these categories, the semi-structured protocol allowed me to pursue additional details on questions.

As was done with the survey I asked content experts, both in STEM education and data-use, to vet the interview items on issues including the content of items to address the research questions, the format of items, and wording. I also, again, worked with the former STEM school teacher to get feedback on the content and understandability of the interview. I developed the interview to last between 45 and 60 minutes.

Procedure for Individual Interviews.

As part of the email to the principles that described the study and the survey, I further asked the principles to recommend teachers that met the interview participant criteria mentioned previously. Some principles forwarded my request directly to teachers, removing the need for a formal recruitment email. In instances where I was only given contact information, I prepared a recruitment email to summarize the research and invite the teachers to contact me if they were interested in participating. Two of the survey participants, having seen the request for participants section in the survey, contacted me to be interview participants. I followed up with each respondent to set a date, time and type of interview (i.e. in person, phone, or voice-over-IP). All interview participants opted for phone interviews. Once dates were set, I sent an electronic copy of the consent form to each participant in the days leading up to their interview and asked them to email me a scan of the signed form.

Before beginning the main interview, I gave a short introduction about the study. I informed participants that all information gathered would be coded under a pseudonym and that all data, including recordings, transcriptions and the pseudonym key, would be kept in a private and secure location. I also informed participants that their participation is voluntary and that they could withdraw consent at any time. Following the semi-structured nature of the interview, I told participants they could ask their own questions or make comments at any point during the interview. Finally, I confirmed that the participants had no issue with me taking an audio recording of the interview.

Data Analysis

Following the outline of a CT mixed-methods design, the qualitative and quantitative data was initially to be analyzed separately (Creswell et al., 2003). I mostly held to this process. After completing the transcription and coding of the interview data, I developed a draft of the qualitative results and discussion sections. While receiving feedback on these, I moved onto developing a draft of the results and discussion of the survey data. Overall, I completed the writing of the quantitative part of the study first, then completed the qualitative section. With both sections effectively completed I moved onto write the synthesis of the study. I attempted to keep my analysis separate through the writing of these separate sections but on occasion have made notes on topics I will address in the synthesis portion of the study. Once the quantitative and qualitative analyses pieces were completed, these separate analyses were synthesized to provide additional insight into the underlying findings. The structure of the study is outlined below.

Data from the survey was summarized with descriptive statistics. Specifically, frequency counts were used in questions asking (1) frequency of use, (2) agreement and disagreement with the need for, and (3) support for implementing aspects of STEM and data-use. Here *aspects* refer to use of inquiry activities and multiple STEM domains in either the STEM instruction or data-use for decision-making actions.

I transcribed the interviews and organized the data in an Excel spreadsheet to organize coding of the qualitative data. When coding, I focused within each case on teachers' experiences with (a) implementing the school's STEM and data-use initiatives, (b) the contexts surrounding and influencing work with STEM and data-use, and (c) using data from their STEM instruction to inform educational decisions. For this analysis and development of a coding scheme, I applied a directed content analysis approach (Zhang & Wildemuth, 2016), in which I read through each interview multiple times to attain an understanding of content. I then defined codes inductively (Saldaña, 2015) based on the content to categorize the actions and perspectives of participants. Finally, I organized the codes that came out of these readings into categories informed by my framework and the literature on STEM and data-use. These categories are:

- Administrative policies and support for STEM and data
- Conceptualizations of STEM
- Role and Implementation of Inquiry Instruction

- Issues Affecting the Implementation of STEM
- Using data for decision making in STEM teaching.

Because I was be the sole coder, to validate my coding scheme I consulted with a content expert to audit my coding process (Creswell, 2012). I developed a summary of codes and coded interview segments to facilitate this audit. I asked the expert to code a segment of interview transcripts using the codes provided to help identify any issues with the coding.

Using the quantitative and qualitative portions of the study I completed a synthesis to derive further insight from these findings. Triangulation, to facilitate combining the analysis from divergent data types (Johnson, Onwuegbuzie & Turner 2007) helped reveal both consistent and inconsistent descriptions in the data, adding to the narrative I derived from the different data sources.

Research validity and reliability

In combining both qualitative and quantitative work, mixed-methods design is vulnerable to threats to reliability and validity (Tashakkori & Teddlie, 1998). A potential threat to internal qualitative validity is in researcher bias regarding effective implementations of STEM and data-use for informing educational decisions that could skew the description of participant's perspectives. This threat can be mitigated through reflection by the researcher on the biases they have that shape their approach to research (Creswell & Miller, 2000). Personal reflection on underlying bias, which I address in the subjectivity statement in the following section, is used to try to ensure that analysis procedures are properly couched in the educational context of the participants.

The external validity and transferability of this research is weakened by the focus on schools that are in the STEM certification program. These schools, at least on paper, place a higher focus on STEM education that may not be reflected in the general school system. Acknowledging this, this research aims to give a view of school environments where STEM has been raised in importance. The overall threat to external validity is minimized when considering the continued expansion of both STEM and data-use in schools, including the continued certification of new STEM schools in MWS. This research will give insight into teachers' perspectives in the growing number of schools where these initiatives have been pushed or implemented.

The issues of quantitative and qualitative reliability were addressed by consulting both content experts and teachers on the wording of survey items. STEM and data-use may present themselves in a spectrum of different implementations. Precise wording of survey and interview questions were used to limit ambiguity in participants' perspectives when they answered questions. Specifically, for qualitative reliability, while I used semi-structured interviews, there were core questions and structure that ensured each interview covered main topics of interest.

Subjectivity Statement

Before moving into education research for my doctoral degree, I spent several years working towards a degree and conducting research in physics. Understanding of physics, and the physical sciences more generally, is a major component of how I view the world and why I am interested in STEM education. This is relevant in this study because my preference for the sciences heavily influences my perceptions of which subjects are important in teaching and of the nature STEM. In this study, I have tried to avoid elevating the role of science beyond the perspectives of this study's participants. I personally feel that robust science content is necessary for a successful STEM curriculum and that a practical model of STEM practice should focus on science as the dominate field, supplemented by technology, engineering, and mathematics. However, that is a very limited view of what STEM could be and I have actively walked back from this idea of STEM in conducing this research.

Another issue I have contended with is that the educational research on conceptions of implementing STEM gives rise to a subtler form of this same bias. Such a wide array of conceptions of STEM have been developed that it is natural to try to categorize them, and the trap is in assuming I have developed an exhaustive list of categorizations. There is still work to be done in identifying the best practices and merits of (1) teaching methods of inquiry, (2) assessing inquiry activities, (3) teaching connections across domains (both the named STEM domains and non-STEM domains), (4) organizing schools around STEM, and (5) directing national education policy at STEM education. In considering these topics in my study, I must state that the framework I have constructed to guide this study was simply a lens to interpret the STEM and data-use actions of participants and not the absolute description. This point is especially important as it turns out the framework was incomplete in addressing some of the participant responses.

I have acknowledged my bias so I can put my views into perspective while seeking to faithfully present the participants' views around the facets of implementing STEM, the teaching of STEM relevant courses and, the use of STEM data in the educational decision-making process.

Ethical Issues (IRB)

Both STEM and DDDM initiatives take the form of policies that educators must implement and anonymity is required to protect individuals who may askew or outright oppose these initiatives. Some educators may have negative opinions of these initiatives or may go as far as to actively subvert carrying these initiatives out. Educators at different levels of the school system may have these opinions, and thus have different vulnerabilities if their views are revealed.

Overall the teachers in this study did not express overt negative views of the STEM focus of their schools but express some concerns surrounding implementation and described administrators is less active in setting the STEM agenda of the schools. This is a view the administrators may not agree with but is what is held by the teachers. De-identifying participants helps limit the likelihood that participants may be identified and potentially confronted for expressing these views.

Summary of Chapter

In this chapter, I have laid out the plans for this mixed-methods. The concurrent triangulation design, with its focus on deriving a synthesis of ideas from the perspectives that may be obtained from quantitative and qualitative inquiry has provided a means to analyze diverse perspectives teachers can have surrounding STEM education, data-use and their interaction.

Participants were mathematics and science teachers, teaching in the 7^{th} through 12^{th} grade, in a selection of STEM schools. This selection was meant to narrow the studies focus to teachers who are the target of policies on STEM, teach a curriculum that necessarily involves one of the STEM domains, and teach in an environment that has policies mandating the implementation of both STEM and data-use.

To help ensure participant anonymity, select details of these STEM schools are withheld from the manuscript, as their inclusion would make the schools too readily identifiable. As observed in the literature, teachers may express or implement views of data-use that do not align with policy. Building from that, effort is taken to protect teachers' privacy as they express perspectives regarding implementing the STEM and data-use policies of these schools. In the following two chapters I will discuss the qualitative findings and discussion of this study.

CHAPTER 4: QUALITATIVE FINDINGS

Overview

This chapter describes the qualitative portion of the findings in this study for four case scenarios. Each case represents an individual STEM certified school, in Midwestern-state, analyzed through the shared insights and experiences of a set of mathematics and/or science teachers from that school. The certification mentioned here is part of a state department of education level focus on defining and promoting STEM schools within the state. The findings are organized within cases to highlight teachers' perspectives within individual schools. A description of each case is provided in the corresponding case section of this chapter.

The focus of examining these cases is to observe how these teachers describe their interactions with STEM education and data-use in an environment that, according to state policy, should have a high focus on these topics. I examine these under the scope of the following research questions.

- What are secondary educators' in STEM focused schools perspectives surrounding teaching and data-use in STEM education?
- What do secondary educators in STEM focused schools see as the role of STEM inquiry activities in informing educational decision-making?
- How do secondary educators, in STEM focused schools, describe their practices of implementing STEM education?

In discussing the intersection of STEM and data, there is a need to distinguish between the perspectives teachers feel should be a part of their classroom versus what they can and do implement. To make this distinction, each case is divided into the following sections:

- Administrative policies for STEM and Data
- Conceptualizations of STEM
- Role and implementation of inquiry instruction
- Issues affecting the implementation of STEM
- Using data for decision making in STEM teaching

These sections are the larger categories that organize this directed content analysis and are developed based on the existing literature regarding STEM and data. Codes developed from the data are organized within these categories.

The organized findings here are based on these teachers' responses to a series of questions probing perceptions and practices around STEM and data-use. While no observations were made to view practices in action, the responses given serve to highlight the major STEM and data issues present for the teachers.

Case A: School within a School- Highschool STEM Academy

Description of the Case

School A is a large suburban high school with a school within a school model. The school is divided up into academies with one being the STEM academy. The STEM academy received the state STEM certification in 2016. Teachers can teach fully or partially within an academy and students apply to take the more rigorous courses in the academy that best align with their interest. The STEM academy portion of the school has six mathematics and five science teachers. This case consists of three science and one mathematics teacher who agreed to take part in this study.

Overall the school enrolls 3400 students overseen by 160 teachers. The demographic breakdown for just the STEM academy is not publicly available. For the whole student population, 80.2% are White, 4.6% are African American, 4.5% are Hispanic and 5.9% are Asian. The gender breakdown is 48.9% female to 51.1% male. Free or reduced lunch recipients are 22.1% of the population. Students here perform above the state average on English and mathematics standardized testing. Performance has stayed above 80% over the past decade.

The first teacher is Greg, a male science teacher who is in his 14th year of teaching and is in his 6th year at this school. Greg currently teaches duel credit biology but is licensed to teach, and has previously taught, mathematics, chemistry and an integrated physical science course. He also serves as the current STEM academy leader which positions him as a mentor and instructional coach for other teachers in the academy.

The second teacher is Mark, a male science teacher who is in his 2nd year of teaching and has not taught at any other schools. Mark teaches physics and chemistry courses. The physics courses he teaches have a higher mathematics content and are calculus based. He is the only teacher in this study who was not in the school at the time it received its STEM certification.

The third teacher is Rey, a female science teacher in her 25th year of teaching. All of her teaching has been at this school. Rey teaches advanced placement biology and a Project Lead the Way based physiology human body systems course with a focus on medical science. She placed a notable emphasis on use of statistics. In discussing assessment practices, she was the only teacher to specifically mention assessment statistics, such as the discrimination index. She also expressed an interest in integrating more advanced statistics into her lessons.

The fourth teacher is Janice, a female mathematics teacher in her 33rd year of teaching and her 22nd year at the school. Janice has the title of assessment coordinator for the school and her responsibilities are split between teaching and overseeing and analyzing the school and state administered testing. She teaches pre-calculus and calculus.

Administrative Policies and Support for STEM and Data

Requirements Surrounding STEM

I first look at the teachers' views of administrative policies at School A as this sets the context for understanding teacher perspectives and practices within the school. Despite being titled with a STEM certification, the teachers at School A indicated that the requirements on their teaching due to this certification are ill-defined. While the teachers indicated they are encouraged to offer more STEM or cross-curricular activities, there are no overarching requirements on implementing STEM instruction. On this point, Mark claimed, "They encourage us … but I actually don't know how much is required in terms of being collaborative and mixing disciplines." When asked if there were requirements in place for how to teach STEM, Janice noted there were no school rules on how to implement it and Greg indicated that the STEM certification of the school did not lead to requirements at his classroom level. Similar responses where shared when the questions changed from asking about requirements to just expectations. Janice noted, "We have expectations for all classes and it's good teaching in all classes, but we don't have specific characteristics they are looking for in a STEM classroom."

When asked what the school administration is doing to support their STEM instruction, Rey responded, "I don't think they even worry about it. They either assume it's happening and don't worry about it, or they just don't think about STEM education that way." Greg, in his capacity as STEM leader, noted, "We have material resources pooled … but [teachers] could be given instructional planning supports that they don't have right now." This comment on the lack of STEM instructional supports is also reflected in a lack of STEM focus in the professional learning communities (PLCs) and professional development (PD) offered by the school, which I will address in detail in a following section.

This last paragraph may paint the administration in an unfair light. While the administration may not have articulated plans for teachers regarding STEM, is does offer resources. Greg noted that "material resources" are available and Mark explained how administrators facilitate access to these resources.

> If you have a good idea and a plan, they're very willing to help out, or, at the very least, if they don't have the direct resources, they can consult. They'll point you in the right direction. They're like, "Oh, OK. Well a teacher, a few years ago did this." You consult with them and they can give you good advice and point you in the right direction. I definitely have not experienced anything on the opposite end of the spectrum where somebody has opposed an idea, or said, "That's too much," or anything. … So far, they have been very supportive, both financially, but then also in terms of just the resources. At least giving you the right direction, they're pointing you in the right direction.

Related to this, in her role as assessment coordinator, Janice noted the administrative office also has data resources for compiling "any data you want."

Despite administrative encouragement for engaging in STEM teaching, Rey pointed out that the administration is,

> …keenly aware that, with the standards and the [State Standardized Test] and all the end of course assessments … that people have to do, that doing those cross curricular projects are often time consuming and don't hit enough standards for them to be worth it in a class that has an end of course assessment.

This statement implies that, from the teacher's perspective, the administrators place less emphasis on the requirements of the STEM certification they are under than they do on the assessment and standards requirements they need to meet. Meeting standardized assessment goals has a larger more immediate effect on the school than the stipulations of its STEM certification, and so it makes sense they would be the focus of administrators.

Rey also pointed out an issue in the structure of the STEM academy regarding collaborative and cross-curricular instruction: “because the kids are choosing their classes and taking classes that they want to, it’s impossible to have … a group of teachers … you can collaborate with.” Rey’s observations are examples of how administrative level decisions about how the school should run influence how the school can implement STEM. In the first instance, the understanding that content standards need to be taught leads to relaxed expectations on STEM teaching in the classroom. In the second instance, giving students the freedom to choose their classes limits the potential cross-curricular planning. In particular, this second instance shows how a school environment that promotes STEM may not necessarily be structured to fully support cross-classroom, cross-curricular STEM teaching.

On the other hand, Greg did describe possible requirements on STEM teaching that were external to the administration’s influence:

> We have Project Lead The Way. We have robotics. I guess those have requirements and that influences the teaching in those classrooms. I feel the goal of using STEM is out there and that might influence some of the things that teachers do.

Greg is describing that external curricula sources, such as Project Lead the Way (PLTW), may have specific STEM teaching requirements that would shape instruction.

While STEM is a part of how these teachers view their instruction, the teachers noted a lack of administrative requirements and expectations that would serve to shape that instruction. The encouragement for offering more STEM is moderated by other issues, such as the need to cover standardized content. In the next section, I will look at the teacher’s perspectives of the expectations for using data.

The Expectations for Data-Use

The lack of requirements or expectations discussed above further extends to influence, or more accurately, not influence, the kinds of data collected from STEM instruction. When asked if there are expectations for the kinds of data or evaluation that should be done for STEM, Rey noted, “No, it's just the general expectations that they have for data in any classroom.” Greg also pointed out there is no expectation of specific data from inquiry activities. There are requirements of data-use expected of the teachers, but these are not based on any aspect of instruction unique to STEM.

Administrative emphasis on formative assessment in the classroom was the primary issue raised by each teacher when asked about the expectations for using data. Greg noted there is an expectation for teachers to constantly (specifically, every 15 minutes) formatively assess and "continually tweak what's going on to match what they are seeing from students." Rey corroborated this by sharing that formative assessment was to be used "throughout the class period" to "make sure everybody's, as much as possible, up to speed" before moving onto new content. She stated simply that, "The school's expectation is that we are constantly taking data and adjusting instruction based on that data." Janice and Rey noted that formative assessment was part of professional development funded by a grant the school received several years prior. Mark mentioned an emphasis in his PLC on "collaboration and comparing data" from formative assessment, specifically for preparing common assessments.

Formative assessment can be useful in STEM and inquiry learning environments as students are learning to use the content from multiple subject domains or the methods of carrying out inquiry within a domain. However, the administrative focus on formative assessment is geared towards general teaching and not specifically tied to the STEM. As noted by Greg, "There is no expectation of, "Oh you're doing inquiry activity, you gathered this Rubric data, you put it on a spreadsheet, and you change this."" Consistent with the school administration's lack of requirements surrounding STEM, the administration is not pushing assessment practices that directly target STEM and inquiry teaching. In the following section, I will discuss the supports and resources School A's administrators offer and how they align with requirement and expectation issues that arose in conversations regarding STEM and data-use.

Professional Development and Teacher Planning Times

The teachers at School A noted having opportunities to work in a PLC, to have common planning times, and to engage in some form of professional development (PD). However, they shared that the focus of the PLCs and PD is more on data than STEM. In Greg's summary of the monthly PLC meetings he noted,

> We talk about math, [State Standardized Testing] data, science [State Standardized Testing] data. We talk about students' grades in terms of which teachers have certain practices, which teachers have other practices in their classrooms that may be really going to get students high grades versus having the students actually understand material.

Along with the monthly meetings, Greg, Rey and Janice discussed engaging in weekly or bi-weekly data-focused PLC meetings where they discuss specific student needs across classes and performance on standardized assessments Mark shared that there were also weekly common planning times for certain classes where teachers teaching a common course could discuss and compare progress in those courses, specifically on common assessments

Regarding PD, Mark noted that beginning teachers are required to attend monthly sessions which, in his experience, are focused on data and issues such as technology use in the classroom and teaching with a growth mindset. As stated previously, Janice and Rey noted there was a strong focus on formative data assessment in the PD because it had been a recent main focus of the school faculty. Mark explained that there is not really any in-house PD on STEM but that there is support for attending conferences and events where such resources are available. Supporting this, Rey and Janice specifically stated that they had never been offered PD related to STEM. In both PD and PLC work, the issues of data-use take precedent over issue of STEM instruction.

Greg's role as the STEM academy leader puts him in the unique position as a potential source of informal STEM PD. As part of his mentoring of teachers, he claimed that he is "continuing to help other teachers to make steps down the continuum away from just alone math and alone science but contextual and integrated with the T and E." At the same time, the other teachers indicated that Greg is the person they could go to discuss questions about STEM instruction. Thus, while there may not be official STEM PD at this school, there are interactions between teachers in the academy that serve to develop teachers' ideas about STEM instruction.

For the teachers in School A the administrative focus, in PLCs and PD heavily favor issues of data-use. However, while there is a lack of instructional supports on the general teaching of STEM, if a teacher takes initiative to try a STEM lesson, they will receive guidance and resources. Instead of being driven by the administrators, the impetus for implementing STEM seems to rely on the individual teacher's choice to focus on STEM. In the next section I will look at additional administrative policy issues discussed by the teachers that influence both their STEM teaching.

Discourse on STEM Instruction

Having individuals available for teachers to talk to regarding STEM is part of maintaining an active STEM teaching environment. The teachers in School A indicated having frequent discussions with other teachers and administrators on STEM and access to individuals to talk to regarding STEM. Greg, in particular, mentioned having access to several content experts through connections with a local university STEM center, individuals in the State Department of Education and professionals at a local hospital. With this, Greg is able to bring in external resources that he connects to STEM professional development discourse and instruction. This content can further disseminate into the school’s discourse as the other teachers discuss topics with Greg in his role as the STEM academy leader. In the next section I will discuss changing policy issues that teachers mentioned affecting their STEM instruction.

Policy Changes Affecting Teachers

Some teachers noted changes to materials and curricula that influence the cross-disciplinary component of their teaching. These changes are indicative of the evolving education landscape that these teachers are working in. All of these changes have occurred over the past several years and overlap with the timeframe of the school’s certification as a STEM school.

There are large-scale changes associated with changes in standards. Janice noted two recent changes: first there was a change in the state grading system to focus more on a growth model or mindset; and second, there was a change when the state’s main standardized test was made a part of the graduation requirement for students. I should note here that, at the time of this study, this testing had a required mathematics but not a science portion, so this change mainly influenced mathematics teachers.

Another change associated with standards is in the development of process standards that now exist alongside content standards. Greg, in discussing the general expectations of teachers in the STEM academy, pointed out how many teachers were trained in their content areas “before the process standards and engineering standards came into being part of the expectation.”

Consequently, many tend to prioritize content standards over process standards that are provided. For context these process and content standards are modeled on the Common Core State Standards (CCSS) and the Next Generation Science Standards (NGSS) but do not follow them as the state declined to implement the NGSS and CCSS. As Greg notes,

> If the state had gone to the NGSS, you would have your three [process and content] domains for every lesson: scientific and engineering practices, cross cutting concepts, and your content discipline. If we had done that transition, it'd have been a lot more clear to teachers of what the expectation is.

Further, there are curricular changes that are likely influenced by the standards changes described previously. Greg pointed out an important change in AP testing.

> A number of AP tests have been redesigned to try to integrate more math and more context to the questions as opposed to having the AP questions be, "What is the type of flower? What is that type of cnidarian? What are the characteristics of those phylum?" That is no longer on the AP biology test.

Rey also noted changes to the AP biology curriculum that have increased the level of mathematics involved in individual lessons.

I have highlighted these policy changes to help show how the STEM teaching and data-use aspects of instruction at School A continue to change. Issues of the changes to standards and standardized testing and required AP curricula all affect teacher's instruction at this school. These issues combined with the policies and resources of the school help reveal a specific organizational context of STEM and data these teaches work in. In the next section, I will look at how these teachers are conceptualizing and implementing the STEM teaching couched within this context.

Conceptualizations of STEM

Teachers working within the STEM focus and policies of these STEM certified schools bring individual conceptions of what STEM education and instruction entails. These perspectives are not necessarily what is implemented in the classroom but may be the idealizations of what could or should be implemented. In this section, I will summarize the characteristics the teachers at School A ascribe to STEM. These responses come from relatively open-ended questions that allowed the teachers to present their main thoughts when they heard the word STEM. The questions focused on topics such as the nature of the STEM classroom (e.g. From your perspective, what are the characteristics, such as activities or content, that you believe would make a classroom a STEM classroom?) and the multi-domain structure implied by STEM. For example,

> In some interpretations of STEM, the integration of aspect from multiple domains is an important part of STEM education. Do you teach lessons that combine multiple domains? How frequency do you teach these lessons? How do you feel about these kinds of lessons, in terms of effectiveness, engagement and practicality, compared with lessons that focus just on your normal content area?

The different aspects of how teachers conceptualized STEM, based on these questions, are described in the following sections.

Integration

The concept of integration or some combination of subject domains is a characteristic often applied to STEM and was a component of each teacher's description of STEM. For example, when asked about characteristics of a STEM classroom, Greg responded with, "I think the term integration is important there. In the ideal STEM classroom, you have a little bit of all these science, technology, engineering, math working together on projects that are meaningful, useful, community improving and life improving." Mark, on the other hand, initially described STEM as an "interweaving", of math, science and technology, to make connections outside of the physics classroom. He later switched to refer to the integration of science with technology, engineering and mathematics to discuss STEM education. In describing a science project involving a catapult to show projectile motion he emphasized "you need to have engineering and technology experience to build it. Then you can use mathematics as well to actually calculate work." Janice, like Mark, described STEM as the integration of science, mathematics and technology, but she also placed a special focus on technology. Rey did not use the term integration but talked about connecting STEM by connecting science, math and engineering concepts.

While integration was part of the discussion surrounding STEM, the scope of integration in terms of the domains and subjects focused on varied within and across teacher interviews. As noted above, Mark mentioned an interweaving of science, mathematics and technology but shortly after made this claim about how he teaches his students:

> I always try to encourage them the reason they learn math is because we're doing the cool physics stuff. I'm trying to get them to think beyond just a math class or just a science class. I do want to try to integrate the two…

In this instance this science teacher is specifically singling out math as the important domain to include in his instruction. Mathematics is an important component of understanding and working with science since many aspects of science are described by mathematics. By focusing on mathematics, Mark is trying to make that connection for his students. Rey, a biology teacher, also singled out mathematics and specific science subjects to be "incorporated" together, sharing: "In biology, it's pretty easy because you're going to make connections with chemistry, physics, and mathematics. All that you can do in one lesson and make all those connections." The focus these science teachers have on connecting with mathematics indicates they see a strong need for including mathematics content into their science teaching.

Greg presented a broader view of STEM. While he first emphasized the importance of incorporating "as much as possible elements of design engineering," he went on to clarify that STEM does not have one fixed form:

> I view STEM education and STEM integration on a continuum, where there are some activities and some classrooms on some days that are all the way STEM... Then there are other times where it's more just the S and M or more just the T and E separately.

Interestingly, regarding this broader take on STEM, Greg described a connected professional development activity.

> We, as a STEM staff, did this little formative assessment activity where eight people had eight different definitions of STEM. Then the teachers align themselves with who they thought had the definition of STEM that they recognized the best. We had probably five to six different categories that people walked into when they defined STEM.

Further, in his role as the STEM academy leader, Greg expressed interest in learning how to help other teachers move away from siloed teaching of STEM domains to more integrated teaching.

Each of the teachers did qualify the discussion of integration. For example, Mark pushed back on the use of integrated instruction, mentioning the importance of educational scaffolding and stating, “It’s important to have stuff integrated, but you need to have prior knowledge or background knowledge for parts of STEM prior to putting it together.” Rey made a related claim indicating the potential need for basic content knowledge for making connections between scientific, mathematic and engineering concepts:

> There are some lessons where you're just trying to learn processes or a particular concept that you could maybe make connections later, but, at the time, you're just really trying to get the students to see something, to see a pattern…

Janice expressed the need for providing training on basic content not in in terms of integration in her classroom but in terms of preparing students to have the mathematics skills needed to take courses in the STEM academy. Compared with the science teachers, Janice viewed her class as supporting the STEM environment over specifically integrating within her classroom. Finally, Greg clarified that teaching mathematics and science does not inherently imply that teaching is integrated:

> I don't like to buzzword and say, "Oh, problem-based learning or project-based learning is if you're doing that in science and math, then you are integrating STEM" because you may not be. But that type of work can more readily lead towards a full STEM integrated lesson.

The teachers of School A all discussed the combination or integration of content from multiple domains as a part of STEM. Some further clarified limitations on how these domains combine in terms of needed scaffolding or effective integration. These different perspectives on integration inform how teachers are thinking about, teaching, and assessing their STEM content. The next two sections look closer at how these teachers conceptualize the integration of domains.

Inherent Integration

One view expressed by the science teachers at School A is that their classroom activities are inherently integrated (for reference, this view was also held by all the other science teachers in this study, but by only one mathematics teacher). For example, Greg described how he views lab work as naturally integrating the STEM domains. Greg shared:

> I teach biology and there's so many people to teach Chemistry or Physics. I think that there's elements of two to three, sometimes four of the STEM being used in those classrooms. For example, there's a Chemistry classroom working on a lab that is going to try to sort out a mixture into its component parts. They're going to do a procedure. They're going to test their procedure to see if it works. In some ways, that's engineering because they're … designing a procedure, and they're not just following one set of steps that have been prescribed.

It is worth noting that what he describes here as the engineering design process in developing experiments, I would classify as being part of the scientific inquiry process. Greg later expanded on his point of science labs incorporating design but pulled back on whether that can be called engineering:

> How often are they engineering? Well, they're designing experiments, right? They're setting up situations that allow for better evidence to be collected, better than other situations. There's a little bit of elements of design in there. Now, would that be considered engineering? It depends on who you ask maybe.

Rey made a similar general claim, making the statements: “I teach science. From my perspective I'm a STEM classroom no matter what I do” and “I consider myself a STEM teacher every day.”

Another example of this view of inherent integration is rooted in the close connection and use of mathematics in science, as expressed by the three science teachers. As Greg explained, “It's hard to make sense of scientific lab data without integrating math.” Mark echoed this, stating, “There are physics topics that you can talk about, but there's others that you can't do effectively if you don't have the math skills.” Additionally, Rey summarized the connection between mathematics and science as follows:

> I feel that, in order to understand the science, you need to understand the math. The patterns of nature are seen in the data. I don't feel like one is more important than the other. Obviously, as a biology teacher, I'm here to teach the concepts of biology, but it's science and you're looking for patterns. When we do our experiments, we definitely want to know how to collect and analyze data and understand the basic statistics.

Many aspects of science are understood and articulated in terms of mathematics concepts so it makes sense that these science teachers would place this emphasis on mathematics content and skills.

Janice, the mathematics teacher, offered a different view of the role of her classroom regarding integration. She stated,

> I feel like we do a good job here of the math. We make sure they have the math skills they need to go do those other things. I'm torn by the phrase STEM education. The other parts of our system are integrated pretty well and fit that model really well. I feel like we're supporting that versus that being integrated in our math classrooms as much.

Janice perceived other classrooms as integrating in the mathematics skill which the students learn from her teaching. Integration of content is a part of instruction in the academy, but she does not consider it a main part of her instruction. This is an interesting scenario where a teacher can be supportive of the STEM focus of the school but at the same time sees themselves in a role that minimizes their classroom STEM focus.

Inherent integration of domains implies a strong perceived connection between those domains. Here the science teachers are talking about mathematics as being an unremovable part of their science teaching. These teachers would likely express this view of the importance of mathematics even if this discussion was not about STEM. In the language of this study's STEM framework, this can be looked at as a combined domain view of STEM. The combined domain viewpoint can be contrasted with the dominate domain view where one domain is the main focus of content while another is used to supplement instruction. The following section I will talk about this view of STEM as it arises in relation to integrating engineering and technology.

Integrating Technology and Engineering

School A teachers' descriptions of the how engineering and technology fit into STEM classrooms and lessons illustrated a particular view of the role of these domains in teaching. When discussing the "T" in STEM Greg shared:

> The T [in STEM], I feel like we use a lot of technology. We use Vernier sensors. We're using data Spreadsheets. We're using Google Sheets, and we're trying to do math via that technology, and we've got infrared cameras we'll use in labs.

In his description of a STEM lesson, Greg described that you are "trying to solve a problem using the engineering design process and using technological tools." Janice, the mathematics teacher, also discussed technology as tool use, describing the inclusion of technology in her classroom as only using graphing calculators. However, her further clarifications add nuance to the view of this tool:

> We have this great tool, and the kids should be able to use it. … [I]f they're in the real world, they would have access to all the technology, but then we're getting caught with some other places [standardized testing environments] that don't want you to use it.

In general, Janice described a STEM classroom first as incorporating technology and then as incorporating different subjects together. Rey did not mention technology, as a subject domain, directly but did refer to specific technologies (i.e. spreadsheets for graphing, Chromebook computers, and lab sensors), in describing her lessons, that she felt it were important for students to learn to use.

Unlike technology, which teachers focused on as technological tool use, discussions of engineering were more nebulous or if discussed at all. Greg used technology and engineering partially interchangeably in describing "problem solving engineering" as a part of technology use in STEM. Mark merged them mentioning the "engineering technology aspects" of teaching. He then went onto discuss how understanding engineering can be helpful in guiding students broader understanding of science activities. He stated,

> …engineers aren't just building stuff that are effective. It needs to be efficient both from a process standpoint as well as a money standpoint. We hopefully get them at the process of it's not sufficient just to build a huge cushion around it if it costs $5,000 or something. You can get the same results for half the budget, that's, in the eyes of an engineer, worth more.

Here Mark has focused in on a specific aspect of engineering (i.e. constraints and requirements) that he feels are important to his students but is not necessarily considering how to include the full scope of the engineering design process. Rey and Janice did not discuss engineering beyond the general statement that engineering is part of STEM.

Under the dominate domain view of STEM, these teachers describe technology predominantly as tools used in instruction. Those tools may have a vital purpose, but they exist under the main domain being taught. This has implications for where this domain fits into how lessons are taught and assessed. Integrating engineering and technology can help teachers to make more student-centered STEM instruction. Going through the design process and having hands on technological tools can help increase student engagement and give students more ownership over their work. The next two sections will explore these issues as I dig further into the teachers' conceptualizations of STEM.

Active Learning and Student Engagement

Another component of the teachers' conceptualizations of STEM is in how STEM instruction can engage students in learning compared with traditional instruction. Mark described traits of an ideal STEM classroom as being student led, which makes students move involved and accountable to the instruction in the class. He later described this as putting the ownership of the instruction back in students' hands. This idea of ownership was echoed by Rey as she described the student engagement that comes from inquiry activities: "When you can select your own testable question and decide what variables you're interested in testing, you already have some investment in the process." Janice noted that instruction under STEM helps students understand how and why things work the way they do. According to Greg, his continued focus on STEM instruction is to help students to be engaged in a classroom: "I feel like STEM is not just passively memorizing facts but using math and science actually to make sense of their world and to improve their world through engineering technology."

For these teachers, the active learning and engagement that comes out of STEM sets STEM apart from traditional instruction. The important issue to consider is that the changes the teachers need to make in their instruction to foster this STEM teaching may lead to changes that have to be addressed in how to conduct assessment. I will address this further in a later section on data-use. In the next section I will look at how some teachers view STEM as giving a personal or relevant context to lessons that helps foster the engagement described previously.

Authentic Context

Authentic context is a component of education that goes beyond just being engaging to encompass education that reflects the real-world scenarios that may be relevant to students. In STEM education, authentic context covers the idea that the integration of content domains and active learning practices to connect with these real-world scenarios. For Greg, Rey and Janice, authentic context was an inherent component of STEM as they saw the impact of STEM education extending beyond the classroom. Greg described STEM projects as ones that are "meaningful, useful, community improving and life improving" and later reiterated the point stating during such projects "students are hands on, minds on, solving problems using math, science, and technology tools and designing things that help improve their life in the community." On this issue of community, Janice mentioned that, as part of the whole school's STEM focus, students have been part of "real world hands on activities where they present things to the community." Similarly, Rey described that, in her STEM instruction, "I do try to make relevant connections with things that the students might be interested in. I have a lot of musicians, a lot of athletes, so I try to find connections in things that they're interested in." She later discussed how she would ask students about their interests and look for ways to incorporate them into the curriculum she teaches. Interestingly, Mark, the teacher who was new to his teaching position, did not describe any aspect of teaching that aligned with this concept of authentic context in teaching. Since this issue was raised by the more experienced teachers in all of the school cases, it may be that this way of conceptualizing education and STEM evolves with teaching experience.

This look at how the teachers in School A conceptualize STEM revealed views on how the teachers view integration, how they consider STEM to engage students, and how they consider the STEM education within the school to connect with the world outside of the school. A real-world context may increase interest and engagement, but also may alter how and what content students are exposed to. The choices of what and how content domains are integrated can have influence on the choice and process of assessment. The different aspects of teacher conceptualization of STEM may intersect to affect data-use. With the conceptions underlying STEM established, in the following sections I will look at how inquiry and STEM are implemented by these teachers in the classroom.

Role and Implementation of Inquiry Instruction

My analysis of teachers' perceptions on inquiry is separated from STEM here because, while they are often connected, they are not synonymous. Inquiry encompasses student centered and active methods of teaching content but does not require content from multiple domains to be taught. A science lesson can involve scientific inquiry but not be an integrated STEM lesson. Alternatively, a science lesson could involve science content giving context to an engineering design process. This setup could be labeled as a STEM lesson, but the inquiry present is only associated with a specific part of the lesson. This section looks at how the teachers in School A describe inquiry to further understand its role and implementation in their teaching.

The teachers shared several characteristics of what they believed was involved in inquiry instruction. First, a perspective held by all science teachers in this school was that it was important to give students some opportunity to make choices in the inquiry process and not just follow prescribed labs. Mark described this concept in detail:

> With those [AP] labs, they are very much student centered in the sense that we don't give them a lab procedure. We give them typically what we expect in a lab notebook. Besides that, it's their job to come up with their own title, their own procedure, their own purpose, objective. I can give them guidance if they don't know what to collect or how to use equipment. It's up to them to make the lab their own. Then go from there, get their own data, and how they interpret it.

The AP curricula labs have this structure built in, which may help define the teachers' perspectives on the structure of lessons. Mark further shared that he was looking for how to move his sophomore curriculum away from the "cookbook style". Greg described a similar focus for some of his labs.

> On a unit basis, I try to have at least one lab where students get the scientific practices, an opportunity to use where they don't just follow a set of steps. They might follow a set of steps, but their getting to be able to make choices as to … what they're going to test, and then sharing out that data with the rest of the class, try to find general patterns between what is evidence based and what's not as evidence based.

Rey described the same general idea for some of the labs she teaches but focused more on the issue of how the choices in inquiry naturally leads to differentiated student instruction. Referring to students with a novice grasp of the material she noted,

> They still do an experiment. They're still collecting data and analyzing it. Everybody gets value out of the exercise at their own pace. They have to be able to come up in front of the class and tell the class what their question was and what they were trying to figure out what's their data and their statistical analysis, and what they've concluded from that.

The science teachers also discussed the idea of explicitly connecting the inquiry and non-inquiry content of the lessons. Greg discussed this both in term of directing students back to the vocabulary they learned outside of the inquiry context and generally trying to convey to students the message of, "Look, we have these big ideas in biology and used them in this experiment. How does that experiment and the variable testing connect to those bigger ideas?" Rey described the same process of connecting the important concepts from the class to the results and conclusions obtained from the experimental data.

Janice, the mathematics teacher, offered a very specific view of the role of inquiry and how it connects with her content. She described that inquiry activities served to explicitly connect with specific derivations of formulas or mathematics concepts. However, for her the mastery of specific content is more important than any learning that comes from inquiry. This is revealed in her statement that inquiry is "showing them how things work or why things work, but then that's not as important to me as whether they can use the formula we derived." For Janice, inquiry serves to support understanding of content but, unlike the science teachers, she does not use inquiry as an opportunity for students to experiment and derive that understanding.

Two science teachers, individually, brought up a few additional points regarding inquiry. Mirroring Greg's earlier statement that STEM is a continuum, Greg also mentioned an "inquiry continuum from ClickBook labs to more open-ended STEM integration type labs or activities." As part of this statement Greg mentioned having discussions on this issue with other teachers in his role as the STEM academy leader. This indicates that this general idea about inquiry has, on some level, been shared with the other teachers in the academy in this school. Indirectly referring to the different levels of inquiry, Rey noted:

> I'd say that, even though I do inquiry, it's not the highest or purest form of inquiry. The kids are going to be boxed into a particular content area. If it were the full-on inquiry, it would be more of a research class, and we don't have that. We have content to get through. We have goals to reach and an assessment at the end of the course.

The influence, mentioned here, of content standards and data use on inquiry and STEM practices will be outlined further in a following section.

Overall, the science teachers talked about inquiry in their science instruction as giving students choices in their learning, giving them the opportunity to make decisions that influence the work in a lesson or lab. While it is not explicitly stated they describe inquiry as an experience that teaches students how to *do* science. Beyond just content students must make decisions and go through the scientific process. This inquiry also serves to connect back to the main subject content of the classroom. Janice, in offering inquiry in her mathematics instruction, presented an idea of inquiry that is supplemental to content instruction. It does not necessarily teach mathematics processes but instead focuses on explaining details about concepts, derivations, and formulas. With this structure of scientific and mathematical inquiry laid out, in the next section I will look at issues surrounding teachers' implementations of STEM.

Issues Affecting the Implementation of STEM

This section looks at some of the issues affecting how STEM education is implemented. The sections on administrative policies and conceptualizations of STEM set a context around which STEM is implemented. The issues discussed here more directly shape how the teachers in School A engage in STEM teaching.

Scaffolding and Differentiation

Scaffolding and differentiation are two aspects of organizing teaching. With scaffolding, content is specifically organized to build upon itself to help students learn. This is an issue in STEM education in instances where students may be introduced to multiple content domains in an open-ended context. Supplementary teaching has to prepare students for productively engaging in such a STEM activity. Alternatively, if the STEM activity itself is supposed to teach the subject, care is needed to make sure the student is not left without any idea of how to progress. Differentiation is where students of different ability or interest levels engage with different levels of content. These levels can be pre-planned by the instructor or, as is the case with many STEM and inquiry lessons, can emerge naturally as students make their own choices to pursue different options within an activity.

In describing the STEM aspects of his physical science teaching, Mark discussed the importance of scaffolding in building student understanding. He described the process as,

> Trying to get [students] to section off little ideas. Build up the scaffolding…where you try to use the analogy that learning physics is like learning a language. To do that you have to start learning letters and then start learning words. Then you get to the sentence. Rather than just jumping right into hardcore physics, you have to break it down and go from there.

He later provided an example when discussing the importance of scaffolding in ensuring student are prepared for content in integrated teaching:

> Say we're talking about how to take instantaneous velocity. You can approximate it without calculus, but the kids that don't get calculus yet, I have to spend time rehearsing that with them and focusing on how we take the slope and all of this stuff and showing them, "OK. You know you did that math class, but now, over here, it has a physical purpose."

This passage touches on both ideas of scaffolding and differentiation as Mark describes trying to breakdown the mathematics content necessary for the lesson while also considering how the content may be approached by students with different levels of mathematics background.

Janice indirectly discussed this idea of scaffolding noting that she sees the inquiry activities as “more to develop a topic” and help students understand why things work. At the same time, she also mentioned a separate need, based on the standards requirements, to make sure students understand how things work (e.g. being able to use a formula). Both Janice and Mark shared a perspective that the STEM education activities are not the way to teach basic content. Instead, for them, subject content needs to be introduced and then can be applied by students.

The levels to which students can apply the concepts they learn ties into the idea of differentiation. Some students will already have the background or skill necessary to tackle certain content, while others need different levels of support and different points of entry into a lesson to be able to engage. Rey discussed how her STEM teaching allows for students to differentiate themselves:

> The students differentiate themselves in this process. The students who are capable of higher-level work, their procedures are going to be better. They're going to try to go for more trials or more achievements. They're going to be thinking more creatively about what they're going to measure, what they're going to change. …Then you have the other students which may be a little bit more...I'm not going to say lower level, but they're just not as advanced in maybe scientific skills or thinking scientifically yet. They might just do something simpler, like go for the temperature … just something simpler, something more obvious.

An important take-away from this passage is that "students differentiate themselves". The open nature of how the STEM lesson is implemented ensures the students can tackle the content at multiple skill levels in a way that is not imposed by the instructor.

Both scaffolding and differentiation are general topics in teaching so it is not unexpected that these teachers would mention them. However, it is notable that these issues are raised specifically in the STEM teaching context. STEM education brings specific challenges regarding scaffolding and differentiation of instruction due to the inclusion of content from multiple subject domains, which some of these teachers appear to reflect on. In the following section, I will look at how the teachers see content standards as influencing their STEM implementation.

Teaching Standards and Primary Content

A major issue discussed by teachers was how content standards and the content of the teacher's primary subject domain directed their teaching. Greg, discussing the requirements of his duel credit courses, noted that,

> …the objectives that I have for my dual credit class is pretty much science objectives and not technology, engineering, and math objectives. If every activity I've got to do is supposed to tie to an objective dictated by a dual credit provider, then that is not STEM, that is S.

Mark made a similar point about his main teaching, stating,

> It's probably always science focused or physics focused. I don't typically feel like I spend too much time teaching from multiple domains. I feel like I can teach math a little, but I've never spent much time looking up the formal standards… for technology and engineering…. In short, I probably teach a little math more than anything, but not as much engineering and technology I would say.

The way Mark talks about his teaching separates his daily practices from how he described unit projects he has the class do. While his general instruction is science and mathematics focused, he tries to offer projects (i.e. bridge building and a "pumpkin chunkin" projectile motion launching) where "you need have engineering and technology experience to build it." So in practice Mark is bound to teach his primary content and is implementing the other domains when possible.

Rey discussed this issue of needing to teach standards while attempting to still tailor the course content to the interest of students. She said,

> …you have to teach the standards. You have to meet those expectations. Sometimes what the students want to do fits in pretty well with that. Illustrative examples that they might be interested in medicine, athletics, or whatever. In biology there's a lot of different ways you can go, a lot of different connections that you can make.

However, she also noted in the case of AP courses that the structured nature of these courses limits what she is able to incorporate. She discussed an example of how she modified one lesson to include mathematics content she felt was important.

> [The lesson creator] wants them just to copy and paste the graphs from the sensor apps into their graph, into their lab. That makes no sense to me because that's such a small part of what you're doing. I have them do it several times and get averages. Then we're going to collect the class averages into a spreadsheet. I'm going to teach them how to make a graph with the spreadsheet, not just copy, paste graphs from the sensor ware. Not necessarily in depth, but just to introduce them, because they do no statistical analysis, we're going to make sure those times are different.

As part of this modification of the AP lesson, she also mentioned how she introduces the t-test and error bars in a simplified way to help students gain a deeper understanding of how to interpret data.

Rey’s comments illustrate how a teacher may push back against and navigate within teaching standards or lesson expectations to improve their instruction. Under this study’s focus on how STEM instruction comes together, she has taken a lesson with a very minor mathematics component and greatly increased its role to expose students to data analysis. Mathematics may still have a much smaller role than the science content, but the focus on increasing it, within the limitations set by the standards, is what shapes how the teacher is implementing STEM.

Janice noted how the number of standards for calculus and pre-calculus limited her opportunities to do inquiry activities. She also expressed concern about knowing what content can be integrated: “I'm just not comfortable enough with it yet or know enough about what pieces I could put in.” Interestingly, she expressed her concerns about integrating content in terms of standardization stating that one of the things she would like to know more about regarding STEM is: "What would the standards be for considering that math is integrated in this?" This question shows a different approach to considering STEM compared with the other teachers. Instead of focusing on how to work around existing content standards to implement STEM integration, Janice is interested in what standards could directly encompass integration. Later she described how the use of the state standardized test as a graduation requirement is generally affecting mathematics teachers STEM instruction in the school.

> When [State Test] became the new graduation test and the state is not doing well in it, my focus changed to working on a test. Making sure we're ready for a test because that's a graduation requirement. I feel like we are derailed at the moment because of this testing component.

Janice’s subjects of calculus and pre-calculus are not included on the State Test, but since she is the school’s assessment coordinator, she is directly affected by this change through how she interprets school data and the kinds of instructional coaching she designs.

The need to meet standards-based content has a major influence on shaping instruction but of equal importance is how teachers navigate and modify their teaching to both meet the standards and include the content they feel is important. However, enacting these changes takes time both for planning and time in the classroom which are the final issues of implementing STEM I cover in the next section.

Limitations of Time

Two of the teachers singled out time as an issue in implementing STEM. Rey pointed out that some of the experiments she has her students do can involve days of dedicated lab time. She noted that while this time commitment is a complaint many teaches have, she feels it is valuable in her science teaching. She also mentioned the competing need for getting through AP curricular content to prepare students for the AP exams. Janice singled out the school's block scheduling as an impediment to getting to do inquiry activities and to get through the required standardized content. She further noted the act of planning out and integrating subjects as a source of time limitation in her teaching.

Comments from the teachers suggest that limitations on time influence the implementation of STEM because it directly influences the lessons and activities teachers are able to prepare and implement in their classrooms. Teachers need time both to prepare the lessons and time within the class to teach the lessons. The teachers may not be able to incorporate the additional content and inquiry needs of a STEM lesson within the lesson times they have available.

Up to this point the discussion has primarily focused on STEM, including the administrative policies, the teacher conceptualizations and issues of implementing. These issues connect across the levels of the study's framework and define a general scope of STEM education within this teaching environment. Teachers hold conceptions of what content or practices should be included into STEM and issues may arise affecting or limiting what may be implemented. This leads into the discussion on data-use as the content that teachers present and the extent to which that content is a part of teaching should influence how teachers approach using data from that teaching. In the next section I will look at how these teachers are collecting and using data from their STEM teaching.

Using Data for Decision Making in STEM Teaching

The teachers at School A shared that they focus on utilizing both formative and summative assessments in their classroom to inform immediate and long-term curricular changes, respectively. For example, Greg stated that he used standardized testing data to "help make decisions instructionally from one year to the next" but uses "ongoing formative assessment information to make decisions about what to do next every period." This was similar to Rey's practice where she described,

> With the formative assessment, I can learn more about how the student's mind, in particular, works, and it may be things that would be useful to help them personally. You need to help them differentiate a little bit so that they can get the most out of the class. Then the summative data tells me what I need to improve in myself, in my instruction, in my lessons.

Mark brought up formative assessment in terms of informing students about their performance, saying he is,

> … letting them know where they stand currently and how they can improve it. I try to grade as often as possible. I'm catching, in the moment, their current level of understanding, rather than just trying to say, "You got an 80 out of 100," arbitrary.

Janice similarly commented on the importance of using assessment tools (e.g. exit slips) to give feedback to students that is not a grade.

The frequent use of formative assessment is one of the data-use expectations set by the school administration. While it is a requirement, the teachers make strong use of the form of assessment. For these teachers, the formative assessment serves as a direct connection with students, helping both the teacher and students be aware of how the class currently stands and giving insight to the teachers on immediate changes they should make moving forward.

In a specific example of using summative assessment, both Mark and Janice noted their main focus regarding data was on tracking content mastery of current topics. Janice, the mathematics teacher, put an emphasis on standards data and student background in subject content, focusing on the importance of "knowing which kids can perform which standards" and how that information can be used to "fill in the gaps for the ones that aren't meeting the standard" to help them achieve content mastery. In his science class, Mark described a process of allowing students "opportunities to break down the test" regarding what they missed and allowing them to retest for mastery via "mini quizzes" on the material. As he noted, "if they keep showing effort and keep trying to master the material, I want their grade to reflect that." Mark's practices here blur between formative and summative assessment as there is still a summative focus on student mastery in his classroom. In a similar way, Rey discussed using exit cards to check for student mastery target areas of the content she might need to reteach. This emphasis on content mastery connects back to how the focus on content standards influences the implementation of STEM. These teachers use of assessment aligns with how subjects are prioritized, due to standards, in STEM teaching. In the next section I will look closer at the kinds of data these teachers take from STEM and inquiry activities.

Data in the STEM and inquiry context of the classroom

The teachers' responses in this section came from a number of interview questions that addressed teachers' perspectives and practices about data and data-use within the STEM and inquiry context of the school. As a follow-up to asking about the kinds of inquiry activities a teacher uses, I also asked about the kinds of data they obtain from such activities. Separately from this, I asked about their process for assessing students when they teach lessons that cover multiple content domains and use this data to alter instruction. I also asked questions to have teachers explicitly connect their STEM instruction and data use. For example, I asked: "From your perspective, to what extent does data from the STEM aspects of your classroom practices, lessons, and curricula inform your decision making, when compared with other data sources, such as standardized testing data, or other data types, such as mathematics or science specific performance scores?" These questions help to get at the ways teachers viewed data in the context of their STEM teaching.

When teaching STEM or inquiry lessons, the teachers indicated they focused primarily on formative or informal means of understanding their classroom. Greg summarized:

> Moment by moment what happens in the classroom is based on how they're working through these real problems and real situations. I'm not thinking like, "Oh, [State Standardized Test] last year showed this." I need to make sure I talk to them about this today, and this today, and this today. Not typically. But they have to design this experiment in such a way that they're going to be gathering these many trials. I'm going to ask them questions to see if that's what they like. What is more valid and reliable about that than other situations?

In the context of lab grading, Rey made a similar point, noting, "I can read that they understood the experiment as a whole and that they're able to make a relevant and reasonable conclusion based on their data and their data analysis[6].” Mark also discussed what he considers when grading lab work, stating,

> When I grade a lab report, it's not "Did they get the right answer?" because we're not doing labs where it's like, "Try to calculate the acceleration of gravity." Those kind of things. I'm more or less trying to grade the way they approach a lab and how they view it, like, "How true is their data and their conclusion to their purpose?"

Each of the science teachers mentioned the importance of seeing students being able to identify and use evidence. Greg pointed out how understanding of scientific processes helps students see how ideas are based on evidence, instead of viewing them as just being passed down from generation to generation. During lessons he noted observing students work and, when appropriate, make comments such as, "Your claims really didn't tie exactly to the evidence that you've shown. You were making claims that were outside of the evidence." Mark echoed this point:

> …the most important part I'm interested in is how they analyze their data. A lot of people, they collect data, but they don't know what to do with it. Trying to get them to just keep asking themselves, what do they have? What did they find?

Rey similarly stated,

> We're having these discussions about the patterns that they see in the data, why they may have occurred, trying to come up with conclusions about what that data means. … Those kind of organic discussions, they're real. They're based on data that the kids collected and that they're trying to discuss with the class.

Connecting back to the large focus on mathematics expressed by the science teachers, Mark addressed how he handles assessment of mathematics.

> In terms of assessing specifically math standards or the math aspect of STEM… I always care more about a process. I tell them to show work and show me how they're getting the answer. I don't really care about the answer. Once you set up

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[6] I should note here that in the following paragraphs the teachers talk about students collecting and analyzing data or evidence in classroom activities. My research is focused on the teacher’s perspectives and practices in *their* data-use. so in reading the next passages keep in mind that the data collected by teachers is the *observation* that their students are making decisions about and analysis of data in their own activities.

> the problem, the rest is math. The beginning of a solution to a problem, to me, is the most important.

From this description, Mark is interested in seeing that the students understand the logic that connects the science and mathematics content but does not place emphasis on completing the mathematical steps. As covered previously the other science teachers also discussed the close connection of science and mathematics but did not directly state how they consider assessing the mathematics content they use. Rey, the science teacher who discussed adding statistics concepts (e.g. averages across multiple trials, t-test) and graphing concepts (e.g. graphing in a spreadsheet, error bars), indirectly indicated that she takes students' understanding of these math and technology concepts into consideration through how she restructures her AP lessons to include them. However, this use of these concepts still falls under how the concepts apply to students use of data within the broader science lesson.

Janice, who as a mathematics teacher had expressed a stronger focus on the mathematics mastery, expressed less emphasis on data from inquiry stating, "Some of inquiry that I do, if they don't see where it comes from, then you can still just carry on with what they were supposed to get. Some of that is not really assessed." She emphasized the relative importance of mathematics content compared with the STEM activities: "It's showing them how things work or why things work, but then that's not as important to me as whether they can use the formula we derived..." The additional pressure on students meeting mathematics standards may explain why Janice expresses a focus on the content skills and mastery over what students may learn directly from engaging in the inquiry process. The next section I will look at the limitations expressed by two of the teachers regarding how they use data.

Limitations of Data use

Two of the science teachers expressed limitations with data use. Mark expressed a concern about the limits of his understanding of how to use or collect data noting,

> I feel like a lot of times I'll either collect a lot of data and not really know what to do with it, or I'll do an activity, but I don't really know how to assess how effective or useful it was.

The issue of how to collect and interpret data from inquiry activities has been observed, in particular, among science teachers.

Greg, in his capacity as the STEM academy leader expressed concerns about how the focus on data could have a negative effect on teaching.

> Data use can also lead to teaching to the test which can be very narrowing of what it is we do as teachers and what it is that we do at schools to try to boil down what a teacher does to one percentage is, that's not why people got into this. To make it too big of a goal is to diminish what we do, a little bit.

This issue can directly impact the STEM focus of the school since teachers may feel pressured to push aside content not aimed directly at their subject domain. Overall, Greg held a critical but positive view of data:

> So the number went up. What does that mean? I don't know. I wonder about data usage, but I think there's potential to use it to make improvements to the system. I do use it for what I hope is that, but it's complicated.

Greg expressed an interest in determining how he and the teachers of the STEM academy can better use data.

Summary

In the final section of this case, I will summarize the connection between the School A teachers' data and STEM practices. School A is an environment that is very supportive of teachers engaging in STEM. The academy the teachers are in is built as a STEM academy and the administrators support teachers' planning of STEM activities. However, the implementation of STEM is hampered by the fact that the administrators do not have specific expectations or requirements of STEM instruction to guide teachers. In addition, the academy structure of the school, which allows students to pursue different courses they are interested in, makes it difficult for teachers to coordinate cross-curricular activities, since many students will not share common classes. Despite these issues, these teachers expressed positive views of STEM in the school.

The general idea of integration was a part of each teacher's view of STEM instruction. The science teachers each expressed that their science teaching is inherently integrated, bringing in content from the other STEM domains, especially mathematics. The mathematics teacher described integration as part of the STEM academy, describing her classroom as a place for students to gain the mathematics knowledge to be able to do STEM. This idea that background knowledge of the content domain is needed for STEM was expressed by both mathematics and science teachers; however, how this plays out in instruction depends on whether the teacher sees integration as part of their classroom or the STEM academy experience.

Some patterns emerged in what subject domains were integrated by teachers. Each of the science teachers considered mathematics to be a part of their science instruction. Both the mathematics and science teachers talked of technology specifically in terms of the technological tools that can be used to support their instruction. Some science teachers also talked about how they might be able to integrate more engineering into lessons. While the idea of integration is supported by the teachers, the actual integration of content appears in these specific ways.

The science teachers also describe inquiry as a means for students to learn the scientific process. When the lesson allows, students can have the experience of making decisions on collecting, analyzing and interpreting data. For the mathematics teacher, inquiry serves to supplement and strengthen the ideas behind an established formula or derivation that students are expected to learn.

The teachers also raised issues that influence the implementation of STEM education. One topic was on scaffolding and differentiation in instruction. What content is needed to engage in STEM lessons and how students of different ability levels can engage in STEM lessons were issues touched on by some of the teachers. All of the teachers brought up concerns about the need to teach content standards associated with state assessment, advanced placement courses, and duel enrollment teaching. Each of these led teachers to express concern on how they can meet the standards while still offering teaching they consider engaging and relevant to their students. Some teachers responded to this challenge by noting they modify lessons to add or address content that would otherwise not be covered.

Turning to data-use the school administration has set an expectation for teachers to use formative assessment. Following from this, the teachers all discussed the use of formative assessment in their practices. For the science teachers, this focus on formative assessment leads into the use of informal assessment as part of their inquiry and STEM teaching. From their inquiry activities the science teachers look to see how students are going through experiments and how they are deriving and presenting conclusions from the data they collect and analyze. One science teacher explicitly mentioned that they consider the inclusion of mathematics in these lessons at the level of students' ability to setup problems but was less concerned about the ability to complete the mathematics stating, "Once you setup the problem, the rest is math." One the flip side of this the mathematics teacher placed all of their assessment focus on ultimately determining the mastery of mathematics content.

School A is the largest case in this study with four teachers, three in science and one in mathematics. They expressed some aspects of STEM and data-use practices often found in the literature while, interestingly, teaching in an environment where administrators are not setting any requirements for STEM teaching. Such requirements might be expected due to influence from the state's STEM certification process.

I should note for the reader that this final finding described here occurs across all four cases. This is an important point to note when considering what differences and similarities will arise from these cases. The next section will look at School B in case B.

Case B: Midsized Suburban Middle School

Description of the Case

School B is a midsized, suburban school that enrolls around 500 students overseen by roughly 30 teachers. The number of students has remained consistent over the 2010s while the number of teachers has returned to around 30 after a steep spike a few years before. This is a Title I school. Among these students 79.8% are White, 5.4% are African American, and 6.5% are Hispanic. The gender breakdown is 50.2% female to 49.8% male. Free or reduced lunch recipients are 44.8% of the population. Students here perform above the state average on English, mathematics, and social studies standardized testing. Performance climbed from around 50% to above 80% over the past decade. This school has been STEM certified since 2017.

The school has five mathematics and four science teachers. This case consists of two teachers. The first teacher is Nina, a female mathematics teacher in her eighth year of teaching, all of which have been at this school. She teachers in the eighth grade and currently teaches both pre-algebra and an honors geometry course that would be considered high school level.

The second teacher is Mary, a female science teacher in her 18th year of teaching and administrating, 15 of which have been at this school. She teaches general seventh grade science classes including one advanced course and two general level courses. Mary was an assistant principal for the school for five years and was in that position, along with being on the school's

STEM committee, when the school went through the STEM certification process. She took on her current teaching position during the second year the school was certified.

Administrative Policies and Support for STEM and Data

Requirements surrounding STEM

According to Mary, there is no mechanism driving or forcing a particular idea of STEM teaching on the classroom. Instead she clarifies,

> I wouldn't say forcing, but it's expected. The boss expects us to do it and we all want to do it, but I wouldn't say it's forced at all because we're doing it. One, we like to do it and two is we should be doing it because there's no other way to grow [the STEM focus of the school], which is what we all want to do.

The administration expects STEM to happen and, according to Mary they are doing STEM. However, there is no specific form of instruction around STEM that is pushed. Nina also described a lack of certain requirements for STEM lessons.

> I don't really think we have any [expectations]. As a math department in secondary school, it is an expectation that we are teaching our inquiry-based textbook. That is a requirement. There's really no requirement in the building or the district to teach a STEM lesson or anything.

This passage indicates there are requirements for teaching inquiry education but not STEM education. So, what constitutes STEM education and inquiry education are different, at least from the administrative level.

Nina further pointed out that since there are no academic requirements for STEM, this affects which mathematics courses students should take. Students looking to take certain STEM focused courses end up not enrolling in appropriate level mathematics courses due to scheduling. This issue implies that the course progression of the school has not adjusted to the new focus on STEM. According to Nina, the administrators are looking into the scheduling issue. In the next section I will touch on the teacher’s perspectives of the expectations for using data.

The Expectations for Data-Use

The main expectation for data-use expressed by both teachers was in using formative data to compare and make improvements in instruction. As Mary summarized it, “We should use our data to do best practices. If one teacher is getting really good results, what are they doing? What's going on there?” For Nina this need for comparison was tied more to making sure standards missed by students were identified and strategies found to address the issue. As she noted,

> …we compare the data with the other teachers in the department to see what standards were missed, what strategies were taught by one teacher, if one teacher taught some content better than another, and sharing ideas. Looking at the students as, "We're all one group of students. How can we help all students at once?"

For these teachers, collaboration is a direct part of their data-use practice. They use comparative data to learn from each other in ways that can inform their instruction. Nina further focused on comparison when describing how she views data-use: “A lot of numbers. … a lot of number crunching, and just comparing numbers. In the sense of us, it's what percentage is comparing percentages of student understanding to each other.” The need for comparison was also mentioned by Mary in the context of more summative assessment. She noted,

> Test scores are important to me because they have to be. If I were to be honest, I would say no. They're important to me because I need them to be able to compare what I'm doing with my colleagues if that makes sense?

She discussed comparing scores with other teachers in her PLC but described the process in the context of how data-use has changed during her time as a teacher. She stated,

> … we need to be able to compare to each other during PLC for best practice. Coming from the era where we didn't do that, it was like you did your own thing and kids either passed or they failed, and you went on. Now, where you're looking at why is everybody passing in teacher X's class and only half the people are passing in teacher Y's class? What is teacher X doing? This is better. That's the best practice. That's the whole idea of it. I know you can cook up the scores and do different things, but you have to compare nowadays.

Mary is supportive of comparison for identify better teaching practices and establishing some consistency in grading. At the same time, she expressed less interest in, specifically, test score. For her this is a type of data that allows comparison with colleagues but may not get at the practices of what the other teachers are doing.

While the teachers were discussing their primary data practices, and changes thereof, they made no mention of STEM. The teachers only connected STEM and data, a covered in a later section, when they are describing their STEM lessons and are asked how they do assessment. This likely indicates that aspects of STEM are not coming under these teacher's main consideration when implementing data-use. In the following section I will discuss the supports and resources offered to School B's teachers and how they align with the requirements and expectations brought up regarding STEM and data-use.

Professional Development and Teacher Planning times

Mary described being able to work with other science teachers in her PLC to compare data. She noted she often invited the principal to the meetings, whom she considered to be good at identifying issues from the data that she might overlook. Nina was also in a PLC with fellow mathematics teachers but claimed to have infrequent attendance by administrators. For both teachers, a part of the PLC time was dedicated to comparing data and student achievement to help inform teaching practice. Each department in the school also gives their teachers a common planning time.

Regarding PD, Nina noted that the school had never offered PD on data-use. She also noted there was no PD on STEM, Interesting she commented that,

> Maybe if you asked for some type of professional development, plan to meet with a STEM teacher, science teacher, or another teacher to meet and co plan or talk about lessons, standards, or whatever, you could, but no one's really asked to find out.

Nina, believed there could be PD if it is asked for but she and the teachers are not asking for it.

Mary expressed a different experience saying she had PD on STEM and that "this corporation is huge on it". The PD for Mary was part of a mid-sized grant that also provided money for STEM activity resources. It seems that teachers feel they have access to different PD opportunities that may be tied to the subject they teach.

While these teachers both claimed there are no specific requirements of teaching STEM, they expressed different perceptions of administrative actions surrounding STEM and data-use. In Mary's experience, there is active STEM PD and useful administrative participation in her PLC, while for Nina these are not readily available. However, data was still a focus of both teacher's PLCs. It is possible that Mary's strong stated interaction with administration is fostered by her former role as an administrator at the school. In the next section I will look at some of the school level discourse these teachers engage in.

Discourse on STEM Instruction

Nina indicated she was the mathematics representative for the schools STEM committee which included other teachers and administrators. This committee fostered a range of discussions on STEM instruction in the school. She also mentioned the school having access to external resources stating,

> We also had a lot of outside resources, like professionals in the community who are engineers or leaders of robotics clubs and other places to help us figure out ways to outreach to the community to get resources, information, and support.

These resources represent an external influence that helps to shape STEM within the school. However, on the more individual level the teachers did not mention any engaging in specific discourse on STEM within the school. In the next section I will look at how these teachers conceptualize the STEM in their teaching.

Conceptualizations of STEM

In this section, I will look at how the teachers at School B conceptualize the STEM content they are teaching. As with School A, these responses come from relatively open-ended questions that allowed the teachers to present their main thoughts when they hear the word STEM and are organized around areas related to integration and student engagement.

Integration

When asked about characteristics of a STEM classroom, integration was a direct focus of Nina's conceptualization. In describing how she envisions a STEM classroom, she stated,

> It'd be a lot of integration of science, math, and technology. [Teachers would be] infusing all of those together in one lesson. You're not just potentially teaching straight science, straight math, any one particular subject. They're combining multiple contents into one and making those kids manipulate across multiple curriculums and then more hands on as well.

Mary did not directly talk about integration but indirectly discussed the idea in describing the role of other subjects in STEM. She noted, “The engineering? That's where I think of the STEM as … problem solving” but further clarified she does not apply much engineering in her teaching.

Both teaches expressed a focus on science and mathematics. Nina placed these subjects above technology, describing STEM as “inquiry-based learning that is cross curricular with science and math, and then using technology to aid in the learning or the investigation.” Mary noted that for her, science and mathematics are connected: “I try to bring everything back around to science. When [students] complain that we're doing math, they go, ‘I already had math today.’ I'll tell them science and math are married, so they go together.” However, despite noting the connection with mathematics, Mary also acknowledged that she did not think of mathematics as an exciting subject and viewed technology as important for bringing lessons together. She did describe mathematics skills as a necessary component of science.

These teachers at School B place a high focus on the integration of science and mathematics in STEM that boarders on being in the combined domain representation of STEM. There teachers are describing a connection that is deeper than just including mathematics or science to the respective teaching. Technology, in these instances is not on the level of combined but is a non-dominate supporting domain of the mathematics and science teaching. In the next two sections I will look closer at how these teachers are conceptualizing the integration of subjects in STEM.

Inherent Integration

Mary implicitly discussed an inherent integration between mathematics and science noting that the understanding of this mathematics concept is needed as part of her science instruction. She emphasized this in discussing chemistry and the skill of making measurements: “If they don't measure right, it just messes everything up. It's so crucial… When I was teaching the scientific method, everything was measuring. It was all metric… They just couldn't get away from it. It was just constant." According to Mary, without the mathematics component there is no path forward on the science activities and content. However, this inherent integration does not mean the subjects are on equal footing. Her description of mathematics is in line with treating mathematics as tool use. This dominate domain view of STEM integration extends into how Mary, and also Nina, described the roles of technology and engineering, described in the next section.

Integrating Technology and Engineering

The teachers of School B placed a heavy focus on technology. Nina's description of STEM included technology but not engineering. Her description of technology was that of tool use: "If you look at technology, we use technology sometimes. Technology would be an iPad or a Desmos calculator on their iPad. It's not anything super high tech." She further noted how technology fits into STEM teaching stating that technology serves "to aid in the learning or the investigation" of science and mathematics content.

Mary's description of STEM touched on engineering, specifically describing it as a problem-solving component of STEM. However, she did not expand further on this and mainly focused on describing technology as a tool (i.e., not as a means of learning about technology but as a tool for learning in mathematics and science), noting "we're always measuring, or graphing, or charting, or categorizing…We're a paperless classroom as far as that. We use as much technology as I think they won't break, that we can afford to let them." As a further, but distinct, example of technology as tool use, she described having her students film a presentation:

> They had to think of a way to represent the rock cycle without using rocks. They had to come up with their own idea. They had to film it, so I guess that's the technology part. They had to film it and figure out how to get it to me.

It could be argued that this is part of a higher level of technology use. Students are having to work with a piece of technology or even a concept of technology (i.e. filmography) to develop and present something new. However, that would be an outlier regarding Mary's view of technology and her description doesn't portray this use of audio/visual technology as different than, say, calculator or lab equipment use.

Both of these teachers described their use of technology as somewhat tentative. As Nina stated, "we use technology sometimes" and according to Mary "we use as much technology as I think they won't break". They both seem to use technology in so much as it supports the mathematics and science focus of their lessons. Despite this, they do both consider that having technology or tools available can help promote student engagement, as discussed in the next section.

Active Learning and Student Engagement

When asked about the characteristics of a STEM classroom, Mary described an active STEM environment noting students are given, “a problem or a task and materials… and they have to come up with a way to solve it.” She also noted how she likes to teach STEM because she finds it “super engaging” for students stating, “they just love tinkering with things and putting their… hands all over them. If these kids are doing and moving, they're happy.” For Mary, STEM takes the form of a very hands on education experience.

For Nina, STEM teaching “helps the kids to be more well-rounded and more willing to work to find answers opposed to waiting and being spoon fed like a lot of lecture type teaching lends to.” She further clarified this point noting,

> I feel like the kids definitely are more engaged. They're more engaged, more interested, and more willing to work above and beyond what is given to them, what is asked of them. Just because I think they see more of a reason for it because it's relating to more than just one subject.

Here student engagement is discussed in terms of perceived enjoyment and perseverance in working on tasks and problem solving. Mary also indicated she actively tries to foster this noting, “I like to know what they like, and what they don't like. What is engaging to them, that's very important to me.” This understanding of students’ interests can allow a teacher to focus on lessons with contexts relevant to their students. I discuss how the teachers expand upon this in the next section.

Authentic Context

In further describing the traits of STEM teaching, Nina pointed out that STEM teaching can make connections for students that have an effect outside the classroom. For her the STEM lessons are “potentially relating more to the real world and more to their life. Doing that would have lots of implications later on in life and later on in their learning.” Mary also described

STEM as “like real world problem solving” but expressed a view that some content she teaches does not lead to this goal: “I'm doing rocks and minerals right now. I don't really think of studying rocks and minerals as … problem solving.” Both teachers consider STEM to connect outside of the classroom but in Mary’s case she feels certain content may not fit within STEM. With the conceptions underlying STEM established here the following two main sections will look at how inquiry and STEM are implemented by these teachers, in the classroom.

Role and Implementation of Inquiry Instruction

In discussing the use of injury in her lessons, Nina claimed that the majority of her lessons were inquiry-based. In her description of these lessons she noted,

> The students are given some type of investigation. They have to work through the investigation to develop the knowledge and rules, algorithms, or whatever the content may be from that lesson. 75ish, maybe, percent of our lessons are completely student guided inquiry. "Can you figure out what the pattern is?" or, "What's happening in all of these questions?"

Mary, who claimed that 95% of her lessons were inquiry based, similarly noted that a part of inquiry is developing problems where you can let students come up with solutions. She did state that she does not have many opportunities for self-guidance in her labs but did offer classroom STEM challenge activities on which students could work. In other words, Mary is not often teaching inquiry labs but is offering inquiry activities that target STEM content. Mary further noted she was excited to see when students “mess around with … and create” as part of these STEM activities.

Connected with these STEM challenges, Mary indicated that as part of her content she directly teaches scientific methods to students as part of the background for these activities. Bridging the science, mathematics and inquiry content she works with, she describes the general direction of a lesson saying to students,

> "Hey, guess what. This is data. This is this part of the scientific method." It's right up there on my board. In the front of my classroom is the whole scientific method… Every time we do a part of it it's to bring it back and say, "Hey, guess what. We just made a hypothesis right here," or "Here, we're collecting data," with things like that.

Mary is directly teaching about the methods of inquiry in this case but, as a science teacher, she is only focusing on science inquiry. So while she labels these as STEM challenges, the STEM aspects appear to be limited to the content covered.

Finally, Mary clarified where non-inquiry lessons fit into her teaching: "If we're not doing an inquiry based [lesson], it's because … it's like a "part two". We'll do one and then we'll reinforce the next day of what happened in that inquiry lab the day before." Here she has expressed the idea that in some cases inquiry is only part of the instruction and certain additional content must be scaffolded in teaching.

Both teachers in School B claimed that inquiry makes up the majority of their teaching and that this inquiry gives students freedom to explore how to solve the lesson problems. However, there is a difference in how they connect the inquiry to the content. Nina mentioned using inquiry investigations to "develop the knowledge and rules, algorithms, or whatever the content may be from that lesson" while Mary, in much more detail, focused explicitly on teaching the processes of the scientific method and using non-inquiry days to connect content back to inquiry labs. The availability of a well-defined 'scientific method' in science may make it easier for her to explicitly discuss inquiry processes in the classroom. With this structure of inquiry laid out, the next section will look at how these teachers are implementing STEM.

Issues Affecting the Implementation of STEM

Scaffolding and Differentiation

In discussing the STEM focused content she finds valuable in her teaching, Nina implicitly mentioned how STEM inquiry instruction allows for differentiated instruction noting it allows, "students to create their own understanding since not every student is going to learn, interpret, manipulate content the same as the person sitting next to them." In her description, this differentiation of content is driven at the student level and not imposed by the teacher. As discussed previously, regarding where inquiry fits into teaching content, Mary indirectly brought up the issue of scaffolding content through making connections in content. For Mary, the inquiry used in STEM teaching may not be sufficient to teach content and time needs to be set aside to explain concepts. Overall, while both Nina and Mary expressed positive views of STEM in describing their conceptions, they had little to say on these two components of implementing

STEM. In the following section I will look at how the teachers see content standards as influencing their STEM implementation.

Teaching Standards and Primary Content

Both teachers described how the needs of teaching their primary domain overshadowed potential STEM teaching. Nina stated, “we are very strictly in the math world in our department. We've stuck to the math side of things. We feel there's not a whole bunch of extra time in the year to step outside of our boundaries”. Based on Nina’s earlier description of integrating science and technology, it is likely that she is describing boundaries here in terms of not being able to include the strong science content focus. The technological tools she mentioned using are less likely to be affected by this need to address standards since the technology serves a supporting role in teaching and is not present as additional content that to be taught.

Mary expressed a similar concern regarding standards: “I do feel like, because my curriculum is so canned, that when I do go STEM it's something that I got to find somewhere else. There's not a lot of room for it within my curriculum.” Mary described the issue further in terms of a specific topic she was teaching, stating science has “more of a canned curriculum. I'm doing rocks and minerals right now. I don't really think of studying rocks and minerals as … problem solving. I think of STEM as like real world problem solving.” From this, she further mentioned lacking the content knowledge to implement appropriate STEM lessons while still meeting standards. While she expressed these concerns regarding including STEM content in her main lessons, she described still conducting separate STEM challenges she felt she could fit into the curriculum.

Mary also discussed how different content affected her opportunities to teach STEM: “When I get into physics, 100 percent that's amazing for STEM. We do a ton of STEM stuff. Cells, not so much.” Here the teacher’s perspective of how she can teach STEM is affected by the specific science topics she is teaching. In principle, cross disciplinary connection can be made in the biological and geological sciences, but the teacher may need additional knowledge or resources to implement them. Further, Mary also described how she sees STEM education, in general, relative to standard teaching, stating STEM education exposes “kids to all the really neat, cool science stuff that's out there that maybe necessarily the regular science teachers don't get to expose them to, because we have to follow the state guidelines.” The perception here is that STEM gives student opportunities to experience content in ways that are different than the "regular science" tied to the state standards.

Despite the discussion surrounding the need to teach primary content, both teachers mentioned a cross-curricular focus present in the school. Mary described a set of lessons connected with language arts where students read non-fiction text on a science topic and are quizzed on the content. The lesson looks to simultaneously target science and language arts literacy. Nina mentioned cross-curricular content as being more general, tying back to how such teaching prepares students for working outside of the classroom. She also mentioned cross-curricular data-use, which I will cover in a section below. In the next section, I will look at issues these teachers raise about having time offer STEM teaching.

Limitations of Time

Nina, the mathematics teacher, noted she has to mainly focus on mathematics content as there is not much time in the year to go outside of the "boundaries" of her subject. Mary also mentioned issues of time in how she considers the STEM aspects of her lessons: "I also feel like true STEM is longer term. Whereas most of my science stuff, they're at the most two day labs with some longer term projects in there. I don't know if I'd call them STEM projects." Here both teachers describe ultimately focusing on their primary content in teaching. Mary's comment highlights an interesting way she is perceiving STEM. While time limitations would affect how much content can be added to a lesson that does not necessarily have to be the case. Despite this Mary is using the length of labs as a measure to determine if the activity is STEM, which is just a reflection of the ambiguity of what STEM is in practice. In the next section I will look at how these teachers are collecting and using data in their STEM teaching.

Using Data for Decision Making in STEM Teaching

Both Nina and Mary noted that pre and post testing was used to plan instruction. As Nina noted, the pre-testing portion lets them know "where kids are currently in their knowledge" allowing teachers to group students so lessons can be tiered towards their general ability levels. Both teachers also placed emphasis on formative assessment, which was an expectation of data-use set by administrators. A Nina described it,

… we always do a formative assessment to see where they have gone, what have they learned, and where are they in their learning at that point. That's important to really look at that kind of stuff of where they are in their learning.

For Mary the formative assessment allowed her to pick questions that have “the absolute main boiled down bare bones nugget” of what the students need to learn which further allowed her to plan reteaching for the students who miss these questions. In describing the beginning of the assessment process, Nina stated,

> We look at, "What are the standards that are necessary?" Then we make questions that would be lead-in type questions. Typically, we do aim towards the building blocks to see, "Do they have the skills necessary to even learn the current eighth grade content?"

Reteaching is planned based on the percentages and statistical measures of students who miss specific questions. Further, Nina pointed out the importance of the reteaching specifically in terms of the mathematics content she needs to teach:

> I use [data] a lot in terms of reteach and remediation for students who don't understand just because it's a math you can't really build upon content if they don't understand the building blocks. I mostly use the data to help bring up the kids who don't understand more so than using the kids who know what they're doing and extend that knowledge.

These teachers described a very comprehensive data focus of this school, but I should note their high-level discussions of working with data did not reference STEM teaching. Pre-testing could establish where students are starting from, formative assessment and retesting served to keep students on track and post-testing should allow for revision of this process going forward. In the next section I will look closer at the kinds of data these teachers take from STEM and inquiry activities.

Data in the STEM and Inquiry Context of the Classroom

Nina described the use of informal data for assessing her inquiry-based activities, sharing,

> I can do informal data checks of who understands what they did, who doesn't, based on who understands what their homework was or who understands at the

end of class. More of an informal type check opposed to here's a specific number of students who understand or who don't.

When asked how these informal checks help in assessing students' overall understanding, Nina clarified,

> It helps because then I can pinpoint which students I need to target a little bit more. Or, pinpoint maybe a few students, a small group instruction to figure out what they don't understand or guide them in a way that maybe will lend to them figuring it out a little bit easier. Just pinpointing which kid will need a little bit more support to actually get through the investigation.

Mary similarly mentioned planning to use informal assessment for a planned STEM activity: "I will assess it by how engaged the kids are. There will be no grade whatsoever. Who got theirs done? Who was into it?...Who's involved?"" For both teachers, data-use in these inquiry and STEM contexts is based on interaction with content rather than mastery of said content.

In assessing inquiry activities, Mary described the importance of students' abilities to work with evidence.

> A lot of times their evidence is not my evidence, but as long as it makes sense and it goes with the lab, I'm 100 percent OK with that. They just have to back it up. Sometimes the answer that the book gives and that I give is completely different than the evidence they give, but as long as it makes sense, I'm OK with that. … For the most part it's pretty much we're along the same lines, but a lot of times they'll get a left field piece of evidence, and I'm like "Yeah," but the way they write it, it makes sense. If it makes sense, I'll count it.

She further stressed this point, noting,

> I always like when they have to give evidence of something they found during the lab. It's not something you can look up. It has to be something they saw, or that happened during the experiments. I'm big on evidence.

Connected with her previous mention of measurement and chemistry, Mary also noted that there are instances where she assesses students on both science and mathematics: "I have to assess on both of those things … especially if they're measuring." Here she is assessing on content outside of science and has justified the need based on the importance of this content in her science lessons.

In comparing data from STEM lessons and data from standardized testing, Nina described the data from STEM as being,

> … more immediate… because you can interact with the kids as they are learning. That way you can kind of pinpoint immediately what they understand, what they don't understand and work from there opposed to waiting until the end and seeing do they understand or do they not.

Mary indicated that, as a science teacher, the standardized testing overall does not affect her. She went on to specify that data from inquiry activities serves to strongly influence the decisions she makes about her students and instruction.

Mary also noted that she makes use of student feedback through anonymous surveys to evaluate her inquiry activities.

> I list every single lab that we did and every single assignment that I took a grade for. I said, "What was good? What was bad?" I get really good data on that because they knock me between the eyes with their honesty. That is a huge part of driving my curriculum.

Again it is informal assessment, combined with feedback, regarding the lesson, which is driving the educational decision making.

Finally, Nina discussed a potential plan the school has been considering for cross-curricular data use.

> One thing we've talked about, this department and as a school, is how can we use our data in the math department to help the science department or help the English department. Are there any similarities? Kids who are struggling in our class, are they struggling across the board? Is there something using it to help students who might be struggling if it's a cross curricular type problem, or is it a single class type problem? Helping students as a whole opposed to, "Hey, you're struggling in math. I'm going to help you in math," and not look outside the box a little bit.

This indicates a potential shift in the school to using data from different subject domains to identify issues in student performance. This is not directly a STEM issue but is a data-use issue that maybe influenced by the evolving focus on STEM or interdisciplinary teaching.

Summary

School B is the second largest case in this study with two teachers, one science and one mathematics. The teachers of School B expressed an interest in teaching STEM and noted there is a general expectation by administrators that STEM is occurring. However, similar to School A, this expectation does not come with specific requirements that could shape STEM in the school. The course progression for students may not yet account for the STEM focused teaching as students end up enrolling in inappropriate, by level, mathematics courses in trying to get into desired STEM courses.

Both placed a specific emphasis on the connection between mathematics and science though only Nina discussed this directly in terms of integration. Technology was mentioned as a tool by both teachers but only Mary discussed a (minor) role of engineering. Both teachers expressed how STEM teaching serves to help engage students in learning.

Both teachers claimed a majority of their teaching was inquiry-based. Mary, the science teacher, mentioned teaching inquiry as part of exposing students to the scientific method and having them be able to use data they collect. Nina described it as “investigation” where students try to figure out the knowledge, rules or algorithms associated with a lesson. These teachers appear to use inquiry as a primary teaching method for students to learn content.

In implementing STEM, both teachers expressed issues of being confined to their primary subject domain. Mary claimed she didn’t have an issue with standards but did have an issue with curricula for different science content. Namely she pointed out the difference in the potential for STEM based on different kinds of science content. While they did feel limited in their teaching, they both noted different cross-curricular focuses present in the school.

Turning to data-use, the school administration set an expectation for teachers to use formative assessment and compare data to inform changes to instruction. Both teachers noted the use if informal assessment as part of their inquiry and STEM instruction. As Nina noted this gives the students the “support to actually get through the investigation”. The science teacher specifically stated the importance of students being able to use evidence to justify claims specifically stating: “If it makes sense, I'll count it.” Owing to the importance of measurement in some sciences this teacher also stated they do assess students on their understanding of mathematics content.

Case B helps to highlight that while there are certain consistent finding across the cases (e.g. lack of STEM requirements, mention of commonly known traits of STEM and data-use) there are more subtle differences that may appear, here in terms of specific views or experiences between mathematics and science teachers. In the next section, I will look at School C in case C. This case consists of one mathematics teacher in a large, suburban middle school.

Case C: Large Suburban Middle School

Description of the Case

School C is a large, suburban school that enrolls around 1100 students overseen by roughly 60 teachers. The number of students has gradually shrunk from 1500 at the start of the 2010s while the number of teachers has come to 60 after recovering from a steep drop at the start of the decade. This is a Title I school. Among these students 22.8% are White, 50.4% are African American, and 18.7% are Hispanic. The gender breakdown is 47.0% female to 53.0% male. Free or reduced lunch recipients are 69.5% of the population. Students here perform below the state average on English, mathematics, and social studies standardized testing. Performance has stayed below 50% over the past decade. This school has been STEM certified since 2015 and is currently in the process of preparing for re-certification of its STEM status.

The school has eight mathematics and seven science teachers. This case consists of a single teacher who agreed to be in the study. Abby is a female mathematics instructor who teaches seventh grade pre-algebra and algebra. She teaches both accelerated courses where students “do both seventh and eighth grade content in a single year in preparation for taking algebra” and remedial courses for students who are “two or three years behind in math standards”. She is also the mathematic department’s e-coach, an informal position where an individual is tasked with overseeing the implementation of new technology in the school. As a part of this position she is given access to administrative data sources that other teachers would normally not have access to. Abby has been in secondary education for 14 years. She started out as an instructional assistant, obtained her teaching license and has been teaching for eight years. She has been in School C for the past seven years.

Administrative Policies and Support for STEM and Data

Requirements Surrounding STEM

Abby stated she was unaware of any expectations for how teachers should teach STEM in the school, sharing,

> I don't think there is any. No, I've not seen an expectation as to what it should look like or how it should be done or the dos and the don'ts or the things that work and the things that don't.

She described this issue as originating from state level decisions regarding STEM.

> From what I have seen in other places in our country and from the experiences I've had, even when I talk to other districts and other schools within the state, the expectations, I don't feel as though we're willing to embrace the STEM piece. Part of that is aligned to the fact that we didn't accept the common core standards. I feel a lot of common core standards force more of the STEM math protocols[7] and force the integration of cross curricular engagement.

This statement reveals a few insights. First, Abby appears to have access to interact with other schools and districts outside of just the teachers and administrators in her school. Second, her interactions have led her to conclude that STEM is not a priority, in general, across the state partially due to certain standards that were not implemented by the state. Abby's fleshed out views of STEM at the state and policy level would seem to support her perception that there is a lack of expectations regarding STEM in the school. If she perceived that her school was doing something different, she would have no doubt described that.

Despite Abby's perceived lack of specific expectations, School C is in the process of renewing its STEM certification. According to Abby, this process has promoted changes in the teaching models and methods of the school in "order to reach children in a way that they have not." As she describes the situation: "In order for us to continue our STEM certification, we have to push ourselves out of what we thought STEM used to be." Based on her other statements in this interview, the rethinking of STEM involves focusing on more intentional integration of content. These changes in how the school approaches STEM may ultimately lead to more

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[7] Abby's mention of "STEM math protocols" does not appear to a mean specific STEM focused instructional measures. Instead, she appears to be using "STEM" as a descriptor to distinguish other math standards from the common core ones which she feels would connect better to STEM teaching.

defined requirements and expectations in the STEM teaching. In the next section I will look at Abby's perspectives of the expectations for using data in School C.

The Expectations for Data-Use

According to Abby, the expectations for using data were to use formative assessment to regularly measure and monitor learning and make sure lessons are aligned to standards:

> We're expected to use data to drive instruction. We are expected to do formative assessments in the moment in order to monitor through learning in the moment to drive instruction. Measure regularly. It must be aligned to standards. You have to align a task that can be measured. Show that the students can do the task and determine whether or not you can move on or need to back up and repeat.

Abby describes a fairly specific procedure for data-driven decision making that she is expected to use in her classroom. Tracking by formative assessment in the classroom determines if content needs to be reviewed or retaught. Further monitoring at the school level occurs on the summative state standardized assessment where the procedure is to take the bottom performing 10 percent of students and remediate them, placing them in a class schedule where they can receive additional, standards-focused, instruction.

When asked about data collection requirements regarding STEM, however, she noted, "From that data, from a STEM activity, no. There's no building wide expectations for that, no." Standards and frequent formative assessment dominate the decision-making process, but there is no specific focus on data from STEM lessons. In the following section I will discuss the supports and resources offered by School C that help Abby in her instruction.

Professional Development and Teacher Planning times

Abby stated this was the first year she was giving a common planning time with another teacher in her subject area. However, she only has planning time with one of the other four mathematics teachers. Within this planning time, Abby stated that about 20% of the time is related to STEM, focusing on issues of "How do we push ourselves for integration of technology, and make it so that the student's doing the learning instead of us giving it to them? How do we make it more inquiry based?" The relative newness of this planning time combined with the small but dedicated time on STEM may indicate this planning time was developed as part of the school changes preparing for the STEM recertification of the school. She further stated that 35 to 40% of time is focused on data and the remainder on “instructional planning and processes.”

Abby described working in two separate mathematics PLCs, a seventh-grade mathematics PLC comprised of four seventh grade teachers and one special education teacher and a full mathematics department PLC that includes seventh and eighth grade teachers along with administrators. The grade level PLC meets about twice a week while the department PLC meets about three times a month. Regarding her work on the grade level PLC, Abby considers her groups data analysis to far exceed the expectations laid out by the district. Her experience as the data e-coach may contribute to the perception of and ability to exceed these.

Abby also noted the school offered weekly, Tuesday PD sessions covering standards-based instruction and data-use while on a monthly basis there was a “Tech-Tuesday” which “is based on how to integrate STEM pieces.” This “Tech-Tuesday” combined with the technology focus in the STEM part of the common planning time suggests that technology has priority in discussions of STEM in School C.

According to Abby, the school has offered many instructional resources. However, she noted there may be a need for changes in how they focus on STEM in common planning time and PD. Their current focus is on integrating technology, but, due to changes proposed in the state STEM framework, the upcoming recertification will require them to have a stronger focus on integrating other content from the STEM subjects. The scenario here is that while STEM may be a part of a school’s focus, the state of STEM is not static and, just like issues of data, may change as external policies change.

Discourse on STEM Instruction

Connected with this school’s STEM recertification process, Abby noted that there has been an effort among teachers to communicate on making “stronger and deeper” connections between subjects. For her this involved, “being intentional about how I can work them together and having that intentionality of making the connections rather than just not.” This direction of connecting STEM instruction is reflected in her description of an upcoming coordinated STEM lesson.

> We're currently in the process of planning and building a wide STEM project in which each content subject that has a piece in it would assess their content separate from everyone else. Each particular individual subject area teacher is going to assess the content that that project relates to individually.

A notable part of this STEM project is that the assessment of individual subjects will be taken on by teachers in the subject. The teachers only have to determine how their content will connect with the other content.

Abby also noted she is part of discussions on STEM through her participation on the schools building-wide STEM committee. The committee consists of teachers from multiple subjects along with an administrator and an e-learning specialist. They meet every two weeks to discuss STEM projects and initiatives. It is this committee that is overseeing the implementation of the STEM project discussed above. Along with this school-wide focus on discussing STEM, Abby also mentioned interactions with other schools and districts which gave her perspectives of the larger attitudes regarding STEM in the state.

This description of school focus on STEM is an interesting contrast with Abby's prior remarks regarding a lack of administrative expectations on STEM. There was a committee to oversee the implementation of STEM projects but at the same time she felt there is no expectations for teaching STEM. It may be the case that the way STEM was being promoted by this committee was very general and did not promote specific classroom STEM practices. This appears to be supported by the description of the building wide STEM project where teachers will be responsible for their individual subject areas. This scenario, of how the school discusses and implements STEM, may change continues to work towards recertification.

Conceptualizations of STEM

Integration

Abby described that it is important for a classroom to be "cross-curricular, so it has content from multiple areas." She specifically pointed out that topics taught "in isolation in math" are not STEM. She explained,

> I think the math is more important. I just think it's really important to give them a context that the math relates into outside of math. So many children do not like

> math. They think math is bad, and they think it's their enemy. If we're not able to show them how fun and creative and interesting, and how it can tie in various different areas into other things, then they are never going to be interested in it. The math is very important but if I'm not tying in the other piece, I will never get their interest.

Overall, Abby described the integration of mathematics, technology and engineering but mentioned having a limited focus on science. In practice she appears to place a higher focus on the context brought about by incorporating technology and engineering over the content that could come from science contexts. While technology integration was the main topic attended to in planning time and PD, Abby alluded to engineering's importance in terms of the utility it offers in providing context for activities., giving an example of "finding areas [when designing a kitchen and scale model] using the engineering and the design process."

In addition to the integration of technology and engineering, Abby also mentioned the integration of social science and language arts content. Her example of social science teaching was in a lesson involving the combination of maps & cartography and how mathematics is used to understand what the map is conveying. In connecting here mathematics teaching to language arts, she mentioned giving students the "opportunity to write or speak in terms instead of necessarily mathing". This implies that part of here assessment in such activities is not limited to student's ability to calculate but takes into account other skills, namely language, that students may use express this content. Excluding science, Abby placed a high focus on connecting mathematics and a diverse set of other content domains. In the next sections, I look closer at how Abby conceptualizes the integration of technology and engineering specifically in STEM.

Integrating Technology and Engineering

Technology is a notable part of School C's focus, as illustrated by its STEM PD carrying the label of "Tech-Tuesday". In her description of STEM teaching, Abby noted: "I think it needs to give students freedom to try and use the design process, allow students the opportunity to fail and be successful, and in some way shape or form an integration of technology." She also mentioned the importance of preparing students for "a different access to technology, than any of us [previous generation] have ever been exposed to." This statement is still a focus on technology as a tool but also holds the unique idea that students need to be exposed to technology as part of the changing world the students live in.

Abby specifically noted that, prompted by work to renew the schools STEM certification, the school's thought process on technology has changed, going from students "just using computers" to trying to identify more intentional points of integration. One example of 'just using computers' was the school replacing textbooks with computer-based access to one-to-one laptops. This use of technology-as-a-tool, for helping teach other subject content ,is something Abby mentioned may change as the school seeks to renew its STEM certification and re-conceptualize how STEM is done in the school.

In the following sections, I will discuss how Abby conceptualizes STEM in terms of the engagement and authentic teaching context it can offer.

Active Learning and Student Engagement

When discussing how she teaches lessons that cover multiple-subject domains, Abby noted how the variety of topics that can be approached under STEM lessons can help to engage more students in learning:

> I try and give a variety to reach all of those kids, because some of them are going to be interested in one thing and not interested in another. If I'm not giving them exposure to those different variety of opportunities, then they may not find something that sparks them at their thoughts and their interest.

She further noted, in comparing STEM and non-STEM lessons, "The ability to engage [students] is drastically improved. The engagement level goes to [sic] the roof." Her description of STEM education is that it includes, "Hands on, real world applications, high level of engagement and vigor." This focus on understanding of students' interests allows Abby to plan lessons with contexts relevant to her students. The "real world applications" here lead into the ability of STEM to offer authentic context in teaching.

Authentic Context

In describing the traits of a STEM lesson, Abby focused on the importance of components outside of the classroom and the connections with her mathematics subject domain. She stated,

> …it's going to be a real-world applications that has cross curricular applications or employment applications. It could be a STEM project if I'm asking them to apply something they would actually do at a job in a real world, because then we're going a cross curricular, crossing outside of the math world.

She reiterated this point stating that teaching STEM is “the way we need to prepare our students not for school, but for life.” Finally, in a connection of integration and authentic context she noted, “Interdisciplinary has to be a real world. Math doesn't float in an isolated bubble in the real world. As soon as we put a real-world application, it is cross curricular.” In line with this, in her teaching she mentioned identifying interest students have to “connect into something that pushes them to higher learning” and makes a connection that “tie it into the math and STEM world.” Abby’s perspective places a sharp division between her mathematics and her cross-curricular or STEM teaching. As soon as external connections are made, the lesson is no longer simply mathematics.

Interestingly, Abby’s description of the role of mathematics could potentially be interpreted as viewing mathematics is a tool to be used in external contexts. This would greatly contrast with the mathematics teachers who described placing mathematics first in instruction. I will address this connection between mathematics and STEM teaching again when discussing how Abby sees the standards influencing her STEM teaching. In the next two sections, I look first at how inquiry and STEM are implemented by Abby.

Role and Implementation of Inquiry Instruction

In describing how she is trying to implement more STEM content in her classroom, Abby claimed that students should be free to try out the engineering design process and should be allowed to learn from their failures. Connecting back to Abby’s description of how STEM gives students a connection to working outside the classroom, she elaborated on her views of inquiry.

> If we are not pushing the envelope in terms of giving them inquiry-based, problem-based, cross curricular, giving them, ‘There's no right answer,’ giving them lots of opportunity to try things and feeling that productive struggle, we're truly not preparing them for our society, and preparing them for the life that they're going to have outside of this. If we simply try and give them a series of steps, and not the ability to think, struggle, work together and collaborate, then they're never going to achieve that goal of being a successful member of our society. The way our society has moved, we have to push them harder.

Notably, Abby discussed inquiry not as a component of the classroom but as practice for a skill that will help students outside of the classroom. Focusing on her classroom practices, she described implementing lessons from an “inquiry-based system” that give students the opportunity to determine and reason through the information they may need to address the main question.

Abby’s main discussion of inquiry here was focused on what students will take with them, regarding inquiry skills, outside the classroom over what occurs in the classroom. She mentioned trying to give students inquiry opportunities to take information and use it to make decisions. With this structure of inquiry laid out, the next section will look at how Abby is implementing STEM.

Issues Affecting the Implementation of STEM

Scaffolding

Abby implicitly brought up the issue of scaffolding in a comment indicating she sees the learning from mathematics instruction as coming before engagement in STEM activities. She stated, “I select activities that I know that relate to current content objectives that they would have a knowledge of a skill set, at least a basic understanding of the skill set before they're expected to dive in.” In this case she is not approaching scaffolding from the perspective of teaching specific content before offering the STEM activities but is instead selecting activities based on skills she feel have been taught by her lessons. In Abby’s view, the basic content is learned first and then the STEM activities give a more open and in-depth experience with the content.

Teaching Standards and Primary Content

In discussing her teaching of STEM lessons, Abby indicated she has to "struggle with the need to teach standards, and the expectation from our district to teach and align to standards." She also noted that the STEM lessons she chooses "tend to be the ones that align to a standard" while at the same time being ones where she can "find ways of stretching the content outside" of the classroom. She reiterated this point when asked about what more she would like to learn in relation to teaching STEM,

> It's not about the teaching of STEM. It's which standards am I either willing to or able to ignore, get rid of, drop, let go of, in order to allow more time for the STEM. How can those things that I want to drop be embedded into the STEM projects in order to do it?

Further, Abby stated there is a tradeoff between targeting standards versus student engagement.

> It becomes a weighing game, is it more important for me to engage the children or is it more important for me to make sure I hit every single standard? Sometimes I have to sacrifice the standard and sometimes I have to say I can't sacrifice the standard and I have to do the content.

In teaching STEM lessons, she expressed the feeling that she may not cover enough of the content or skill expected by the standards, placing her in the position of either falling behind on content or needing to "sacrifice something else for that particular standard."

While Abby often mentioned the importance of cross-curricular integration with her classroom, she did note that to her the mathematics content is more important. Further, in referring to the external influence of the state, she pointed out that "math content is also more important because that's what school letter grades and student achievement is measured on." Abby's teaching, as she describes it, is a weighing game. She considers STEM to be an avenue for engaging students, but this has to be compared against the need to hit mathematics standards which in turn may influence the school ranking. This is consistent with her previous statement that she teaches mathematics content in order for students to engage in STEM. The mathematics and content standards come first and then are used in STEM as compared with the alternative where STEM helps initially engage students in, and teach, the content.

In the next section I will look at how the issue of time further influences how Abby implements STEM.

Limitations of Time

Abby expressed the concern that teaching STEM lessons may take away time she needs to focus on teaching standards. She described a way to overcome this issue by, "prioritizing our time and giving myself the permission to stray away from the traditional standards instruction in order to do STEM activities."

Further, Abby discussed that School C was looking to implement building-wide STEM projects which raised logistical concerns on how to plan classes so that all the students can work towards the same project over the same timeframe: "We've got to be very thoughtful about our planning process if we want to push something out and expect everyone to do it. We feel like we just needed more time to process through that." Abby is giving a broad and logistical view of time issues here, perhaps due to her experience at the organizational level participating on the school's STEM committee. The time issues of implementing STEM are not limited to just time in the classroom but also to the additional planning time needed to develop relevant lessons. This especially applies to the cross-class lesson plan described here. This could lead to an issue where the school's attempt to improve its focus on STEM, through implementing these STEM projects, could lead a weaker focus if time commitments surrounding these projects are not taken into account. Time for developing and planning data-use and assessment is one such hurdle that can affect the implementation of STEM and in the next section I will look at how Abby is collecting and using data in her STEM teaching.

Using Data for Decision Making in STEM Teaching

As mentioned above, Abby noted that using formative assessment to drive instruction was expected of teachers (at least in mathematics) at School C. She placed an additional focus on students' ability to demonstrate mastery on specific mathematics standards. Despite her focus on the importance of cross-curricular content for giving context to mathematics lessons, Abby noted that her assessment was based solely on the mathematics content. She described that it is difficult to measure standards mastery out of STEM activities.

> I find that the STEM projects are difficult to measure if they're able to master it. I see if they're able to apply it, and I can see if they're able to use it, but not necessarily if they're able to do the basic, "Can I do it?" basic mastery. It's much

> higher-level application of the standards, but I'm not able to measure their actual mastery of the standard.

For Abby, the ability for students to apply the standards at a “higher-level” seems disconnected from “mastery’ of that standard, which she measures in terms of being able to correctly solve mathematics problems. Placing mathematics skill mastery first is consistent with Abby’s view that the mathematics content is needed by students in order for them to engage in STEM. Abby also discussed how she approaches the assessment process, stating,

> When we have an assessment, either like a summative assessment or building-wide assessment… I'm the first one that downloads the content and I call it data mining. I look for outliers in it. I figure out what are my students doing that I have missed? I use that information to guide instruction and what did I do well, compared to others? How do I fix this? How do I move forward? Is there something with my questioning? Is there something with the students?

Finally, she noted using this data to differentiate her instruction, giving extra projects to better performing students and further instructional attention to others. As seen in the next section, while Abby claims her main assessment is on mastery of mathematics content, she does still informally assess student performance in her STEM teaching.

Data in the STEM and inquiry context of the classroom

Abby reiterated the issues of measures of mastery in STEM several times, stating,

> I am such a data person that I would need to find ways of getting that kind of data from a STEM project. I have yet to see a STEM project, either online or in use in any settings, that have given me the data from mastery of content standards that I would need.

She pointed out that she feels other subjects (e.g. science, social studies, and language arts) can get a measure of mastery from STEM projects so the issue, to her, is limited to mathematics and the standards it covers. This is consistent with the overall way she had described mathematics as connected to but distinct from STEM.

Abby also notes a lack of consideration of STEM data at the state and district level: “Until the state puts a focus on that STEM data, I don't feel as though our district is going to put a focus on STEM data." According to her, a lack of requirements has led to a lack of administrative action on this kind of data.

She does, however, assess students on STEM and inquiry activities through informal assessment:

> Students will get a participation grade for staying engaged in the activity. Yes, if they are making attempts, if they're having a productive struggle or unproductive struggle as long as they're working with peers. As long as they're working towards the end goal, having off task conversations, as long as anything that they're doing is towards the end goal. I feel like that engagement to me measured as high or their participation grade would be considered high.

She justified this informal assessment noting, "I do not assess on the process of learning because I feel like they have as many different ways of getting to it." This line is backed up by her prior statements on allowing students to express some ideas without the "mathing" aspect. However, she did state end products of these activities (e.g. posters, presentation slides, or videos) may be assessed. Abby described the importance of giving students STEM experiences but felt she cannot get mathematics mastery out of STEM. Her focus on informal assessment appears to serve as a compromise, of content versus assessment, that allows her to implement these lessons. In the next section I will look at the some of the limitations of data-use expressed by Abby.

Limitations of Data use

When asked what more she would like to know in relation to using data Abby stated she wanted a method for obtaining "the thought processes within data rather than just a final answer." Since the school has one-to-one computers for students, several assignments are distributed via an online learning management system. This setup, along with how standardized testing is graded, left Abby with the concern that "I don't see how they've solved it. I don't see how they've done it. I don't see the methodology or the thought process that went behind it." Notably, the assessment system described here is very different from the kind of assessment that would be part of STEM instruction. I interpret this "thought processes" data, Abby is interested in knowing, as the kind of data that could come out of STEM instruction if there was the time and ability so support that instruction. Despite the STEM certification being a program of the state, it appears, that from Abby's perspective, the state is not interested or perhaps not capable of accepting and working with this kind of data it its decision-making process.

Summary

School C is one of two cases with a single teacher participant in the study. This teacher expressed a high focus on teaching STEM while noting a lack of expectation on such teaching from administrators. This situation may be changing as the school re-evaluates its STEM focus in preparation of the re-certification of its STEM school status.

Integration was a component of this teacher's view of STEM. With the exclusion of science, she brought up the importance of technology and engineering and even the connection with non-STEM domain content all of which give context and purpose to the mathematics. This serves to both engage students and present the content in ways that are relevant so they can take the knowledge outside of their school experience. At the same time, she admitted that her focus for student assessment was only on mastery of particular mathematics skills in the standards. Thus, her use of data for driving instruction is not highly centered in the use of STEM in her classroom.

She described the teaching of inquiry as a way to let students learn how to try out ideas and build skills they can take outside of the classroom. In implementing STEM, she described her process as trying to find a way around the mathematics standards to teach STEM. She expressed that student understanding of mathematics is necessary for the student to engage in STEM but at the same time considers what standards can be dropped to fit in a STEM component, assuming the STEM component does not align with an existing standard.

Turning to data-use the school has a focus on formative assessment and alignment to standards. Following from this the teacher placed an emphasis assessing student mastery of mathematics to align with her understanding of data requirements both at the school and state level. Within her focus on STEM she only applies informal assessment. She feels that assessment in STEM, while potentially useful for science teaching, cannot give her the information related to mathematics understanding.

Case C shows a mathematics teacher with a rather specific perspective on how mathematics and STEM fit together. It also highlights issues in the changing instruction environment in a school that is looking to re-certify to the new, more stringent STEM certification qualifications. In the final section, I will examine School D in case D. This case also consists of one mathematics teacher in a rural, midsized middle school.

Case D: Midsized Rural Middle School

Description of the Case

School D is a midsized, rural school that enrolls around 500 students overseen by roughly 30 teachers. Both the numbers of students and teachers have been fairly constant over the 2010s. This is a Title I school. Among these students 86.3% are White, 3.0% are African American, and 5.2% are Hispanic. The gender breakdown is 51.1% female to 48.9% male. Free or reduced lunch recipients are 54.0% of the population. Students here perform below the state average on English, mathematics, and social studies standardized testing. Performance has gradually declined over the past decade. This school has been STEM certified since 2015. Similar to School C, this school would need to recertify to maintain its certification. However, no mention was made of any work towards this by the interviewee.

The school has three mathematics and four science teachers. This case consists of a single teacher who agreed to participate. Sam is a male mathematics instructor who teaches eighth grade pre-algebra. He has been teaching for 23 years and has been in his current position for six years. He was in his position when the school went through its certification process.

Administrative Policies and Support for STEM and Data

Requirements surrounding STEM

When asked about the school's expectations for how teachers should teach STEM, Sam offered a very curt response: "I don't know if there's...tough question. The expectations aren't necessarily clear. I'll just leave it at that." For context, Sam is the one teacher in this study who expresses concerns about a lack of support from administration, which he feels affects his ability to implement STEM.

Despite stating there is no expectations on how to teach STEM, Sam did describe that there is a requirement for grade-wide STEM activities:

> We basically plan out a project or order that everybody does together as far as like a cohort. Eighth grade would have four different projects. It's quarterly dues. We

> have projects that are planned out. Then everything else that's done is basically up to the individual teacher to either collaborate with another domain as she put it or department and work together with them on a project. We basically just report on four different projects throughout the year.

Under this policy, there is a minimum number of STEM projects students should participate in at School D. It is up to the teachers to develop the projects. From Sam's description, it seems this school is following a narrow interpretation of its STEM certification designation, making sure a certain number of STEM projects are taught so that they can meet the checkmark that STEM teaching is occurring.

The Expectations for Data-Use

Sam stated simply that there is an expectation to "use data daily to inform … instruction." However, there was a implicit expectation of data-use to meet content standards. Sam noted that the discussions with his principal focused on "where are [teachers] at on this standard overall, because they want to know the big picture and what are [teachers] doing for those that are up to standard." Sam did not mention administrators having expectations for, say, formative and summative assessment. Instead he described needing to develop his own assessments, without support, to track and remediate students. He stated, "As I'm teaching and assessing, everything relates back to the state standards." From this emphasis on meeting standards he then developed summative and formative assessments to modify his "classroom lessons and direction off of those data points"

From Sam's perspective the higher-level administrators have a focus on meeting standards but are not offering expectations on what data teachers should be using. Sam feels he has to come up with assessment on his own which fits with how he feels there is a lack of instructional and resource support from administrators.

Professional Development and Teacher Planning times

Sam indicated he has a common planning time with other mathematics teachers to discuss classroom data. He also noted he has regular conversations regarding data with three teachers that he oversees in the mathematics department along with the principal. He did specify that he doesn’t feel these interactions constitute a PLC, indicating that from his perspective he is not in any PLCs. However, at the same time he notes having connections with teachers and organizations outside of the school (e.g. Gates Foundation’s Teacher Advisory Council). Regarding the grade wide project described previously Sam noted that teachers are organized into teams or cohorts to plan those activities. Finally, Sam mentioned having some professional development relating to data and STEM but did not give further details. In the next section I will describe a policy level issue relating to assessment brought up by Sam.

Policy Changes Affecting Teachers

A teacher in Case A described a policy change of the state moving to a growth model for students. Sam described a seemingly different assessment policy change of the state moving to “more of a standard based grading system.” It is unclear if these are different policies or different interpretations of the same policy. Sam’s understanding of these changes is that they require that he not assess on content outside of the standards he is under: “I have to make sure that whatever project we're doing, though it may involve some other things outside of our standards, that I'm only assessing those things that apply to eighth grade standards.” He noted that this change makes assessment more difficult as he feels there is not much carryover between his STEM projects and the state assessments, when compared with his teaching of straight mathematics content. If Sam’s interpretation of this policy is correct, then this policy works counter to the STEM certification framework. The policy, or the interpretation of the policy, has left Sam where he feels he can only apply assessment to his content standards. In the next section I will look at how Sam conceptualizes the STEM content that he is teaching.

Conceptualizations of STEM

Integration

Sam described STEM in both an integrated and non-integrated fashion. Under integration he noted,

> To me, for something to be considered STEM, I feel like there probably needs to be brought in another subject, possibly, or something to extend it just a little bit.

> Whether it's working with the science department in some way or working with technology aspect.

While he singles out science and technology, here, he also made a unique claim regarding the mathematics.

> I do feel that math can stand alone in the idea that it can be a STEM project. It doesn't have to necessarily involve… but I think most times we try to involve other departments or other disciplines in to give it that characteristic of being a STEM project.

Here Sam is talking about two ways of implementing STEM. On way involves working with other teachers who bring in content from other domains, and the other involves covering the other subject content in his classroom. His statement that "math can stand alone[8]" appears to mean that he feels he can cover other disciplines content in his classroom. This aligns with his later claim that he does use content from other subject domains in his lessons. A single teacher being able to teach content from other domains is not usual and what sticks out here is Sam's apparent view of the school environment as limiting his opportunities to teach in these ways. As an example of this, Sam expressed his dislike for the word STEM and felt the school gets too caught up in the question of what STEM is: "We get trapped in this, 'What's STEM? What's not STEM? Why is it STEM? Why is this not STEM?'" Overall, Sam has a strong interdisciplinary idea of teaching but has encountered issues with STEM policies that have led to frustrating experiences with teaching STEM.

When asked which subject domains become the main focus in the school STEM projects, Sam expressed, in the context of mathematics and science content in a water dam lesson, that "When we're doing projects like that, I don't know if [mathematics or science content] takes necessarily a priority. It depends on what the emphasis is at the time." Overall Sam's description of STEM appears to elevate the content of other domains, in particular science, and seems to align with a combined domain view of STEM teaching. Both domains may not be equal at all times but share taking priority when relevant. In the next two sections I will look closer at how these Sam is conceptualizing the integration of subjects in STEM.

[8] Part of the way the talked about teach STEM could be interpreted as him saying he feels he could have a good STEM or inquiry lesson that is only focused on mathematics and does not integrate other subjects. If so, this would be this study's one example of a pre-stem lesson, using the language of my framework. However, Sam's further statements lead me to believe this is not how he is thinking about STEM

Inherent Integration

Sam indirectly describes his teaching is inherently integrated through his claim that his classroom is consistently engaged in STEM.

> I don't like to use the word STEM, like "Today's a STEM day," almost like it's, "Today is Christmas." STEM is something that just should happen. I don't know the kids even really know that it's happening or shouldn't know that it's happening. We do have days in our school where we say, "These are STEM days," and that's OK, but I always feel weird about that because we're a STEM school all the time. Saying that, "This is a STEM day," bothers me. I feel like every day that I'm working with math in my classroom, which is every day, I feel it's a STEM day every day. I feel like there's characteristics or things going on in my class every day for it to be a STEM classroom.

Sam already sees the integration of this content as a part of the classroom and effectively sees his school's manner of implementing STEM as limiting this integration. Just as one can claim the labels of mathematics and science silo those subjects from each other, Sam sees STEM as siloing that form of learning from the regular classroom practice.

Integrating Technology and Engineering

Sam briefly touched on technology and engineering in his descriptions of his teaching and parts of the school's STEM projects. He mentioned the use of technology as tool use giving specific examples such as students use of computers and spreadsheet software for the collection, plotting, and evaluation of data (i.e. via creating trend lines). He also mentioned the use of "mechanical engineering" as part of a project. This is an example of students potentially being exposed to engineering concepts as part of the STEM projects; however, Sam did not expand on what specifically was covered under this engineering experience. Sam had more to say on how STEM can influence student overall engagement, as described below.

Active Learning and Student Engagement

In discussing the characteristics of a STEM classroom, Sam described that for lessons to be considered STEM they need to be able to engage students.

> There needs to be, most times, some type of a stimuli provided. Something that is presented to the kids to engage them and get them to inquire about how to either solve a problem, help something, fix something, improve something.

To meet this description, he looked to incorporate numerous hands-on projects and activities in his teaching. However, Sam also cautioned that STEM lessons, while interactive, need to connect back to learning in a measurable way.

> We do a STEM activity because it feels good. We like it, it's fun, but then at the end of the day, we're not necessarily assessing what we've learned in the activity and what we need to reteach or expand on and go further with.

Sam directly identified the issue of how the active learning activities of STEM may not be properly monitored or useful for data-driven assessment, which ties into the larger question of how to properly assess student learning from the STEM activities. He also expressed concern that engagement by itself is not enough for learning. Despite raising this concern, Sam still expressed how STEM can give students context for their learning, as I discuss in the next section.

Authentic Context

In describing STEM education, Sam noted how it connects with students' interests, stating that STEM project or activities are "something that relates to the student personally that's relevant that they can see where they can make a change." Student interest and personal creativity were two topics Sam touched on in describing his instruction. As he put it, he is interested in finding out what "lights their fire". In Sam's case, it is worth remembering that he is holding these views while at the same time expressing that he feels constrained by administrators and policy on his teaching. While the overarching focus is on standards Sam is seeking to make connections with students that more generally support their learning.

With the conceptions underlying STEM established, the following two main sections will look at how inquiry and STEM are implemented by Sam in the classroom.

Role and Implementation of Inquiry Instruction

In describing the structure of inquiry in STEM activities, Sam indicated he gives students opportunities to self-guide within the activity.

> The characteristics in my classroom would be presenting students with a project, letting them know what the end goal is in mind, and seeing if they can achieve that. Sometimes, letting them either figure out the steps to get there, or providing them with some of the steps, letting them fill in the blanks along the way.

Sam described inquiry as a way to give students options to make decisions in a lesson though he did make a point to note this applies to his classroom and that he could not speak for other teachers.

Issues Affecting the Implementation of STEM

Teaching Standards and Primary Content

In talking about how he assesses lessons that cover multiple subject domains, Sam noted that the state standards and the changing assessment policies have affected his ability to teach STEM.

> That's probably the toughest part of this whole STEM initiative thing we talked about. We're moving towards more of a standard-based grading system. To actually assess it becomes more difficult because we only take grades on standards work and standards assessments. I have to make sure that whatever project we're doing, though it may involve some other things outside of our standards, that I'm only assessing those things that apply to eighth grade [math] standards.

In Sam's case issues of content standards and what can be assessed are strongly intertwined in influencing how he can structure STEM.

In general, Sam noted that adherence to the state standards drives everything in his teaching and assessing. This is reinforced by how he described his interaction with administrators.

> A conversation with my principal will be different than my department. My principal would be more about where are we at on this standard overall, because

> they want to know the big picture and what are we doing for those that are up to standard. It's different between my department and my principal. My principal is more interested in the hard numbers. In department, we're figuring out, helping each other become better teachers, and seeing what the students are doing.

This passage is consistent with the feeling of a lack of support described by Sam earlier. He perceives his principal and department as having very different teaching outcomes in mind, connected with standards, and these, in turn, affect the STEM environment in the school. In the next section I will look at how the issue of time further influences how Sam implements STEM.

Limitations of Time

Sam indicated that time to plan is a major issue for his ability to teach STEM. The structure of School D places a number of responsibilities on the teachers, as he noted, “We are responsible for creating our own assessments, our own curriculum, and forming our instruction from the data we collect from that.” He elaborates on this further, explaining,

> It comes down to time. I get my kids for 42 minutes a day, teach some periods. I've got a 42-minute prep. I'm not provided a curriculum so I have to do that. I just feel under supported, with the idea that if I didn't have to create my own curriculum, then I could probably create more things for STEM. A lot of my creativities and planning time, all that is just dedicated to getting my lessons around or the standards that I have to teach, the lessons that I have to teach in math.

In Sam’s view, he already has a significant time commitment to the responsibilities for preparing his regular teaching content. Incorporating STEM would add to this time since he would need to research and make his own curriculum to include the STEM elements. This limitation combined with the administrative focus on “the hard numbers” paints School D as a STEM education environment that is very much driven by what the teacher is able to pull together in terms of resources and time. In the next section, I will look at how Sam is collecting and using data to help meet administrative requests as well as guide his own teaching practices.

Using Data for Decision Making in STEM Teaching

Sam discussed the importance of students' personal interest as information for his teaching:

> It goes beyond hard data for what they know …, as far as math goes. A lot of times, I want to go deeper and find out who they are, find out what lights their fire or what their interests are. Obviously, educational data as far as what their skill sets are and what they know are important. Though, a lot of times it goes beyond that. It goes more personal. Who they are and what makes up their character? That kind of stuff. I do a lot of activities early in the year to try to figure out what makes them click and figure out who they are as a person.

While he places an emphasis on student interest, he did interject that "educational data" on skills and knowledge (i.e. student mastery of subjects) is also important.

> Formative assessment, summative assessment, trying to know exactly what my kids have learned, what they have retained, and where I need to take them to the next level or remediate or move forward from that direction. Data, to me, is super important. I use it to plan everything that I do.

Guided by adherence to state standards, he noted of students, "I assess them, reassess them, and rate them where they're at". Sam's use of data described here aligns with his description of the school's expectations of daily data-use to inform instruction. Finally, as mentioned before, Sam noted that teaches are responsible for using data to create their own assessments, curriculum and instruction. Sam's data focus appears to balance between the needs to measure progress on standards and the "more personal" understanding of student performance in the classroom. In the next section, I look closer at the kinds of data Sam takes from STEM and inquiry activities.

Data in the STEM and Inquiry Context of the Classroom

As part of teaching, Sam stated he worked to have students use the evidence they collect to make predications. On STEM activities, he indirectly notes applying informal assessment to understand what students are learning. As he describes it, his assessment looks at,

> Going a little bit deeper into their thought processes. Looking at the teamwork that they did to get there. It's not necessarily all about the math part of it, but there is some assessment done on their teamwork and working with their part.

Later Sam describes his assessment of STEM lessons as “organic” though in this case that term reflects Sam’s feeling that his ability to assess STEM is less formal regarding informing instruction. He felt he made more changes in instruction based on the formative assessments that he applies in his content focused teaching.

Interestingly, while Sam focused on this informal and personalize assessment in his current STEM activities, he expressed an interest in working towards more standardization. When ask what he felt were important steps to building his capacity to use data in the STEM environment he noted,

> You need a set of rubrics to set up. …One has to relate directly to the standards that we're teaching. Second then, setting up a rubric that relates to that so that we can say, "Yes, this student got to the same thing I talked about with how I would assess any standards." Where are they out on the scale of what they learned about that standard? Sometimes we pick the activity and then try to fit the standards to the activity rather than picking the standards, trying to find an activity that fits the standards.

This change would bring the assessment of STEM more in line with the implicit assessment expectations of the administrators. As Sam did not speak negatively of the informal assessment he does, it seems likely that this call for standardization is driven by wanting to satisfy those expectations. This would again be Sam balancing the focus on standards and non-standardized data in his classroom.

Summary

School D is the second case to involve a single teacher. This teacher expressed an interest in the kind of teaching STEM represents but had concerns about how STEM, as a school initiative, may limit the scope of teaching. The teacher noted there is a requirement to have a certain number of STEM projects but no specific administrative requirements on what STEM entails. This teacher is also the only one with explicitly negative views of the teaching situation surrounding his STEM and regular instruction in the school.

The teacher's view of STEM *in the school* is that is STEM implies cross-curricular interaction with teachers in other subjects. This view aligns with the requirement to develop grade-wide STEM projects where each teacher works on parts relevant to their subject. At the same time, his personal view is that he could do STEM that incorporates content from other domains directly within his classroom. In other contexts/schools, that might be an expected part of STEM teaching, but the administrative policies of this school appear to support primarily cross-classroom STEM teaching.

The teacher described inquiry as an opportunity for students to learn how to work towards achieving a goal and learn from their mistakes. This view on teaching contrasts with what he expressed as a very standards-focused environment. His interactions with administrators focuses primarily on how successful students are with the standards. He also feels that changing policies on standards are forcing him to focus just on performance on mathematics standards and not allowing him to consider other subject content as information.

Despite the standards focus of this environment, the teacher holds a holistic view of other data that can help him understand his students.

> It goes beyond hard data for what they know I guess, as far as math goes. A lot of times, I want to go deeper and find out who they are, find out what lights their fire or what their interests are.

Overall, he looks to assess around the informal aspects of activities, such as teamwork and participation, while navigating the requirements to focus on standards.

Case D shows a mathematics teacher whose views of data-use and STEM are at odds with the policies surrounding these in his school. He places importance on specific kinds of data and sees the role of STEM differently than what he feels are the administrative policies. This contributes to feelings of a lack of support in preparing STEM instruction.

Transition to Discussion

Across the cases these teachers brought up a number of known aspects of STEM education and data-use. However, the intersection of the STEM and data environment and the external influences of administrators' expectations and accountability standards have led to particular was teachers are structuring their STEM teaching and assessment. I will explore this in detail, in terms of this studies' research question, in the following chapter.

CHAPTER 5: QUALITATIVE DISCUSSION

Overview

In this chapter, I discuss the qualitative results of this study to answer the following research questions.

- What are secondary educators' in STEM focused schools perspectives surrounding teaching and data-use in STEM education?
- What do secondary educators in STEM focused schools see as the role of STEM inquiry activities in informing educational decision-making?
- How do secondary educators, in STEM focused schools, describe their practices of implementing of STEM education?

Acknowledging the wide range of what data-use and STEM education can mean, both when conceptualized and in practices, I developed a framework to help organize the teachers' responses regarding data-use and STEM. This framework was modeled from the structure of Schildkamp and Poortman's (2015) data-use theory of action framework, which examines the cycle of data-use embedded in the organizational context surrounding the education environment. These organizational contexts encompass the external influence of administrators, the interactions of teachers in the school, and the personal impressions of teacher based on their training and background. Extending the ideas of this framework, I developed a layout for talking about the organizational contexts surrounding the implementation of STEM instruction. I further attempted to define categories for labeling what a teacher was describing when they talked about STEM by discerning if the teacher was teaching content, using inquiry, or using data from one or more subject domain. These categories were meant to help limit the ambiguity that comes from the still nebulous definition of STEM, however, as will be discussed later, this aspect of the framework was not truly representative of how the teachers talked about STEM instruction. Despite this, I have used the framework to clarify the data-use and STEM views and practices described by the teachers.

Qualitative Answering of the Research Questions

What are Secondary Educators' in STEM Focused Schools Perspectives Surrounding Teaching and Data-Use in STEM Education?

Administrative Requirements and Expectations on STEM and Data

In general, school leadership serves to set the agenda and focus of a school, affecting decisions such as the choices of assessment data and the plans for professional development (Young, 2006). This also applies to setting a school's STEM focus (Lynch, Behrend, Burton & Means, 2013). The four school cases in this study present an interesting scenario where administrators in STEM focused schools are not, from the teachers' perspectives, implementing specific requirements or expectations of how STEM should be taught. The fact that teachers across these cases felt that administrators in their schools have not set rules for teaching STEM is important for interpreting this study, as the perspectives and practices that teachers describe are ones influenced, not by a policy, but by a perceived lack of policy. This interaction between teachers and administrators can be contrasted with the work of Bruce-Davis and colleagues (2014) who observed teachers and administrators in a diverse selection of STEM high-schools collaborating on curriculum regarding STEM content. In this study, much of the decisions regarding STEM appear to come from the teachers.

The lack of expectations or requirements does not equate to a lack of focus or resources directed towards STEM. In School A, for example, Mark stated, "If you have a good idea and a plan, they're very willing to help out, or, at the very least, if they don't have the direct resources, they can consult. They'll point you in the right direction." Here, there is support for STEM, but the initiative is on the teacher. To compare with Mark's experience, Sam, from School D, described how his school does have a single requirement for four grade-wide STEM activities. This requirement appears to be based on the MWS STEM framework requirement for a fixed number of STEM activities. However, as Sam further explained, beyond the requirement to do the activities, all the other decisions regarding each activity are left up to the teachers to plan and figure out. In both schools, the administrators are leaving it to teachers to make STEM teaching happen, but the actual process of this takes on different forms.

The scenario with the administrators in the different schools reveals a weakness in my current theoretical framework. In the data-use literature, teachers and administrators can have different conceptions of valid data (Coburn & Talbert, 2006) and teachers then respond, navigating these differing conceptions, to carry out data policy initiatives (Apple, 2004). Using this as a template, it made sense to assume there would be different conceptions of STEM between teachers and administrators. However, it appears there is, practically speaking, no organizational level conception of STEM is held by the teachers in my study. On one extreme, it is possible that administrators are setting agendas for STEM but, for some reason, this is not being picked up by teachers. On the other extreme, administrators may be overlooking STEM to focus on other school requirements, namely data-use. Regardless of the cause the outcome is that, other than a perception of general support of STEM, the teachers do not hold organizational level perceptions that influence how STEM is implemented. How STEM is implemented and understood comes from the collaborative and personal perceptions of teachers. Since this happened across all four schools, this indicates that the current STEM certification process and its associated STEM framework do not guarantee that administrators in the schools will take a proactive role in defining the STEM teaching of the school. Further research within MWS is needed to identify if this lack of administrative direction in STEM is present across the STEM schools and to identify potential changes to the certification and framework process that would further engage administers in the STEM aspects of their learning environment. Interestingly, as I will expand on in the next section, while there was a lack of guidance on STEM from the administrative levels, each of the teachers described many commonly associated traits of STEM in their conceptions of it.

Conceptions of STEM

Teachers across all schools brought up established features of STEM education that had influence on their teaching: integration, active learning, student engagement, and authentic context. Under the topic of integration, three additional features were expressed by some teachers: the close connection of mathematics and science, a special focus on the importance of either engineering or technology, and the focus on technology as tools to be used. I will touch on these in detail in the following sections.

Integration

While integration was expressed in different ways, for example by the specific domains a teacher highlighted in their descriptions, the general idea of integration was prevalent in each school and was a part of each teacher's discussion of STEM. Within this idea of integration different teachers gave special attention to select domains, while at the same time not necessarily implementing those domains equally in terms of their content. For example, Sam, as a mathematics teacher, singled out science for its content and context it gives to his mathematics lessons and singled out technology as a tool for data analysis. In contrast, Abby, another mathematics teacher, focused on including technology and the engineering design process while having limited inclusion of science. This was an example of teachers, in the same subject, holding different views of integration in different schools. In School A these differences can be seen to arise in the same school. Among the science teachers, Mark focused on the importance of science, mathematics and technology while Greg focused on engineering over technology. These descriptions reveal a collective focus on integration among these teachers, but the form that integration takes varies across both the teachers and subjects taught within and between STEM schools.

Generally speaking, this lack of consensus related to the integration of STEM is consistent with the idea that there is still no agreed upon view of the implementation of STEM education (Breiner et al., 2012; Pitt, 2009). However, it does raise questions at the cross and within case levels. Across the cases, the schools are all subject to the same STEM framework as certified STEM schools in the same state. While this framework does outline a definition of STEM in its introductory section, the language treats this as a guideline. Because of this, it seems that it is left up to the districts and schools to devise an implementation of STEM. However, it appears, from the teachers perspectives, that administrators associated with these schools are not defining STEM teaching and are leaving that task to the teachers. The teachers conceptualize STEM based on the ideas they bring into the school compared with policy ideas of STEM that may filter down to them. In the following section, I will further discuss how these teaches appear to conceptualize STEM integration within the categories of my theoretical framework.

Combined and Dominate Domaine Integration

In the framework of this study, I outlined three levels of implementing STEM. *Pre-STEM* covers teaching that is described as STEM but is really traditional single-subject teaching. *Dominant- domain STEM* covers situations where there is one main subject domain that is the focus of instruction, but aspects of another domain are incorporated into instruction. Finally, *combined-domain STEM* is the near-equal teaching of two or more content domains. Within these categories, I further broke down the implementation based on which subjects serve as the source of inquiry activities and data for assessment. These teachers' conceptions of STEM aligned with some of these categories.

Beginning with combined-domain STEM, the science teachers singled out mathematics as an important, unremovable part of science. Using Rey's words from School A to illustrate this, she noted, "in order to understand the science, you need to understand the math". Only one mathematics teacher, Sam at School C, spoke to the corresponding importance of including science education in his teaching. The other mathematics teachers focused primarily on the integration of technology in their mathematics lessons. This differs from Frykholm and Glasson's (2005) observations where mathematics teachers did generally express the importance of making connections with science content in integrated lessons. STEM, as an educational initiative, has grown considerably since the time of that study and along with that the focus on engineering and technology has increased. It is possible that the rise of technology and engineering alongside science may give mathematics teachers more choice in other domains they consider to be important to consider tying to their instruction. As an example of this, Abby discussed a kitchen design lesson combining mathematics and "the engineering and the design process".

The predominate instance of dominate-domain STEM was the use of technology as a tool. Frykholm and Glasson (2005) observed, in integrated mathematics and science lessons, that both mathematics and science teachers tended to treat mathematics as a tool within activities to support science instruction. I am building off this to present how the teachers in this study are using technology as a tool, in their general and STEM instruction, to support their mathematics or science instruction. Under the view that each of the domains of STEM education are equally important facets of education, the technology part is more than just the technology used in the classroom (Sanders, 2008). However, teachers from each of the schools talked about technology in its capacity as a tool to assist instruction. While individual teachers may have included technology, the concept, as a part of their idea of STEM, they would then clarify that they were talking about the different forms of technology.

Computers, or tablets (e.g., Ipads) were mentioned across the schools. Both Rey, from School A, and Sam, from School D, discussed the use of computers and spreadsheet software for having students work with data. Abby, from School C, mentioned how their school had replaced textbooks with one-to-one Chromebook laptops. Nina, from School B, stated she had students use iPads to access and use mathematics software (i.e., Desmos). Sanders (2008) had noted that "there is a common misconception that the "T" … means computing" (p.20), and these schools appear to extensively use computers as the base of their classroom technology. However, other forms of technology were mentioned among the science teachers. Some science teachers in School A specified using electronic sensors while May, the science teacher in School B, discussed having students produce and film a presentation as students using technology. To the extent that teachers are using technological tools to support instruction, this may indicate that there are some technological uses or needs of science teachers that the mathematics teachers do not have.

Overall, the teachers express the importance of technology to support instruction. This use of technology can help students learn but at the same time may not align the importance of general technological skills, akin to science, mathematics or engineering skills that are a part of STEM education. If a STEM school is to distinguish itself from a normal school that has a strong mathematics and science focus, the actual implementation of technology (and engineering) needs to raise the importance of that domain in teaching and integration. In the next section I will discuss the perspectives of STEM that teachers expressed that connect to and extend the ideas of integration.

Active Learning, Student Engagement, Authentic Context versus Traditional Teaching

Across the schools, teachers mentioned concepts of STEM that fall under active learning, student engagement, and authentic context. Sander (2008) has described how integration of content domains can lead to activities that focus on real world problem solving. This, in turn, allows for engaging and contextualized learning experiences (Wang. Moore, Roehrig & Park, 2011). Mirroring that research, most of these teachers across the schools pointed out both that

STEM teaching allows them to have interactive activities for students, and that the traits of the STEM environment help engage students in learning. A statement by Greg, from School A, tied these aspects of STEM together: "I feel like STEM is not just passively memorizing facts but using math and science actually to make sense of their world and to improve their world through engineering technology." The other teachers mentioned these concepts in more isolated contexts. The fact that they brought up concepts outside of integration shows these teachers are thinking about STEM as more than just the integration of content domain knowledge. The contextual and student engagement focuses of their views on STEM align with a view of how STEM experiences can foster student learning (Kennedy and Odell, 2014).

It is interesting that the teachers' conceptualizations of STEM do not appear to radically differ from established ideas of STEM. First, which subject domains are integrated is not standardized but the idea of integration is still present. Second, these common non-integration aspects of STEM were discussed by teachers. I have two possible explanations for this. First, it may be that STEM education has become so ubiquitous that individual teachers have simply picked them up over time. Second, these instructional ideas about STEM are not as unique as first envisioned and are a natural extension of the primary subject instruction the teachers were already familiar with. Both explanations have implications for how teachers in a STEM school may begin implementing STEM when there are limited policies in place on STEM education.

In the next section I will discuss how the teachers described their data-use and STEM teaching interacting in their instruction.

Conceptions of Data and STEM

Teachers across the schools mentioned administrative expectations for using frequent formative assessment for monitoring and improvement of their instruction. This assessment focus combined with the more open-ended and cross-subject teaching of STEM appears to have steered teachers to take more informal, formative assessment of student work.

For the middle school teachers, part of this informal assessment regarded student engagement and participation in the activities. Abby noted she cannot assess the "process of learning" in STEM activities since there are potentially numerous ways of going through the activity. Instead engagement, as measured by work with groups and time on task, is the data used for assessment. Mary described tracking "Who was into it" and "Who was involved" while Sam stated he doesn't consider assessing math in these situations but instead focuses on teamwork and who is "working on their part". Student participation, especially in a group, can help students learn the practices of the subject they are engaging in (Gresalfi, Martin, Hand & Greeno, 2009) and give student students opportunities to express and revise their thinking processes (Turner & Patrick, 2004). However, in this situation it must be considered that these informal assessments may be driven by a lack of appropriate pedagogical content knowledge by teachers. Teachers can find themselves wanting to give students inquiry activities but not have a knowledge of appropriate assessment practices (Rangel, Monroy, & Bell, 2016) or tools such as rubrics for collecting assessment data in a non-traditional setting. The choice of assessing mainly on participation may be the natural outcome of these teachers wanting to implement STEM activities within the current absence of administrative expectations to guide them.

Notably, no teacher from school A, the high school, explicitly mentioned assessing on teamwork and engagement, which many be a reflection of different expectations on student participation between middle and high school. These high school teachers do teach advanced placement and duel credit courses so, in those instances, their assessment would need to conform to the expectations of those curricula. This difference could also be due to policies in School A's STEM academy that was the setting for all of the high school teachers in my study. Students choose to take courses in the academy so those teachers may be working under instructional standards not held in the non-STEM academy mathematics and science courses at the other schools.

The second example of teachers' use of informal assessment is on students' use of evidence to support claims. Mark described how he grades how students approach the lab over getting the right answer. Rey mentioned having discussions with students on the conclusions they form from the data they collect. Mary discussed accepting student work based on solid reasoning, stating, "A lot of times their evidence is not my evidence, but as long as it makes sense and it goes with the lab, I'm 100 percent OK with that." Only Abby, in school C, did not mention this goal of assessment but did note she accepts the "productive struggle or unproductive struggle" if it is directed at the goal of the activity. Kim and Song (2006) had observed a lack of evidence-based arguments being used in science and mathematics classroom despite these being fundamental parts of science (NRC, 2007b) and mathematics practice (Schwarz & Hershkowitz, 2010). The focus on students' use of evidence expressed by these teachers across the schools may, in general, be connected to a growing focus on evidence and inquiry that has expanded into the education practice (Llewellyn, 2013).

An important take away is that this focus on informal assessment seems to indicate that in the cycle of data-driven decision making, the data from STEM domains outside of an individual teacher's content area is not the data that is entering the decision process. There is still "STEM" data from engagement in activities, but it does not take on a domain specific form. However, this does not mean that STEM and data-use are not connected. It may be that data-use and STEM teaching and assessment are connected in the sense that data-use practices greatly influence and shape what happen with STEM. This is a point I will argue in full under research question 3.

Non-Subject Specific Data and the Limitations of My Framework.

The discussion above leads me to consider a need for changes in how my framework can talk about teachers' implementations of STEM teaching. In my theoretical framework, I had categories where I could break-down teachers' implementations of STEM based on whether they were teaching content from one or more subject domains and using data from one or more subject domains. I made the assumption that the integration of subject content would dominate any consideration of teaching STEM. However, the teachers' responses reveal this is an incomplete and misleading way to talk about their STEM implementations. Due to this, I will not try to fit the teachers' responses into these seemingly invalid categories in this discussion but have left the categories in the framework as a template for future revision. In the next section, I will discuss some of the concerns teachers raised about the STEM environment they work in.

Teacher Concerns Surrounding STEM education.

Teachers across the schools raised concerns about STEM education that fall under two categories. First, teachers raised issues of teaching STEM in the subject, standards and test focused education environment. Second, teachers expressed concern about the general nature of STEM within the school.

As much as these teachers expressed support for teaching STEM, each mentioned that some requirement (i.e. course, standards, or curriculums such as advanced placement and duel enrollment) limits their ability to include broader STEM content. Teachers felt this pressure in different ways. For example, at School C, Sam felt the pressures of an administrative focus on meeting the standards and the “hard numbers” primarily shaped his ability to offer STEM activities. Mary, from school B, felt the “canned” nature of her curriculum was the obstacle while Greg, in school A, expressed a similar concern regarding the requirements of his duel credit courses. Overall, the teachers’ perspectives of STEM are partially influenced by their perspectives of teaching requirements and standards that surround their STEM instruction. From this, they try to determine how they can teach STEM while still meeting these expectations. I will discuss how the teachers modify their instruction to accomplish this in a later section on teachers’ practices in STEM education.

The other concern expressed by some teachers pertains to the organizational structure of STEM in the schools. One issue was that the layout of school courses has not evolved to accommodate the STEM focus of the schools. Nina pointed out an issue, in School B, that the course progression for students had not adjusted to account for the new STEM focused classes. Due to the lack of academic requirements on STEM, students were enrolling in courses without a proper mathematics background. Rey, in School A, expressed a related concern that students’ freedom to choose courses in the STEM academy made it difficult to organize cross-curricular activities since students do not share courses.

An additional issue was about how being a STEM school may change the nature of instruction. Janice expressed that she was “torn by the phrase STEM education” as she felt that the role of her teaching was more to support the STEM endeavors of the school over teaching STEM in her classroom. Sam expressed concern that the school can get caught up in a cycle of asking “’What is STEM? What's not STEM? Why is it STEM? Why is this not STEM?’” that limits the lesson design process.

Bruce-Davis and colleagues (2014) observed that teacher participation in the STEM school environment can help to align teacher instruction with the interest of the school. My study reveals an environment where this alignment is more ambiguous. The lack of perceived administrative expectations on STEM appears to have resulted in a lack of direction on STEM. The ubiquity of certain commonly discussed components of STEM seems to have filtered into the teachers’ general conceptions of STEM. For some teachers the changes brought about by the certification process has raised concerns such as course arrangement in the STEM school and the role a teacher holds in the broader STEM environment of the school.

The teachers who consented to interviews all expressed an interest in the importance of teaching STEM. Then from this they have started to consider how they can teach STEM or implement the essence of STEM education within the current limitations they face in their schools. The actions and concerns of these teachers within these STEM schools has implications for teacher experiences in the evolving STEM education landscape. Within MWS this also has implications for concerns teachers may experience as more schools go through the STEM certification process.

What do Secondary Educators in STEM Focused Schools See as the Role of STEM Inquiry Activities in Informing Educational Decision-Making?

STEM and inquiry education are distinct but related aspects of education with inquiry serving as a way to build multi-disciplinary education (Crippen & Archambault, 2012). As examples of this, Abby, in School C, directly stated how the inquiry-based and cross curricular components of education are combined parts of instruction necessary to prepare students and Mary, in school B, noted inquiry was the basis of the STEM challenge activities she developed for her class.

School A provided the one example where teachers were asked to make specific distinctions regarding STEM and inquiry teaching. As Rey noted, “it is an expectation that we are teaching our inquiry-based textbook. That is a requirement. There's really no requirement in the building or the district to teach a STEM lesson or anything.” While, as illustrated here, there is inquiry teaching separate from STEM teaching, the teachers’ discussions on STEM teaching were predominately as inquiry activities. As such, there is overlap in how I present STEM and inquiry teaching in this section

Administrative Influence on Inquiry

The perceived lack of administrative requirements surrounding STEM again sets the tone for understanding the role of STEM inquiry. Regarding data-use requirements connected with inquiry Greg, from School A, directly stated, “There is no expectation of, "Oh you're doing inquiry activity, you gathered this rubric data, you put it on a spreadsheet, and you change this."” For the teachers, the lack of requirements surrounding teaching STEM generally covered having a lack of requirements for assessing STEM, and in turn the inquiry activities surrounding STEM.

Even though this section looks at inquiry, the ubiquitous lack of data-use requirements leads to the same outcome as the data-use discussion regarding STEM. The teachers mentioned requirements for frequent formative assessment, a kind of assessment that is useful in assessing inquiry activities as "students' understanding and skills unfold naturally as they work with materials and explore their ideas through investigations" (Carlson, Humphrey & Reinhardt, 2003, p.2). However, the choice by administrators to focus on formative assessment appears to be, overall, unrelated to the inquiry and STEM teaching in the schools. From here, as discussed under research question one, the assessment of the activities primarily focuses on student engagement and abilities to draw conclusions from evidence.

Having already discussed the kinds of data that are considered in this kind of instruction, I will focus on how teachers view inquiry in teaching of process and content and how two of the teachers see STEM and inquiry as allowing students to self-differentiate their engagement in activities.

Learning Process and Content

In this section, I compare the view of inquiry held by the one high school mathematics teacher with the views described by all the other teachers because this outlines two different roles of inquiry in instruction.

The School A science teachers noted how inquiry leads to the engagement and attempts at problem solving that they can assess student on. Specifically, regarding inquiry and lab, they focused on the importance of giving students opportunities to determine parts of the activities (e.g., variables, methods, goals) to give them agency and give them "some investment in the process." For these teachers, the inquiry activities served to teach the process, namely the "investigative skills" (Chiappetta & Adams, 2004, p.50) of doing science.

Janice, the mathematics teacher from School A, expressed a very different conception of inquiry describing it as a means of supporting learning that is not as important as student mastery of the mathematics concepts. To her, inquiry was, "showing [students] how things work or why things work, but then that's not as important to me as whether they can use the formula we derived." She discussed inquiry as a way to reinforce mathematics content but at the same time noted that, if the inquiry activities did not 'click' with a student they could be given the right answer and "carry on with what they were supposed to get." The principle difference here is in the use of inquiry to teach about working within a subject versus the use of inquiry to support the learning of other material. Some of the science teachers mentioned the importance of connecting what was observed in inquiry back to the content that was taught, but they did not emphasize the mastery over the inquiry experience the way Janice did.

Janice's description of inquiry can be further compared with the mathematics teachers at the other schools. At School B, Nina shared: "They have to work through the investigation to develop the knowledge and rules, algorithms, or whatever the content may be from that lesson." While there is a content focus to this quote, she also noted an inquiry she asked students ""Can you figure out what the pattern is?" or, "What's happening in all of these questions?"" Nina's talk of inquiry is more in line with the process view expressed by the science teachers over the mastery view expressed by Janice. The same applies to Abby, the mathematics teacher from School C, who indicated just giving a "series of steps" will not foster "the ability to think, struggle, work together and collaborate" and Sam, the mathematics teacher from School D, who described "letting [students] fill in the blanks along the way" to try to see if they can achieve the lesson goals. Overall, the difference of Janice's view may point to a unique situation in School A, or a highly traditional teaching view of this mathematics teacher.

Mathematics teachers who begin to focus on explorative or inquiry learning have been observed "to relinquish their traditional teaching methods and design opportunities for students to perceive mathematics directly (Simon, Tzur, Heinz, Kinzel, & Smith, 2000, p.596). While the middle school mathematics teachers described their instruction in this way, the high school mathematics teacher did not. However, Janice's views seem less influenced by the grade level and more by her impression of her role in the STEM academy. While all other teachers discussed implementing integrated STEM, and associated inquiry, within their classroom, Janice focused on how the school academy was integrated and how her role was to teach students the mathematics to allow them to function in that integrated environment. This connects back to Frykholm and Glasson's (2005) study where they observed that even mathematics teachers were using mathematics as a tool to supplement science in STEM lessons. Janice is taking this a step further by using her mathematics instruction to support School A's STEM focus instead of just her classroom. Because her focus in on mastery of the mathematics, she adjusts her implementation of inquiry teaching to accommodate this view.

Janice's views, compared with the other teachers, raises important questions about what views teachers may form about STEM and inquiry in STEM schools, especially those with limited administrative requirements. Janice's actions may be the best choice for the School A structure, but at this time the intersection of STEM school structure and STEM instruction is still unexplored. Further research is needed to untangle this aspect of teachers' instruction and their role in supporting STEM across a whole school environment.

Differentiation in Instruction

As mentioned previously, many of the teachers described giving students choices in determining the procedures and methods of carrying out investigations in STEM lessons. One mathematics teacher and one science teacher from schools A and B further discussed how their STEM inquiry activities allow for differentiated instruction. These two teachers specifically drew attention to how students differentiate their learning experience based on the complexity of decisions and topics they choose to engage with. Rey, from School A, noted that higher ability students can apply more creative thinking skills to develop more complex inquiry experiments in an activity while Nina mentioned how individual students will develop a level of understanding based on how they can interact with and manipulate the content of an inquiry lesson. I should note here that these teachers are referring to a differentiation of experience that is driven, primarily, by the interaction of the student with the STEM and inquiry content.

Differentiated instruction to address issues of equity is a high-level goal in the state's rubric for STEM implementation, however the differentiation described by these teachers does not appear to be driven by that aspect of the state's framework. Planning lessons around differentiated instruction combined with allowing students to make choices helps students develop the autonomy to engage in inquiry investigation (Llewellyn, 2010). Differentiation can involve presenting different levels of content to students or the prior assessment and grouping of students to do different activities based on the content (Glass, 2009; Richards & Omdal, 2007). Part of the effectiveness of differentiation relies on the ability to "effectively address variance" (Tomlinson, 2005, p. 263) in the students' learning. The teachers in this study described a specific avenue of differentiation that is initiated by the students. The students still engage in the activity but are allowed to make choices on experimental design, variables, or presentation that match their ability levels. This form of differentiation is in line with Tomlinson and Allan's

(2000) description of *differentiation of product* which includes students choosing the level of complexity of the outcome they pursue. In this study, these teachers appear to respond effectively to how this differentiation plays out and are able to support their students. Part of this may tie to the teachers' choices to focus on participation and use of evidence to assess student learning in these activities. Understanding how to support this kind of differentiation, as it appears to arise in STEM and inquiry activities, will be important because as the number of STEM schools and programs grow there may be a push to more directly assess STEM inquiry. There is a need to understand how content can and should be differentiated and assessed in this changing learning environment.

How do Secondary Educators, in STEM Focused Schools, Describe Their Practices of Implementing of STEM Education?

Standards Requirements Influence on STEM

While each of the teachers expressed positive views of STEM teaching, many expressed concerns about having the opportunity and time to meet content standards (i.e. state, duel enrollment, and advanced placement) for their subject area. This partially aligns with Al Salami, Mackela and Miranda's (2017) finding that high school teachers expressed meeting standards as one of their biggest concerns in implementing STEM. Both middle and high school teachers expressed this concern in my study, which may be due to the fact that these are STEM schools and aspects of the teaching of STEM directly affect all of these teachers.

Teachers from several schools responded to this situation by finding ways to incorporate the additional STEM content, or content not covered under the standards of their subject, that they felt was relevant to their teaching. In School A, Rey described adding STEM content through modifications she made to her lessons. First, within the science content, she described looking at students' interests to find "illustrative examples" from topics such as medicine or sports for making connections to the standardized content. By incorporating more mathematics and technology content into her AP course, she noted that she restructured some lab work to give students exposure to working with statistic concepts and manipulating data in electronic spreadsheets.

Instead of modifying content, both Mark from School A and Mary from School B discussed developing extra class activities (e.g., Mary's STEM challenges) as a way of fitting more STEM content into their teaching. These activities give students the opportunity to participate in STEM, but, at the same time, that STEM content is sectioned off from the main instruction. Finally, Abby, in School C, described a more antagonistic relationship between teaching her primary content and STEM. Her description was not in terms of adding STEM but in what standards she can ignore or drop "in order to allow more time for STEM."

Notably, from these teachers' descriptions of their practices, even when they are looking for more ways to incorporate STEM, the main driver of instruction is the standards. Even Abby, who was considering standards to drop, still needed to weigh her options to address other standards. As Ashby (2009) noted, teachers may narrow the scope of their curricula and the data they assess on to meet accountability standards. The focus on assessing on content standards can limit the teaching that promotes "learning of scientific and mathematical content and practices" (NRC, 2011). While mathematics and science are not *all* of what constitutes STEM, if even these individual subjects are affected by the need to meet content standards, then that necessarily points to complications in the teaching of STEM. The intersection of a STEM school focus and content standards is another issue that seems unaddressed in the literature and is an important issue to study as more STEM schools and STEM programs are founded in a standards-focused education system.

Teachers' views of the intersection of standards requirements and STEM teaching may be, in part, influenced by the administrative supports offered to teachers, as I will discuss in the following section.

Professional Support Influence on STEM

Part of teachers' practices regarding STEM appears to be influenced by the kind of support offered by administrators and the interactions with other teachers in the school. Administers set the tone for how teachers interact with STEM content. While administrators did not impose requirements for STEM teaching, teachers in all schools except School D expressed that the administrators were very supportive of STEM instruction. The outlier, Sam, felt unsupported in STEM instruction, noting that his administers were exclusively interested in student performance on standards. All of the teachers mentioned the concern of meeting standards; however it may be the case that how administers focus on standards and the requisite data-use may influence how teachers perceive working in their STEM environment.

Administrative leadership can influence teachers' data use (Park & Datnow, 2009) and if this leadership marginalizes the role of STEM, the teachers may, in turn, feel unsupported in implementing STEM.

Common planning time and professional development were supports provided by three of the schools (A, B, and C), but the implementation and focus of these supports varied across the schools. For example, in School B the mathematics and science teacher expressed very different experiences with PD. The mathematics teacher reported never receiving PD on either data or STEM, while the science teacher noted the district had a substantial grant funded STEM PD and resource initiative. The different experiences of these teachers can be compared with the consistent, primarily data focused PD mentioned by both the mathematics and science teachers in School A. Abby's experience in School C was mixed as she noted that 20% of her common planning time could be considered STEM focused through discussions on how to include more technology and to add more inquiry-based work. She was also provided with weekly PD sessions at School C on data and standards and had a monthly "Tech-Tuesday" which comprised a technology learning focus on STEM.

From this it is clear that the professional support for STEM differs across the schools. In the literature on data-use, the agendas set by administrators set the norms for guiding teacher data-use (Young, 2006) and teachers respond to these initiatives even as they may maintain certain beliefs regarding data-use (Apple, 2004). Using the data-use literature as a template for understanding the situation surrounding STEM implementation, it seems, within these schools, that no specific STEM agenda is influencing teachers. Interestingly, it is the existing data-use focus of the schools that appears to be guiding STEM practices. The need to address and meet standards influences decisions on structuring STEM activities. The administrative focus on using formative assessments in teaching has evolved to support the formative, informal assessment the teachers can use. In short, the practices of STEM teaching in these STEM environments appears to be, in part, shaped by the teachers conforming practices of data-use that come about due to existing accountability focus of education.

Modeling Young's (2006) work, I suggest that the administrators in Schools A-C have set a school agenda that teachers are responding to, but, from the perceptions of most of the teachers, that agenda is supportive of STEM but does not direct how it should be. Sam, in school D, was the one teacher who felt administrators were directly prioritizing standards performance over anything supporting STEM. Despite this difference, the main assessment practices for implementing STEM were the same. This may make sense under Coburn and Talbert's (2006) observation that administrators tended to focus on psychometrically measurable (e.g. standardized) data while teachers looked for data that provided "insight into student thinking and reasoning or was authentic and rooted in teacher judgment" (p.484)." STEM teaching, in its current form, exists close to the classroom and the judgment of the teachers. There is effectively no standardization of STEM teaching and, important to this conclusion, assessment at any level of education. It makes sense that, in the absence of a perceived externa influence, these teachers would ultimately settle on forms of assessment consistent with making direct observation of how students are engaging and thinking within STEM.

This is an important part of understanding how teachers may respond to a STEM environment. The practices of STEM may take on forms influenced by other education policies. If policy maker and administrators want STEM teaching and assessment to meet certain criteria, they will need to take an active role in working with teachers to guide STEM education to these outcomes.

This completes the qualitative portion of this dissertation. In the following two chapters I will present the findings and discussion of the quantitative analysis of the survey for this study.

CHAPTER 6: QUANITATIVE FINDINGS

Overview

This chapter describes the quantitative portion of the findings for this study. The quantitative data come from mathematics and science teachers' responses to a survey that was distributed to a selection of STEM certified, Midwestern-state schools. The items of this survey were written to capture the broad perspectives of these teaches surrounding STEM and data-use. Descriptive statistical breakdowns of responses are used to highlight points of interest regarding teachers' perspectives and practices and the focus of examining these responses is to observe how these teachers portray their interactions with STEM education and data-use. I examine these under the scope of the following research questions.

- What are secondary educators' in STEM focused schools perspectives surrounding teaching and data-use in STEM education?
- What do secondary educators in STEM focused schools see as the role of STEM inquiry activities in informing educational decision-making?
- How do secondary educators, in STEM focused schools, describe their practices of implementing STEM education?

After the demographics section, I have organized the presentation of the results in sections dedicated to each of the three research questions.

While my research questions do not imply a comparison of mathematics and science teachers, in my analysis I have separated the science and mathematics teacher's responses to highlight differences that may emerge between these two groups. Science and mathematics are both major focuses of STEM education reform, but mathematics teachers may have different experiences due to both the standardized testing focus that influences mathematics instruction and the view that mathematics is very sequential (e.g., you need understand algebra to do pre-calculus but do not need to know physics to do chemistry).

In this study, I am only interested in presenting a snapshot of perspectives and practices that can occur in a STEM focused school. The limitation of this disaggregation on this small sample size for the quantitative data (n=15) is somewhat offset by the synthesis that will occur from examining this data alongside the qualitative data present in this mixed-methods study. For the sample size, aggregating these groups would increase the responses to each question and could allow me to apply inferential analyses for generalizability. However, I am not interested in making inferences on STEM schools outside of my sample. Further aggregating the data would hide the important distinctions observed between the teacher groups.

Demographics of Teacher Respondents

The online survey was opened by 34 teachers who completed the first question, which asked if they are a science or mathematics teacher. These responses were split evenly with 17 indicating science and 17 indicating mathematics. After this first question 22 teachers continued further into the survey and 15 teachers completed it entirely. At the time of data collection, there was roughly 10 secondary schools (covering 7^{th} to 12^{th} grade) that were certified in the state. Among these schools, in total, there were roughly 50 mathematics and 50 science teachers. Among the schools where I distributed my survey there were 29 mathematics and 27 science teachers. Since this study focused only on science and mathematics teachers, while the response rate is low, it is relative to the smaller population of teachers experiencing this STEM and data-use environment. The demographic questions were included at the end of the survey and so are indicative of the number of teachers who persisted to the end of the survey.

Of the 15 consistent respondents (i.e. respondents who completed the main body of the survey and the final demographic questions), nine were science teachers and six were mathematics teachers. Out of these teachers, only two of the mathematics teachers indicated they were not in their current school when the school received its STEM certification. The science teachers consisted of a gender diverse group (four male and five female) while the mathematics teachers were more uniform (five female and one unspecified).

Eight of the nine science teachers indicated having at least ten years of teaching experience with an average of 26 years. One science teacher indicated they had zero years of experience. Among the mathematics teachers, four indicated having at least ten years of teaching experience and two indicated having less. The overall average for the mathematics teachers was 13 years of experience.

When asked about the number of years teaching in their current position, only one science and one mathematics teacher indicated having been in the position for one year or less. Among the science teachers, four taught just physical science courses, one taught only life science courses and three taught a combination of both. The mathematics teachers taught a combination of pre-algebra, algebra, and geometry. Overall, the respondents to the survey had several years of teaching experience and were present when their school transitioned to a STEM school. In the following sections I will layout the findings of this quantitative portion of the study in the context of the research questions.

Results

What are Secondary Educators' in STEM Focused Schools Perspectives Surrounding Teaching and Data-Use in STEM Education?

STEM education and data-use do not have universally defined meanings. To understand teachers' perspectives on these two topics, it was necessary to pull out the specific aspects of STEM and data that inform their perspectives. First, I explored the definitions of STEM education and the main sources of data used for decision making expressed by teachers in their own words. Second, to address this question, I examined teachers' responses to survey questions that addressed the following six aspects of STEM and data-use in the teaching environment.

- Does STEM enhance student grade performance?
- Does STEM enhance student engagement?
- Is exposure to STEM necessary for success of students in the primary subject?
- Is data from STEM useful in assessing student growth?
- Is data from STEM used to inform instructional decisions?
- Is data from STEM necessary to assess the performance of students in the primary subject?

Teachers responses on these ideas allowed me to get at the perspectives the teachers have both of STEM, data-use and the intersection of these.

Defining STEM and the Primary Sources of Data

Definitions of STEM

Table 5 and Table 6 show the definitions of STEM given by 22 science and mathematics teachers. Integration of content domains was expressed both explicitly and implicitly. The domains included under STEM varied with some definitions mentioning all four subject domains while others singled outs specific domains. One mathematics teacher singled out technology as a domain to specifically incorporate in their classroom. Notably, this teacher's comment of "it is more than just using a computer" indicates this teacher is thinking of the integration of technology, not just as a tool in the classroom, but as an independent subject that can impact student learning. Lastly, the majority of science teachers (nine out of 12, 75%) described STEM in one way, solely in terms of integration, while mathematics teachers' descriptions were more diverse with three out of 10 (30%) focusing solely on authentic context, three out of 10 (30%) bringing up more than one aspect of STEM, and the remainder offering definitions that mostly listed the subjects present in STEM.

A single science teacher and two mathematics teachers touched on issues of active learning. One mathematics teacher brought up "hands on activities" while the teacher that focused on technology noted how using technology can "increase…interest for all students". The science teacher mentioned that "Lessons serve as problem-solving practice and function as a "sampler platter" of different STEM disciplines." Further, 10 out of these 22 (45%) teachers described STEM in terms of the authentic context it gives for leading students to use either mathematics or science outside of the classroom, specifically in the real world or workforce. This view is notable as it implies these teachers have a focus on how students will not just learn their content but be able to use that content in future employment.

Finally, three out of the 10 (30%) mathematics teachers and one out of the 12 (8%) of the science teachers did describe STEM by directly or effectively listing the STEM domains. This may indicate these teachers have not worked with STEM in a way that has led them to consider the traits of STEM education, but it is also possible these teachers chose not to engage with this survey item.

Table 5

Science Teachers' Definitions of STEM. (n=12)

Aspects of STEM	Definitions of STEM
Integration	Linking traditional STEM topics to everything else.
Integration	I define STEM as the (somewhat) integrated teaching of Science, Technology, Engineering and Math.
Integration	Integration and recognition of the connection between science, technology, engineering and math.
Integration	The integration of different sciences to understand how they are related
Integration	STEM is a way of integrating our Science curriculum with Technology and Math, as well as other core curriculum.
Integration	STEM is a group of classes that ideally collaborate with each other to enrich a student's experience. It is also representative of the fact that people who work in one of these areas often must move between each one of the disciplines to be successful.
Integration	Teaching the students HOW to use math, science, and engineering in their thinking and problem solving.
Integration Authentic Context	Interdisciplinary approach to working real world problems using science engineering and math
Integration Active Learning Authentic Context	Mixing Science, Math, Engineering and Technology into appealing lessons that make the pursuit of STEM careers attractive. Lessons serve as problem-solving practice and function as a "sampler platter" of different STEM disciplines. All the while, students gain confidence in the use of tools and machines and the properties of different materials...basically a shop class, too!
Authentic Context	A group of subjects that need to be pressed hard with students so we have adults with the needed skills for our changing workforce.
Authentic Context	Preparing youth for a changing world by integrating academics and innovation.
NA	Science, technology, engineering, and math that are incorporated into the curriculum.

Table 6

Mathematics Teachers' Definitions of STEM. (n=10)

Aspects of STEM	Definitions of STEM
Integration	The necessary Science, Technology, Engineering, and Mathematics to train a student's brain with logical methodical thinking.
Integration Active Learning Authentic Context	The integration of technology and engineering into math and science curriculum. It is also allowing students to complete more real-world problems with hands on activities.
Integration Active Learning Authentic Context	STEM is a means to prepare my students for the world of technology we live in. It is more than just using a computer, it is finding ways to intentionally maximize technology in the classroom to increase the level of learning and interest for all students.
Integration Authentic Context	Students are engaged in real world scenarios that use science, technology, and math across subject areas.
Authentic Context	The use of mathematics in the technical world
Authentic Context	A way of teaching that allows students experiences so that they gain skills that will help them in a future career related to Science, Technology, Engineering, and/or Math.
Authentic Context	Using math in real world situations
NA	Science Technology Engineering Mathematics
NA	Science Technology Engineering and Math
NA	Science, technology, engineering, and math

In defining STEM, science teachers had a near uniform focus on 'integration' while the mathematics teachers had more variability in their responses with one focusing on integration, three focusing on active context and three expressing a combination of these and active learning. The individual definitions of STEM, in their own words, vary among respondents but contained many common elements associated with STEM. Knowing this helps constrain the meanings teachers are assigning to STEM when interpreting their responses in this study.

Primary Data for Decision Making

Just as they can have different definitions of STEM, teachers may have different sources of data that they primarily base their instructional decisions on. In a STEM school, the addition of STEM instruction to the normal teaching practices brings about a new instructional scenario that may inform or be affected by instructional decision practices. As was the case with the definitions of STEM, both the mathematics and science teachers brought up several, often discussed, components of data-use (see Table 7 and Table 8). The state standards were mentioned by both science and mathematics teachers as a source of information that influences their decisions. Related to this, two of the nine (22%) science teachers touched on the issue of student mastery. Three science teachers (three out of nine, 33%) and one mathematics teacher (one out of seven, 14%) mentioned data from collaboration. This included both collaboration with colleagues and external groups and social media. Finally, two of the seven (29%) mathematics teachers listed professional development and two listed up administrative influence.

Table 7

Science Teachers' Sources of Data (n=9)

Data Source	Summary of Data Sources
Standards	The state's standards
Standards Mastery	Student mastery and standards.
Standards	The state standards, and what resources and equipment I have available.
Standards	Previously used curriculum, state standards, student performance on assessments
Mastery	How well students can understand what I am trying to get them to understand about the relationship between science, math, and/or engineering.
Collaboration	Other teachers with more experience, groups/pages online.
Collaboration	Colleagues, online research, social media (following other teachers)
Collaboration	I find our collaboration with grade level and subject level teachers very helpful. We meet a couple times a week to discuss and plan.
NA	What I think will help students learn information that will help them be better people, consumers and producers of information, and global citizens.

Table 8

Mathematics Teachers' Sources of Data (n=7)

Data Source	Summary of Data Sources
Standards	State standards.
Standards	The standards in my subject come first. My background as an engineer. How school was different where I was raised.
Standards	I mainly focus my teaching around the state standards for mathematics. We, the math teachers, try to integrate other contents to support the standards where we see fit. With as many standards as necessary, it is challenging to fit in a lot of supplemental curriculum.
Standards General Assessments	Indiana standards drive my scope and sequence of what I will teach throughout a school year. Monitoring student learning through daily formative assessments drives the pace at which I will move through my scope and sequence. It also determines in what modality I will teach my students (lecture, small group, partners, remediation groups, or enrichment groups). Summative assessments given approximately every 3 weeks decide, which standards need to be reviewed and retaught within the next unit of study.
Standards Professional Development	Professional Development and State Assessment.
Collaboration Professional Development Administrative Influence	Scholarly articles, collaboration with colleagues, ideas from PD sessions or conferences, suggestions from administration.
Administrative Influence	What is dictated by administration.

The responses in this section show that the primary sources of information for their decisions varies among the teachers, but individual responses do align with common components of instructional data-use and decision-making. Notably the teachers did not reference using any source of data that would be explicitly tied to or unique to STEM. As was the case with the definitions of STEM, knowing the main sources do data helps constrain what teachers are considering sources of data when interpreting their responses in this study.

Perspectives on STEM and Data

Teacher Perspectives on Student Performance and Engagement

One aspect of teachers' perspectives on STEM education is in how teaching STEM lessons has the potential to influence both student performance and the level of student engagement. Table 9 and

Table 10

Views on STEM's Influence on Student Grades and Engagement According to Mathematics Teachers (n=7)

look at teachers' individual views of how STEM education influences these along with their perceptions of how their fellow teachers and administrators think about these issues.

Table 9

Views on STEM's Influence on Student Grades and Engagement According to Science Teachers (n=11)

	Measure of Relative Agreement				
View of STEM	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
I see evidence that the STEM focus of this school enhances students' grades.	-	-	5 (45)	3 (27)	3 (27)
Teachers I collaborate with consider the STEM focus of this school to enhance student grades.	1 (9)	1 (9)	2 (18)	3 (27)	4 (36)
School administrators consider the STEM focus of this school to enhance student grades.	1 (9)	-	1 (9)	6 (55)	3 (27)
I see evidence that the STEM focus of the school enhances engagement in learning.	-	1 (9)	2 (18)	1 (9)	7 (64)
Teachers I collaborate with consider the STEM focus of the school to enhance engagement in learning.	-	-	2 (18)	3 (27)	6 (55)

School administrators consider the STEM focus of this school to enhance engagement in learning.	-	-	1 (9)	6 (55)	4 (36)

Table 10

Views on STEM's Influence on Student Grades and Engagement According to Mathematics Teachers (n=7)

	Measure of Relative Agreement				
View of STEM	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
I see evidence that the STEM focus of this school enhances students' grades.	1 (14)	1 (14)	2 (29)	1 (14)	2 (29)
Teachers I collaborate with consider the STEM focus of this school to enhance student grades.	1 (14)	2 (29)	1 (14)	3 (43)	-
School administrators consider the STEM focus of this school to enhance student grades.	-	-	2 (29)	2 (29)	3 (43)
I see evidence that the STEM focus of the school enhances engagement in learning.	-	-	2 (29)	2 (29)	3 (43)
Teachers I collaborate with consider the STEM focus of the school to enhance engagement in learning.	-	1 (14)	1 (14)	5 (71)	-
School administrators consider the STEM focus of this school to enhance engagement in learning.	-	-	-	3 (43)	4 (57)

One point to note is there is a shift to higher levels of agreement among all teachers on the questions about enhancing engagement compared with enhancing performance. Overall, the teachers see STEM as enhancing student engagement and also perceive that other teachers and administrators see it as enhancing engagement. For examples of this shift, when comparing between the question on enhancing performance compared with the one on enhancing engagement, only about half of the science teachers (six out of 11, 55%) and mathematics teachers (three out of seven, 43%) overall agreed that STEM improves grades while, respectively, eight out of 11 (73%) and five out of seven (71%) agreed it improves engagement. The change in these items here is accompanied by a decrease in disagreeing and neutral responses. A similar change in responses is seen in teacher's perspectives of how the teachers they collaborate with think about STEM in terms of performance grades and engagement.

While there is an overall trend going between the questions on performance and on engagement, there are also points of distinction between science and mathematics teachers along with a persistent lack of uniformity in views on STEM in these STEM environments. In response to a survey question asking if they personally feel that STEM improves grade performance, the mathematics teachers selected options ranging from agree down to disagree, while the science teachers only selected agree options or neither. None of them chose to disagree with that statement. However, on a question asking whether they believe the teachers they collaborate with believe that STEM improves grades, both the mathematics and science teachers had a wide range in responses from disagree to agree. Based on these responses some teachers who felt that STEM was improving their students' grades had colleagues who they felt did not agree with this. Because this question was on teachers, overall, it implies some of these teachers would feel they are the only ones holding certain positive view on STEM.

Finally, both the mathematics and science teachers agreed with the claims that administrators feel that STEM enhances grades *and* engagement. This is notable as these responses about administrators' views do not have the same upward shift in agreement described previously. This seems to indicate that the views of STEM teaching to enhance performance and engagement at the teacher level (i.e. themselves and the teachers they collaborate with) differs from what they think is being assumed about STEM's effectiveness at the administrative level.

Teachers' Perspectives on the Necessity and Usefulness of STEM

A further part in understanding teachers' perceptions of STEM is to look at the necessity and usefulness they see in STEM teaching (see Table 11 and Table 12). This idea of necessity and usefulness seeks to understand how teachers view STEM situated in their teaching. For example, do teachers feel subject-specific teaching is a prerequisite to engage in STEM, or can STEM activities allow students to learn primary content?

Table 11

Perceptions of the Necessity and Usefulness of STEM Teaching According to Science Teachers (n=11)

	Relative Agreement				
Perception	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
It is necessary for students to learn content from my subject area before they can learn from STEM lessons.	7 (64)	2 (18)	1 (9)	1 (9)	-
Engagement in STEM lessons is necessary for students to learn content from my subject area.	1 (9)	2 (18)	1 (9)	4 (36)	3 (27)
I feel that the integration of content from outside of my subject area provides a meaningful way for students to learn content within the subject I teach.	-	-	-	4 (36)	7 (64)
I feel that the integration of content from outside of my subject area provides a meaningful way for students to learn content outside the subject I teach.	-	-	1 (9)	2 (18)	8 (73)

Table 12

Perceptions of the Necessity and Usefulness of STEM Teaching According to Mathematics Teachers (n=7)

	Relative Agreement				
Perception	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
It is necessary for students to learn content from my subject area before they can learn from STEM lessons.	3 (43)	-	1 (14)	1 (14)	2 (29)

(table continues)

Table 12 continued

Engagement in STEM lessons is necessary for students to learn content from my subject area.	2 (29)	2 (29)	1 (14)	2 (29)	-
I feel that the integration of content from outside of my subject area provides a meaningful way for students to learn content within the subject I teach.	-	-	1 (14)	2 (29)	4 (57)
I feel that the integration of content from outside of my subject area provides a meaningful way for students to learn content outside the subject I teach.	-	-	2 (29)	2 (29)	3 (43)

A majority of science teachers (nine out of 11, 82%) disagreed that it is necessary for a student to learn science content before they can learn from a STEM lesson. The mathematics teachers were more split on this with three out of seven (43%) disagreeing and the same number of teachers agreeing that a student must learn mathematics content before they can learn from a STEM lesson.

There was a range in responses, from both mathematics and science teachers, on whether engagement in STEM is necessary to learn content from their respective subject domains. Among the science teachers, 64% (seven out of 11) agreed with this statement while 18% (two out of 11) disagreed. Among the mathematics teachers, this pattern was reversed with 57% (four out of seven) disagreeing and 29% (two out of seven) agreeing. Interestingly, both the science and mathematics teachers overwhelmingly agreed that integration of content from outside of the content they teach can help students learn both the subject content they teach and learn about content outside of the subject they teach. This implies these teachers see utility in this type of STEM or multi-subject domain teaching for learning in their classroom.

Teachers' Perspectives on student growth measurement and data for decision-making.

Two aspects of data-use are using data to assess student growth (i.e. student academic progression) and using data to inform educational decisions. Table 13 and Table 14 look at teacher's individual views on whether data, from the STEM focus of their school and lessons, informs their assessment and decision-making process.

Table 13

Views on STEM Data in Assessing Student Growth and Informing Decisions According to Science Teachers (n=9)

	Measure of Relative Agreement				
View of Data	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Data, from the STEM focus of this school, is useful in assessing student growth.	1 (11)	-	1 (11)	4 (44)	3 (33)
Teachers I collaborate with consider data, from the STEM focus of this school, to be useful in assessing student growth.	1 (11)	1 (11)	1 (11)	4 (44)	2 (22)
School administrators consider data, from the STEM focus of this school to be useful in assessing student growth.	-	-	1 (11)	5 (56)	3 (33)
I use data from STEM lessons or activities to inform my educational decisions.	-	1 (11)	1 (11)	3 (33)	4 (44)
Teachers I collaborate with use data from STEM lesson or activities to inform their educational decisions.	-	-	1 (11)	6 (67)	2 (22)
School administrators use data from STEM lessons or activities to inform educational decisions.	1 (11)	1 (11)	2 (22)	3 (33)	2 (22)

Table 14

Views on STEM Data in Assessing Student Growth and Informing Decisions According to Mathematics Teachers (n=6)

	Measure of Relative Agreement				
View of Data	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Data, from the STEM focus of this school, is useful in assessing student growth.	-	1 (17)	2 (33)	3 (50)	-
Teachers I collaborate with consider data, from the STEM focus of this school, to be useful in assessing student growth.	-	-	4 (67)	2 (33)	-
School administrators consider data, from the STEM focus of this school to be useful in assessing student growth.	-	-	2 (33)	1 (17)	3 (50)
I use data from STEM lessons or activities to inform my educational decisions.	1 (17)	3 (50)	1 (17)	1 (17)	-
Teachers I collaborate with use data from STEM lesson or activities to inform their educational decisions.	-	2 (33)	3 (50)	1 (17)	-
School administrators use data from STEM lessons or activities to inform educational decisions.	-	-	4 (67)	1 (17)	1 (17)

A majority of science teachers (seven out of nine, 78%) agreed overall that data, from the STEM focus to the school, is useful in assessing student growth compared with three out of six (50%) mathematics teachers. This difference persisted when considering teachers' perspective on how the *teachers they work with* see the usefulness of STEM data. Here six out of nine (67%) of science teachers and two out of six (33%) of mathematics teachers agreed with that statement. Finally, eight out of nine (89%) of science teachers and four out of six (67%) of mathematics teachers overall agreed that administrators see this STEM data as useful in assessing student growth. As was seen previously, the teachers tend to agree that administrators are more supportive of certain views of STEM and data than even the teachers and their colleagues.

On the issue of using data from STEM lessons or activities to inform educational decisions, the science teachers tended to agree with this statement (seven out of nine, 78%) while the mathematics teachers tended to disagree (four out of six, 67%). Similarly, the science teachers tended to agree that the teachers they collaborate with are also using data from STEM to inform their decisions while mathematics teachers had a more mixed response. However, in a break with the trend seen regarding administrators, only five out of ten (50%) of science teachers and two out of six (33%) of mathematics teachers overall considered that administrators use STEM data to inform decisions.

Combined, these finding indicate there are science and mathematics teachers that consider STEM data useful in their assessment and decision making. While more of the science teachers are using this data compared with mathematics teachers, there is still a lack of uniformity in responses as seen in the number of science and mathematics teacher who indicate they are not considering this data. This may point to issues in the assessment aspects of the policies surrounding the STEM schools.

Techers' Perspectives on the Necessity and Usefulness of data from STEM

A further part in understanding teachers' perceptions of data-use from STEM is to look at the necessity and usefulness they see in the data they can obtain from STEM teaching (see Table 15 and Table 16). Here, the idea of necessity and usefulness is used to unpack how teachers feel they can use data from STEM to assess content in and outside of their primary subject domain.

Table 15

Perceptions of the Necessity and Meaningfulness of Data connected to STEM Teaching According to Science Teachers (n=9)

	Relative Agreement				
Perception	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Assessing student performance on content from my subject area is necessary to gauge my students' performance on my STEM lessons.	-	-	-	6 (67)	3 (33)
Assessing student performance on my STEM lessons is necessary to gauge my students' performance in my subject area.	-	-	1 (11)	3 (33)	5 (56)
When teaching STEM lessons I feel that the assessment of content from outside of my subject area provides a meaningful way to gauge student understanding in the subject I teach.	1 (11)	1 (11)	-	5 (56)	2 (22)
When teaching STEM lessons I feel that the assessment of content from outside of my subject area provides a meaningful way to gauge students understanding outside my subject area.	-	1 (11)	-	7 (78)	1 (11)

Table 16

Perceptions of the Necessity and Meaningfulness of Data connected to STEM Teaching According to Mathematics Teachers (n=6)

	Relative Agreement				
Perception	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Assessing student performance on content from my subject area is necessary to gauge my students' performance on my STEM lessons.	-	-	2 (33)	3 (50)	1 (17)
Assessing student performance on my STEM lessons is necessary to gauge my students' performance in my subject area.	-	1 (17)	3 (50)	1 (17)	1 (17)
When teaching STEM lessons I feel that the assessment of content from outside of my subject area provides a meaningful way to gauge student understanding in the subject I teach.	-	1 (17)	3 (50)	1 (17)	1 (17)
When teaching STEM lessons I feel that the assessment of content from outside of my subject area provides a meaningful way to gauge students understanding outside my subject area.	-	-	5 (83)	-	1 (17)

The majority of the science teachers expressed overall agreement with the two statements that assessing performance on subject area content is necessary to gauge performance in STEM (nine out of nine, 100%) and assessing performance on STEM is necessary to gauge performance in the subject area (eight out of nine, 89%). The high agreement in both of these statements may indicate the science teachers see a particular connection between their primary subject and STEM teaching that lets them view assessment in this way. The mathematics teachers did agree overall (four out of six, 67%) that assessing performance on subject area content is necessary to gauge performance in STEM, but that agreement dropped (two out of six, 34%,) for the reverse statement. Here more of the mathematics teachers see assessment of their subject taking precedent over assessment from STEM.

The science teachers also agreed overall (seven out of nine, 78%) that assessment on content outside of their subject area can be useful in gauging student understanding in their subject area. However, two of the science teachers did disagree with this. This pattern also held for the statement that assessment of content outside of their subject area, in the context of a STEM lesson, can be useful in gauging students understanding *outside* of their subject area. Overall, eight out of nine (89%) of the science teachers agreed with this. Mathematics teachers were mostly neutral in on both statements.

Summary of Research Question One

STEM and data-use can have a broad range of meanings, however individual science and mathematics teachers expressed definitions of these that were consistent with common traits discussed in the literature and also mirrored traits mentioned by teachers in the qualitative portion of the study. Regarding STEM, teachers mentioned traits of integration, active learning, and authentic context in teaching. Regarding the primary influences on decision making the teachers brought up issues of standards, student mastery, teacher collaboration, professional development, and administrative influence.

Breaking down the individual responses of the teachers on these definitions leads to three important observations for understanding the results of this study. First, the teachers are working within commonly accepted definitions of STEM which narrows how I can and should interpret what the teachers are thinking when responding to questions about STEM. Second, there are differences between the science and mathematics teachers' responses that necessitate separating them in discussion. In this case, the majority of science teachers based their definition of STEM primarily on integration of content across subject domains while the mathematics teachers' responses were more varied in terms of the individual traits focused on in their definitions. This leads into the third observation that there is a notable range or variance in the responses to some of the survey items. This variance shows up both as the different definitions and the number of concurrent conflicting responses in some questions. The notable differences between science and mathematics teachers combined with this frequent lack of uniformity in responses is a persistent result in this study and is relevant to the interpretation of the results tied to each research question.

Along with the specific characteristics of STEM the majority of both mathematics and science teachers indicated it is important to include the content, inquiry methods, and inquiry activities of each of the other STEM domains within STEM instruction. The survey did not identify what the teachers were envisioning as inquiry methods and activities from each of the subject domains but only revealed they assign some level of importance to their inclusion in STEM instruction. This expressed importance on other STEM domains will later contrast with the expressed practices of STEM or multi-subject domain teaching.

The breakdown of the responses revealed a number of views held by teachers. The teachers agreed overall that a STEM focus enhances student engagement and that the teachers and administers they work with agree on this. There was an increase in neutral and disagreeing responses on whether the STEM focus of the school improves student grade performance. Teachers tended to agree that the integration of content from outside of their domain can help with learning content inside and outside of the subject they teach. Science teachers tended to disagree that learning science is necessary for engaging in STEM while agreeing that engaging in STEM is necessary for learning science. Mathematics teacher responses were more mixed but tended to disagree that engagement in STEM is necessary to learn the mathematics content. Science teachers, overall, held that data from the science focus of the school is useful in both assessing student growth and informing educational decisions. Mathematics teachers were mixed on this first claim and overall disagreed on the second. Science teachers overall expressed higher agreement on the necessity of assessing student performance on STEM lessons and science content to gauge student performance on corresponding science and STEM lessons. Mathematics teachers did not see as much need in assessing student's performance on STEM lessons to gauge performance in mathematics. Finally, both the science and mathematics teachers expressed that administrators tend to see the use of STEM in improving student learning and the use of data from STEM to inform instruction.

What do Secondary Educators in STEM Focused Schools See as the Role of STEM Inquiry Activities in Informing Educational Decision-Making?

Inquiry learning and STEM education can intersect but they are same thing. An inquiry activity can be confined to a single domain, forgoing any STEM connection. To look at the role of STEM inquiry requires identifying how much of instruction is based on STEM and inquiry teaching and then how much of the decision making is rooted in either of these educational ideals. I specifically focus on inquiry in addressing this question because understanding how these teaches are parsing the ideas of inquiry and STEM will be useful in parsing the STEM practices that will be discussed under the third research question.

STEM and Inquiry

I was able to unpack teachers' views on the role of STEM inquiry through the responses indicating how often STEM, inquiry and associated data use are a part of teachers' practices. Table 17 shows the percentage of their teaching that science and mathematics teachers claimed to incorporate content from multiple subject domains. Significantly more science teachers claimed a higher percentage of their teaching incorporates content from multiple subject domains compared with the mathematics teachers, which may indicate a relatively higher focus on this kind of teaching.

Table 17

Percentage of Teaching Incorporating Content from Multiple Subject Domains

	Number of Teachers	
Percentage range	Science Teacher (n=11)	Mathematics Teacher (n=10)
	n (%)	*n* (%)
Between 0% and 25%)	0 (0)	6 (60)
Between 25% and 50%	5 (45)	1 (10)
Between 50% and 75%	2 (18)	3 (30)
At least 75%	4 (36)	-

Note: Teachers were given a slider to choose their percentage of teaching. For analysis and readability, I have binned the responses. This process also applies to the following three tables.

This contrasts with Table 18, which shows the percentage of their teaching that science and mathematics teachers claimed was inquiry based. These responses indicate that in their practices, inquiry and multi-domain teaching are not synonymous. There are teachers teaching inquiry for part of their instruction time that they are indicating does not include content from subjects outside of their primary content area.

Table 18

Percentage of Teaching that is Inquiry Based

	Number of Teachers	
Percentage range	Science Teacher (n=11)	Mathematics Teacher (n=10)
	n (%)	*n* (%)
Between 0% and 25%)	0 (0)	2 (20)
Between 25% and 50%	0 (0)	2 (20))
Between 50% and 75%	5 (45)	3 (30))
At least 75%	6 (55)	3 (30)

Proportionally, more mathematics and science teachers claimed to be teaching inquiry-based lessons compared with lessons covering multiple subject domains. For example, six out of 11 (55%) of the science teachers claimed *at least* 50% of their teaching incorporated content from multiple domains while all 11 respondents claimed at least 50% of their teaching was inquiry based. A similar shift is seen for the mathematics teachers. According to these responses, inquiry teaching has a larger role in instruction compared with multi-domain STEM teaching.

To examine the role of STEM inquiry in teacher's educational decision making, I further looked at what percentage of their instructional decisions they consider to come from lessons that focused on multiple subject domains (see Table 19). Consistent with Table 17, which showed a higher percentage of science teachers teaching lessons incorporating content from multiple domains, this table show science teachers are making some educational decisions based on this STEM type teaching.

Table 19

Percentage of Educational Decisions Coming from Lessons Focused on Multiple Subject Areas

	Number of Teachers Making Decisions	
Percentage range	Science Teacher (n=9)	Mathematics Teacher (n=7)
	n (%)	n (%)
Between 0% and 25%)	1 (11)	5 (71)
Between 25% and 50%	6(67)	1 (14)
Between 50% and 75%	1 (11)	0 (0)
At least 75%	1 (11)	1 (14)

These findings contrast with Table 20, which shows the percentage of their decisions teachers claimed are derived from inquiry activities. As was seen in the comparison of Table 17 and Table 18, here there is an increase in the percentage of decision coming from inquiry activities compared with teaching based on multiple subject domains. For the science teachers, the difference between these tables again shows that multi-domain teaching is distinct from inquiry and also that more educational decisions are based on inquiry over STEM.

Table 20

Percentage of Educational Decisions that are Derived from Inquiry Activities

	Number of Teachers Making Decisions	
Percentage range	Science Teacher (n=9)	Mathematics Teacher (n=4)
	n (%)	n (%)
Between 0% and 25%)	0 (0)	0 (0)
Between 25% and 50%	1 (11)	2 (50)
Between 50% and 75%	4 (44)	1 (25)
At least 75%	4 (44)	1 (25)

Note: Only 4 mathematics teachers responded to this question, so these responses may not properly reflect the group of math teachers.

Summary of Research Question Two

STEM and inquiry teaching is not synonymous for the teachers. A higher percentage of teaching is inquiry based and, for the science teachers a higher percentage of decisions come out of inquiry activities compared with STEM. Tentatively, this also appears to apply to mathematics teachers despite the low number of responses. Overall, inquiry is playing a role in the decision-making process but the exact role of at the intersection of STEM and inquiry is not well defined.

How do Secondary Educators, in STEM Focused Schools, Describe Their Practices of Implementing STEM Education?

To examine teachers' STEM practices, I first present how frequently they claimed to use multi-subject teaching and apply data from such teaching. Second, I look at the frequency with which teachers use various teaching methods and take in data, from these methods, for decision making. This serves to give a snapshot of the teaching practices happening in the classroom and the data coming directly out of these. Finally, along with these classroom practices, I also look at teachers' claims of having discussions, both formal and informal, with other educators in their school on topics of STEM and data-use. This will help reveal the level of school discourse on STEM and data that may be influencing the teacher's practices.

Multi-subject vs. Single Teaching and Data-use Focus

As part of getting at teachers' STEM practices I looked at how frequently teachers focus on single domain and multi-domain lesson teaching (see Table 21 and Table 22). Consistent with the framework of this study, the first three rows of this table align with levels of implementation of STEM where a teacher may (a) focus on only teaching their main subject domain, (b) may have a dominate domain that is supplemented by content from another, or (c) combine domains at equivalent levels of importance. The fourth and fifth rows of responses look at the dominate domain and combined domain setup in instances where a teacher may be combining both a STEM domain and a non-STEM domain.

Table 21

Frequency of Teaching Individual and Multiple Subjects According to Science Teachers (n=11)

Teaching Focus	Frequency of Teaching Focus						
	Daily	Multiple -Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Teaching, ultimately, focuses on a single subject area.	2 (18)	3 (27)	-	5 (46)	1 (9)	-	-
Teaching heavily focuses on one STEM subject while using topics from another STEM subject.	1 (9)	7 (63)	-	2 (18)	1 (9)	-	-
Teaching evenly combines two or more STEM subjects.	-	4 (36)	3 (27)	2 (18)	-	-	2 (18)
Teaching heavily focuses on one STEM subject while using topics form another non-STEM subject.	-	3 (27)	2 (18)	3 (27)	1 (9)	2 (18)	-
Teaching evenly combines a STEM and non-STEM subject.	-	1 (8)	2 (15)	3 (23)	3 (23)	3 (23)	1 (8)

Note: Thirteen science teachers responded to the last question in this item. This is why the percentages differ from the other rows.

Table 22

Frequency of Teaching Individual and Multiple Subjects According to Mathematics Teachers (n=7)

	Frequency of Teaching Focus						
Teaching Focus	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Teaching, ultimately, focuses on a single subject area.	4 (50)	3 (38)	-	-	-	-	1 (13)
Teaching heavily focuses on one STEM subject while using topics from another STEM subject.	-	2 (29)	1 (14)	-	1 (14)	2 (29)	1 (14)
Teaching evenly combines two or more STEM subjects.	-	-	-	3 (43)	-	1 (14)	3 (43)
Teaching heavily focuses on one STEM subject while using topics form another non-STEM subject.	-	-	-	2 (29)	-	4 (57)	1 (14)
Teaching evenly combines a STEM and non-STEM subject.	-	-	1 (13)	1 (13)	1 (13)	1 (13)	4 (50)

Note: Eight mathematics teachers responded to the first and last question in this item. This is why the percentages differ from the other rows.

Science teachers indicated they include content from multiple domains more frequently than the mathematics teachers. Under the dominate domain implementation of STEM, where the teaching heavily focuses on the primary subject content, eight out of 11 (72%) of the science teachers indicated teaching this way at least multiple times weekly compared with two out of the seven (29%) mathematics teachers. Similarly, under the combined domain implementation, seven out of the 11 (64%) of the science teachers indicated teaching this way at least once a week. No mathematics teachers indicated teaching this way that frequently. The science teachers also indicated they include content from non-STEM domains far more frequently than mathematics teachers.

An important point to note about these responses is how spread out some of them are across all the available lesson frequencies. As an example, from the mathematics teachers three out of seven (43%) claimed to include content from another STEM domain at least once a week while four out of seven (57%) claimed to include that content, at most, once a month. Again, I should not that throughout these responses, while there are overall differences that can be seen between the science and mathematics teachers there is considerable variance in how teachers, in each subject, are responding.

I further looked at teachers practices on STEM in terms of how frequently teachers claimed to make decisions from single domain and multi-domain lesson teaching (see Table 23 and Table 24).

Table 23

Frequency of Decision-Making based on Primary and Multiple Subjects According to Science Teachers (n = 9)

	Frequency of Data Focus				
Data Focus	Never	Sometimes	About Half the Time	Most of the Time	Always
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
I focus on data from my primary subject area.	-	-	1 (11)	7 (78)	1 (11)
I heavily focus on data from my primary subject area but consider some data from another STEM subject.	-	4 (44)	1 (11)	3 (33)	1 (11)
I evenly consider data from two or more STEM subjects.	2 (22)	6 (67)	-	1 (11)	-
I consider data from across STEM and non-STEM subjects.	2 (22)	4 (44)	1 (11)	2 (22)	-

Table 24

Frequency of Decision-Making based on Primary and Multiple Subjects According to Mathematics Teachers (n = 6)

	Frequency of Data Focus				
Data Focus	Never	Sometimes	About Half the Time	Most of the Time	Always
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
I focus on data from my primary subject area.	-	1 (17)	1 (17)	1 (17)	3 (50)
I heavily focus on data from my primary subject area but consider some data from another STEM subject.	1 (17)	3 (50)	2 (33)	-	-
I evenly consider data from two or more STEM subjects.	2 (33)	3 (50)	-	1 (17)	-
I consider data from across STEM and non-STEM subjects.	1 (17)	4 (67)	-	1 (17)	-

These responses indicate that teachers, both in science and mathematics, claimed to use data from other STEM domains, or even from non-STEM domains, in their decision making. The claim that they use other STEM and non-STEM data further implies this content is a part of their teaching, which is overall consistent with the responses in Table 21 and Table 22. This does raise questions about the data-use situation for the few teachers do claim to never use content outside of their subject domain.

Teaching Methods and Data Used in Single and Multiple Subject Teaching

A further aspect of understanding teachers' practices in teaching STEM is to look at how frequently they claim to use certain teaching methods when focusing on teaching lessons from their primary subject domain (see Table 25 and Table 26) and when teaching lessons that cover content from multiple subject domains (see Table 27 and Table 28).

Table 25

Frequency of Use of Teaching Methods to Teach Primary Subject Domain Content According to Science Teachers

	Frequency of Use						
Teaching Method	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning	5 (46)	4 (36)	1 (9)	1 (9)	-	-	-
Lab Activities	1 (9)	8 (73)	1 (9)	1 (9)	-	-	-
Research Projects	-	1 (9)	2 (18)	3 (27)	1 (9)	3 (27)	1 (9)
Student Presentations	-	1 (9)	1 (9)	3 (27)	2 (18)	4 (36)	-
Class Discussions	5 (46)	1 (9)	4 (36)	1 (9)	-	-	-
Group Discussions	4 (36)	5 (46)	-	2 (18)	-	-	-
Lectures	-	3 (27)	4 (36)	2 (18)	-	-	2 (18)

Table 26

Frequency of Use of Teaching Methods to Teach Primary Subject Domain Content According to Mathematics Teachers (n=8)

	Frequency of Use						
Teaching Method	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning	1 (13)	3 (38)	-	2 (25)	-	1 (13)	1 (13)
Lab Activities	-	1 (13)	-	-	1 (13)	2 (25)	4 (50)

(table continues)

Table 26 continued

Research Projects	-	-	-	1 (13)	-	2 (25)	5 (63)
Student Presentations	-	1 (13)	-	-	-	5 (63)	2 (25)
Class Discussions	3 (38)	2 (25)	1 (13)	-	1 (13)	1 (13)	-
Group Discussions	2 (25)	3 (38)	1 (13)	1 (13)	1 (13)	-	-
Lectures	3 (38)	3 (38)	1 (13)	1 (13)	-	-	-

Table 27

Frequency of Use of Teaching Methods to Teach Content from Multiple Subject Domains According to Science Teachers (n=11)

	Frequency of Use						
Teaching Method	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning-	5 (45)	5 (45)	-	1 (9)	-	-	-
Lab Activities	2 (18)	7 (64)	1 (9)	-	1 (9)	-	-
Research Projects	1 (9)	1 (9)	2 (18)	1 (9)	2 (18)	2 (18)	2 (18)
Student Presentations	-	2 (18)	1 (9)	1 (9)	2 (18)	3 (27)	2 (18)
Class Discussions	3 (27)	2 (18)	4 (36)	-	2 (18)	-	-
Group Discussions	4 (36)	4 (36)	-	-	3 (27)	-	-
Lectures	-	-	5 (45)	2 (18)	2 (18)	-	2 (18)

Table 28

Frequency of Use of Teaching Methods to Teach Content from Multiple Subject Domains According to Mathematics Teachers (n=7)

	Frequency of Use						
Teaching Method	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning	-	-	-	1 (14)	-	5 (71)	1 (14)
Lab Activities	-	-	-	-	-	1 (14)	6 (86)
Research Projects	-	-	-	-	-	3 (43)	4 (57)
Student Presentations	-	-	-	1 (14)	-	3 (43)	3 (43)
Class Discussions	-	1 (14)	-	1 (14)	1 (14)	2 (29)	2 (29)
Group Discussions	-	1 (14)	-	1 (14)	1 (14)	2 (29)	2 (29)
Lectures	-	2 (29)	-	1 (14)	-	3 (43)	1 (14)

In teaching just their primary subject domain, science teachers indicated a high frequency of use of active learning (e.g. problem-based learning) and laboratory activities. With a frequency of at least once a week 10 out of 11 (91%) science teachers indicated using active learning methods and also 10 out of 11 (91%), this time distributed differently among the frequency options (i.e., daily, multiple times weekly, and once a week), indicated using lab activities. For the mathematics teachers, four out of eight (50%) indicated using active learning methods at least once a week with one out of eight (13%) indicated using lab activities. Just as with comparing inquiry and multi-subject domain teaching, here, as indicated by the science teacher's responses, active learning and lab activities are not synonymous among the teachers. This shows that there is science project or problem-based work the teachers are using that these teachers do not consider to be lab work. This last point is relevant for comparing science and mathematics teachers since, while it is unsurprising that science teachers use more lab activities, here they are also using more active learning, than mathematics teaches, in general.

When looking at the methods used when teaching lessons that cover multiple domains the science teachers indicate an overall higher frequency of applying each of these teaching methods. Among the teaching methods mathematics teachers claimed to use more frequently when teaching their primary subject domain, there is a notable decrease in the use of each of these methods for lessons covering multiple domains. This, on its own, is not unexpected as one might expect there to be fewer lessons combining content from multiple domains compared with lessons focused on the primary domain. However, this drop-in frequency of teaching methods is not nearly as pronounced for science teachers and in some instances there is no appreciable change. Science teachers reported, overall, teaching content from multiple subject domains more frequently than the mathematics teachers.

A further aspect of understanding teachers' data-use practices in the STEM school environment is to look at how frequently they claim to use data from certain teaching methods when focusing on teaching lessons from their primary subject domain (see Table 29 and Table 30) and when teaching lessons that cover content from multiple subject domains (see Table 31 and Table 32). As a whole these teachers are using data from both within and outside their subject domains at many different frequencies of use. Overall, it appears data outside of teachers' primary subject domains are making it into these teachers' decision-making process, though this is more frequently observed among the science teachers.

Table 29

Frequency of Use of Data Sources from Teaching in the Primary Subject Domain According to Science Teachers (n=9)

	Frequency of Use						
Data Source	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning	2 (22)	5 (56)	-	1 (11)	1 (11)	-	-

(table continues)

Table 29 continued

Lab Activities	2 (22)	6 (67)	-	1 (11)	-	-	-
Research Projects	-	1 (11)	1 (11)	1 (11)	2 (22)	3 (33)	-
Student Presentations	-	2 (22)	-	3 (33)	-	3 (33)	1 (11)
In-class Tests	-	-	-	3 (33)	4 (44)	2 (22)	-
Quizzes	-	1 (11)	2 (22)	4 (44)	2 (22)	-	-
Standardized and State Assessments	-	1 (11)	-	-	-	3 (33)	5 (56)
Homeworks	-	-	3 (38)	3 (38)	1 (13)	-	1 (13)
Exit slips	-	-	2 (22)	3 (33)	-	4 (44)	-
Class Participation	7 (78)	-	-	1 (11)	-	-	1 (11)

Table 30

Frequency of Use of Data Sources from Teaching in the Primary Subject Domain According to Mathematics Teachers (n=6)

	Frequency of Use						
Data Source	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning	1 (17)	2 (33)	-	1 (17)	-	2 (33)	-
Lab Activities	1 (17)	-	-	-	-	2 (33)	3 (50)
Research Projects	-	-	-	1 (17)	-	2 (33)	3 (50)

(table continues)

Table 30 continued

Student Presentations	1 (17)	-	-	1 (17)	-	3 (50)	1 (17)
In-class Tests	-	1 (17)	1 (17)	3 (50)	1 (17)	-	-
Quizzes	-	3 (50)	1 (17)	2 (33)	-	-	-
Standardized and State Assessments	-	1 (17)	1 (17)	2 (33)	1 (17)	1 (17)	-
Homeworks	-	3 (50)	-	-	-	1 (17)	2 (33)
Exit slips	1 (17)	4 (67)	-	1 (17)	-	-	-
Class Participation	5 (83)	-	-	1 (17)	-	-	-

Table 31

Frequency of Use of Data Sources from Teaching in Content Outside the Primary Subject Domain According to Science Teachers (n=9)

	Frequency of Use						
Data Source	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning	1 (11)	5 (56)	-	-	2 (22)	1 (11)	-
Lab Activities	2 (22)	2 (22)	1 (11)	2 (22)	1 (11)	1 (11)	-
Research Projects	-	1 (11)	1 (11)	1 (11)	2 (22)	3 (33)	1 (11)
Student Presentations	-	1 (11)	-	4 (44)	-	3 (33)	1 (11)

(table continues)

Table 31 continued

In-class Tests	-	1 (11)	-	2 (22)	3 (33)	3 (33)	-
Quizzes	1 (11)	-	1 (11)	5 (56)	1 (11)	1 (11)	-
Standardized and State Assessments	-	-	1 (11)	-	-	3 (33)	5 (56)
Homeworks	-	-	4 (44)	1 (11)	1 (11)	1 (11)	2 (22)
Exit slips	-	-	-	4 (44)	-	5 (56)	-
Class Participation	6 (67)	1 (11)	-	-	-	1 (11)	1 (11)

Table 32

Frequency of Use of Data Sources from Teaching in Content Outside the Primary Subject Domain According to Mathematics Teachers (n=6)

	Frequency of Use						
Data Source	Daily	Multiple-Times Weekly	Once a Week	Few Times a Month	Once a Month	Few Times a Semester	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Active Learning	-	-	-	1 (17)	-	5 (83)	-
Lab Activities	-	-	-	-	-	1 (17)	5 (83)
Research Projects	-	-	-	-	-	2 (33)	4 (67)
Student Presentations	-	-	-	-	-	2 (33)	4 (67)
In-class Tests	-	-	1 (17)	1 (17)	-	3 (50)	1 (17)
Quizzes	-	-	1 (20)	1 (20)	-	3 (60)	-

(table continues)

Table 32 continued

Standardized and State Assessments	-	-	-	1 (17)	1 (17)	4 (67)	-
Homeworks	-	1 (17)	-	-	-	2 (33)	3 (50)
Exit slips	-	1 (17)	-	1 (17)	-	3 (50)	1 (17)
Class Participation	1 (17)	1 (17)	-	-	-	4 (67)	-

While the earlier findings indicated teachers are using data from outside of their content domains, these finding indicate that the actual sources of data used are varied. As with the teaching methods, this is again an indicator that the STEM certification process and framework has not standardized data-use in multi-subject teaching.

Another point to note is that the majority of both science (seven out of nine, 78%) and mathematics (five out of six, 83%) teachers claim to frequently use class participation as a source of data when teaching their primary content, but only science teachers (six out of nine, 67%) continue to frequently use this source of data when teaching content that comes from multiple subject domains.

Discussions on STEM Among Teachers and Data

A further part of understanding teachers' practices of STEM is to identify who they discuss STEM issues with and how they approach those discussions (i.e., formal versus informal interactions) (see Table 33 and Table 34). In these tables a teacher may have engaged in both informal discussions and planned meetings so the percentages across all three columns does not add to 100%.

Table 33

Discussions that Focus on STEM s According to Science Teachers (n=11)

Collaboration Type	Interaction Type: Informal Discussions	Interaction Type: Planned Meetings	No Interaction
	n (%)	*n* (%)	*n* (%)
Individual teachers in my subject area.	9 (82)	10 (91)	-
Individual teaches in my grade level(s).	8 (73)	7 (64)	-
Individual teachers outside of my subject area.	7 (64)	3 (27)	1 (9)
Individual teachers across grade levels in my school.	9 (82)	3 (27)	-
Grade level teams of teachers.	6 (55)	5 (46)	2 (18)
Subject focused teams of teachers.	6 (55)	7 (64)	2 (18)
Data Coaches	2 (18)	3 (27)	6 (55)
Building level administrators.	7 (64)	9 (82)	1 (9)
Central Office administrators.	3 (27)	3 (27)	8 (73)

Table 34

Discussions that Focus on STEM s According to Mathematics Teachers (n =7)

Collaboration Type	Interaction Type: Informal Discussions	Interaction Type: Planned Meetings	No Interaction
	n (%)	*n* (%)	*n* (%)
Individual teachers in my subject area.	5 (71)	6 (86)	1 (14)
Individual teaches in my grade level(s).	6 (86)	5 (71)	1 (14)
Individual teachers outside of my subject area.	5 (71)’	2 (28)	2 (28)
Individual teachers across grade levels in my school.	6 (86)	2 (28)	1 (14)
Grade level teams of teachers.	2 (28)	4 (57)	2 (28)
Subject focused teams of teachers.	1 (14)	5 (71)	2 (28)
Data Coaches	2 (28)	3 (43)	4 (57)
Building level administrators.	3 (43)	4 (57)	2 (28)
Central Office administrators.	-	1 (14)	6 (86)’

One point to note is the excess number of science teachers who claimed to have informal discussions in grade level teams and subject focused teams, compared with mathematics teachers. There is also a higher percentage of science teachers who claimed to have informal and planned interactions with building level administrators. Finally, a subset of science teachers (three out of 11, 27%) claimed to have these interactions with central office administrators, though most did not. These numbers would indicate there are some difference in how science teachers interact informally with teacher teams and administrators when compared with the mathematics teachers.

However, where the mathematics and science teachers are similar is in the number of teachers who interact with individual teachers within and across their subject and grade levels. In other words, individual teacher interactions do not seem to be different based on subject taught.

An important part of the responses here is that the majority of teachers are claiming to be having discussions on STEM topics. Further, in some cases, informal discussion is happening as often, or more often, than planned meetings. Consider that for science teachers seven out of 11 (64%) claimed to have informal discussions with teachers outside of their subject area compared with three out of 11 (27%) having planned meetings with those teachers. Similarly, for the mathematics teachers five out of seven (71%) held those informal discussion compared with two out of seven (28%) having planned meetings. Since these are, at least by certification, STEM focused schools we would expect to see discussions on STEM, which appear to be occurring.

Mirroring the focus on STEM, part of understanding teachers' practices of data-use is to identify whom they discuss data issues with and how they approach those discussions (i.e., formal versus informal interactions) (see Table 35 and Table 36). The importance of these tables is in how they compare with Table 33 and Table 34 which looked at whom teachers were collaborated with on discussing STEM. There are several notable decreases in the informal discussion had by both science and mathematics teachers in going from the topic of STEM to data use. For example, while nine out of 11 (82%) of the science teachers claimed to have informal discussions on STEM with teachers in their subject area only three out of 11 (27%) claimed to have these informal discussions on data. Planned meeting do not show this same decrease. This points to differences in how the discussions on STEM and data are happening, at the informal level, in these schools.

Table 35

Collaboration Situations that Focus on Data-Use According to Science Teachers (n=11)

Collaboration Type	Interaction Type: Informal Discussions	Interaction Type: Planned Meetings	No Interaction
	n (%)	*n* (%)	*n* (%)
Individual teachers in my subject area.	3 (27)	9 (82)	-
Individual teaches in my grade level(s).	6 (55)	5 (45)	1 (9)
Individual teachers outside of my subject area.	6 (55)	4 (36)	1 (9)
Individual teachers across grade levels in my school.	6 (55)	2 (18)	1 (9)
Grade level teams of teachers.	4 (36)	6 (55)	2 (18)
Subject focused teams of teachers.	4 (36)	7 (64)	1 (9)
Data Coaches	1 (9)	3 (27)	5 (45)
Building level administrators.	3 (27)	5 (45)	3 (27)
Central Office administrators.	2 (18)	-	7 (64)

Table 36

Collaboration Situations that Focus on Data-Use According to Mathematics Teachers (n =7)

Collaboration Type	Interaction Type: Informal Discussions	Interaction Type: Planned Meetings	No Interaction
	n (%)	*n* (%)	*n* (%)
Individual teachers in my subject area.	3 (43)	6 (86)	-
Individual teaches in my grade level(s).	4 (57)	5 (71)	-
Individual teachers outside of my subject area.	1 (14)	2 (29)	4 (57)
Individual teachers across grade levels in my school.	1 (14)	3 (43)	2 (29)
Grade level teams of teachers.	1 (14)	4 (57)	2 (29)
Subject focused teams of teachers.	2 (29)	5 (71)	1 (14)
Data Coaches	1 (14)	1 (14)	4 (57)
Building level administrators.	1 (14)	5 (71)	-
Central Office administrators.	-	1 (14)	5 (71)

Summary of Research Question Three

Overall, the science teachers expressed higher agreement on items favoring STEM and use of data from STEM lessons compared with mathematics teachers. This may indicate that the mathematics and science teachers are interacting with this STEM content and data in different ways, possibly due to external concerns such as issues of standards and accountability testing. It is the mathematics teachers who tend to have to prepare students for standardized testing, which shifts the focus of their classroom.

The majority of the science teachers claimed to teach in ways that use content from multiple domains as well as use data that comes from this kind of teaching. Fewer of the mathematics teaches made the same claim. This indicates that STEM data are making its way into some teachers' decision-making practices but not in a standardized way that might be expected if there were specific STEM teaching policies imposed in these STEM schools.

Differences seen in the science and mathematics teachers' practices also raise questions on the collaborative aspects of decision making. In the findings on teacher discussions, mathematics teachers indicated they do have planned and informal meetings to discuss topics of STEM. However, the overall stated practices may indicate that these discussions are not ultimately influencing the teaching or assessment practices to focus more on STEM.

Transition to Discussion

Through the survey teachers indicated their practices and perspectives on aspects of data-use and STEM education. There was a notable difference in mathematics and science teachers' responses while also a lack of uniformity in some responses both of which highlight the complex nature of this data in STEM environment. I will explore these findings in detail, in terms of this studies' research question, in the following chapter.

CHAPTER 7: DISCUSSION OF QUANITATIVE RESULTS

The quantitative survey responses reveal several aspects of STEM certified school teachers' perspectives and practices of STEM education and data-use. While some options in a few survey items were favored by a majority of teachers, there was a notable and persistent variance in response choices for all items. This may indicate that the STEM certification process for the schools and the adherence to the state's STEM framework could vary from school to school. Below, I will unpack ideas surrounding the findings shared in Chapter 6 and discuss these quantitative results to address the research questions for this study.

What are Secondary Educators' in STEM Focused Schools Perspectives Surrounding Teaching and Data-Use in STEM Education?

Integration in STEM brings the different subject domains together often for the purpose of solving real-world problems (Sanders, 2008). It further fosters the active learning and authentic context of lesson as it can "give students more meaningful learning experiences by connecting disciplinary knowledge with personal and real-world experiences" (Wang, Moore, Roehrig & Park, 2011, p.3). In their own words, the mathematics and science teachers in my study expressed different definitions of STEM in the survey that align with these traits of integration, active learning and authentic context. Individual teachers did not include all of these traits in their definitions, but each of the traits that they raised is a part of the broader academic discussion on STEM.

The majority of teachers expressed that, in their personal view, there was some importance in the inclusion of content, inquiry activities and methods of inquiry from each of the STEM subject domains. However, the actual inclusion of this content, in terms of reported frequency of lessons covering content from multiple domains, was less prominent than this reported importance might suggest. The pattern of these responses may indicate that, while teachers see importance in integrating content, they may lack the knowledge or experience to teach it and in turn relegate it to a smaller component of their teaching (Frykholm & Glasson, 2005). Another, possible interpretation is that while the teachers see this integration of content as being important in STEM, they are interpreting STEM on a boarder level (e.g., at the level of the STEM school) and thus do not consider that content as a part of their individual course teaching.

Overall, the teachers in the survey agreed that the STEM focus of their schools served to enhance student engagement in learning. The teachers further felt that their colleagues and administrators agreed with this assessment. Kennedy and Odell (2014) discussed how STEM can help to engage student learning but did note that “STEM education must go beyond improving the individual STEM disciplines and look at STEM more holistically” (p.253). In other words, just calling an environment STEM will not affect engagement. Based on this, it seems that how STEM education is implemented in these STEM schools leads these teachers to report seeing it as engaging students.

However, to contrast with this, teachers’ responses were mixed on the claim that the STEM focus of the school enhances students’ grade performance. The finding is partly consistent with the research of Wiswall, Stiefel, Schwartz and Boccardo (2014) In their study of the effects of STEM schools in improving performance in mathematics and science, they found that, while a STEM school’s raw performance scores may be higher than peer non-STEM schools, this increased performance disappears when adjusting for individual student characteristics. They observed this may be caused by a “substantial sorting in school choice based on previous academic performance” (p.98). Wiswall and colleagues’ study points to situations where a STEM school has high performing students, but that performance is not due to the STEM focus of the school but instead to the students who choose to go to the school. Based on this it would be reasonable to assume that the teachers in those schools are not seeing a large increase in student performance but instead simply seeing higher performing students overall. This idea aligns with the teachers’ responses in this study. Gaining the STEM certification does not, in the short term, change the characteristics of the school population. It may be the case that teachers are seeing the same students in what is, overall, the same education environment, and thus are not perceiving any increase in student performance but are seeing other positive impacts such as improvements in student engagement.

Aspects of STEM, such as active learning (Freeman et al., 2014) and integration (Hurley, 2001), have been linked to student achievement. Thus, the teachers’ claims may indicate either that the STEM offered by these teachers is not including these aspects in a way that improve performance or that the STEM school environment changes how these teachers perceive the improvement of grades. To illustrate that last point a school could switch to being STEM school causing an initial increase in student performance. However, once the STEM school has been established for a while, student grade performance would come to some new norm and it would no longer appear as if the STEM focus was influencing overall grading.

This point may be backed up, at least for the science teachers, who overall agreed that data from the STEM focus of the school is useful for assessing student growth. This could be interpreted as the science teachers recognizing how students improve within these STEM school environments, but the students are only improving to some level now dictated by the culture of the STEM school. The mathematics teachers' mixed response on this issue could indicate the growth they are looking at is not compared with the internal level of the STEM school but to external factors, such as performance on standards. If this internal versus external comparison of grades is valid it makes sense that the majority of science teachers overall agreed they use data from STEM to inform their decisions while the mathematics teachers overall disagreed.

One observation that comes out of the survey data is that most of the teachers felt that administrators see STEM as improving student grade performance. In fact, more teachers indicated this about administrators than they indicated it about themselves. In studying the differences in how teachers and administrators use data, Coburn and Talbert (2006) observed that administrators tend to use more psychometrically verified or standardized data compared with teachers who relied more on in-class data. If I take the teachers' claims about STEM enhancing grades as being grounded in the teachers' views of assessment, then their views appear to run counter to Coburn and Talbert's research. Here the administrators would be placing a focus on non-standardized testing component of student education specific to the STEM context of the school. It may be the case that this should be interpreted as administrators seeing student performance on standardized testing improving due to STEM however in other questions (e.g., *School administrators use data from STEM lessons or activities to inform educational decisions* where five out of nine science teachers overall agreed) the wording would seem to connect this decision making to classroom, not standardized, data and assessments. If this interpretation is valid it points to some potential differences that the STEM data focus of the school may bring about at the administrative level as administrators respond to heightened focus the school has on STEM. If this interpretation is not valid and I take the teachers' claims about STEM enhancing grades as being a part of their general perceptions of the STEM school environment, then this raises questions about the interactions between teachers and administrators that are leaving teachers to conclude that administrators have these views of STEM. To get a fuller picture of the teacher and administrator interactions in STEM schools, further qualitative research is needed to identify the reasons teachers might hold these views of administrators and to look at the actual views held by the administrators.

Another component of teaching and STEM education is in how teachers compare their subject and STEM teaching. Frykholm and Glasson's (2005) study of preservice mathematics and science teachers revealed that, in an integrated mathematics and science lesson, the mathematics was sometimes only considered as a tool by teachers for use in the activities. The issue with a tool is that you have to learn how to use the tool before you can use it in a situation. Related to this, science teachers in this study tended to disagree that students needed to learn science content before engaging in STEM lessons. Mathematics teachers were mixed in agreement and disagreement on the parallel statement that students need to learn mathematics before engaging in STEM. This pattern held for the reverse of this statement with science teachers agreeing that engagement in STEM is necessary to learn science content, while mathematics teachers were again mixed on this. This finding might happen because mathematics content is often sequential so it makes sense that some mathematics teachers would feel learning the content is necessary before being able to use it in STEM. The interesting finding then is the equal number of mathematics teachers that feel that is not the case. To repeat a point made previously, it is possible those mathematics teachers are not interpreting STEM lessons as a lesson they implement as part of their class but instead as a general STEM lesson, which may have a need for the mathematics they teach. These responses seem to indicate that the science teachers see more overlap or interchangeability between what they are considering their science instruction and what they are considering their STEM instruction.

Finally, it seems that the STEM focus of these schools has not led to changes in what teachers consider to be their primary sources of data, when compared with teachers in traditional, non-STEM schools. The individual mathematics and science teachers also brought up a number of sources of data that they consider to primarily influence their decisions related to teaching and instruction. Similar to how the teachers definitions of STEM aligned with traits of STEM, the teachers' responses included a number of topics known to influence teacher decision making: standards and student mastery of content (Jacobs et al., 2009; Ingram, Louis, & Schroeder, 2004), collaboration with other teachers and groups (Marsh, Bertrand, & Huguet, 2015), and professional development and administrative influence (Young, 2006). Notably none of these primary sources of data directly tie to STEM or some component that might be unique to the STEM school. With the rising number of STEM schools (NRC, 2011) and the different organizational structures they take on (Peters-Burton, Lynch & Behrend, 2014), more in-depth qualitative research is needed to determine if these existing data practices are sufficient and applicable for STEM schools or if there are practices that better align with specific STEM school goals.

What do Secondary Educators in STEM Focused Schools See as the Role of STEM Inquiry Activities in Informing Educational Decision-Making?

Both mathematics and science teachers in this study indicated it is important to have inquiry activities and methods of inquiry from outside of their subject domain as part of their STEM instruction. The teachers' responses did not reveal what they were envisioning this inquiry to consist of but do show the teachers are not outright rejecting inquiry from the individual subject domains in their ideas of STEM. On the other hand, their responses on their practices revealed a different picture. Overall, teachers indicated a greater percentage of their teaching was inquiry based compared with the percentage of their teaching that was based on content from multiple subject domains. Similarly, teachers indicated a greater percentage of their decisions were based on assessment of inquiry lessons compared with assessments from multiple subject domain teaching. There may be specific STEM inquiry offered by some teachers, however a fair amount of the inquiry teaching appears to be subject specific. This would not be unexpected in a non-STEM school environment but is worth noting in the case of STEM schools where we might expect a closer alignment between the inquiry and multi-subject domain teaching (Crippen & Archambault, 2012).

It may be that the path to STEM and STEM inquiry has to build up from the preexisting educational ideals and practices. Participation in a STEM school environment helps to align teachers with the interest of the school (Bruce-Davis et al., 2014), but it is specific exposure to the role of subjects outside of their teaching domain that can change how teaches view and consider the integration of those subjects (Nathan, Tran, Atwood, Prevost & Phelps, 2010). Currently, the surrounding context of the MWS STEM school's STEM focus may be having a similar influence in leading teachers to indicate importance of the content and, importantly, the inquiry aspects of each of the subject domains, while at the same time not necessarily leading teachers to incorporate the aspects of other domains into their instruction. That is, despite the relative importance the teachers expressed on content, methods and inquiry from the different STEM domains, it seems that these teachers' focus on inquiry has not, at this time, built up a focus on STEM.

One final point to consider is how teachers' implementation of inquiry instruction may differ between STEM and non-STEM schools. Science teachers indicated a greater percentage of their teaching was inquiry focused when compared with mathematics teachers. This runs counter to Marshall, Horton, Igo and Switzer's (2009) inquiry work which observed, in a large-scale survey, that mathematics teachers reported spending a greater percentage of their time on inquiry compared to science teachers. My study does not have the sample size to make claims across MWS's STEM schools, but the difference observed between science and mathematics teachers on teaching inquiry, and on many other teaching issues, point to potential differences both within the teaching domains in the STEM schools and across the STEM and non-STEM schools.

How do Secondary Educators, in STEM Focused Schools, Describe Their Practices of Implementing STEM education?

One component of STEM is the integration of content and methods of inquiry from the different STEM domains (Breiner, Harkness, Johnson & Koehler, 2012; Sanders, 2008). Integration can pose a challenge as the ability of a teacher to integrate content relies on knowledge they have of the domains they are integrating (Pang & Good, 2000). As observed by Stinson, Harkness, Meyer & Stallworth (2009), content knowledge teachers may lack from their own subject domain may lead to problems as the teachers try to combine content.

While there is this barrier to integration, the teachers in this study indicated that they consider the inclusion of content, inquiry activities, and methods of inquiry from all of the STEM domains as being at least somewhat important to their STEM instruction. However, in practice, the actual frequency of implementation of multi-subject teaching was inconsistent across teachers. Science teachers claimed to integrate content from multiple domains more often than mathematics teacher but still at varied frequencies ranging from multiple times weekly to never. The state's STEM framework does specify that integrated STEM should be at least 20%

of a teacher’s implemented instruction, but the teachers here come in both below and above that baseline. This lack of consistency in teaching STEM content may point to a lack of direction given to teachers, by administrators, to bring their teaching into alignment with the STEM policies.

The other two components of STEM mentioned in the teacher’s definitions were the connected concepts active learning and authentic context. These are the aspects of instruction that “trough authentic performances…help student make connections across subjects, and bring greater real world relevance to classroom learning” (Hoachlander & Yanofsky, 2011, p.63). In practice, there was again large variability, both within and between content subjects, in the frequency of using certain types of teaching methods when teaching content from multiple subject domains. The within-subject differences may indicate that components of STEM teaching are not standardized for or required of teachers by school administrators or across the schools under the STEM certification. The across-subject differences point to more potential differences in how teachers from different subjects teach STEM. Many mathematics teachers claiming to rarely (i.e., Few Times a Semester at most) apply teaching methods such as active/problem-based learning (six out of seven, 85%), research projects (seven out of seven, 100%) and presentations (six out of seven, 85%) compared with science teachers, who claimed to apply these more frequently. This is consistent with the previous points on integration as the teachers who do not frequently teach content from multiple domains would also less frequency use teaching methods that facilitate this kind of teaching. These findings also point to the possibility that science teachers may be in a position to use teaching methods that are more conductive to teaching STEM, compared with mathematics teachers. Part of this may be due to the fact that some of these teaching methods are already associated with science teaching (Hofstein & Lunetta, 2004; Ottander & Grelesson, 2006). Another aspect may be that since most accountability focus is directed at language arts and mathematics, the science teachers have more freedom to pursue this in their teaching while mathematics teachers’ curricula have been narrowed to address the standards (Charlesworth, Fleege, & Weitman, 1994).

The final part of the teachers’ practices in implementing STEM is in their interactions with other teachers and administrators. Teachers indicated having both informal discussions and planned meetings with individual teachers and designated groups (e.g. subject and grade level teams, building administrators). A large percentage of the teachers indicated having interactions with teachers outside of their subject domains or across their grade level on STEM. This finding differs from Brown and colleagues (2011) survey where few teachers indicated interacting with teachers outside their domain on STEM. Compared with their study, it is possible that the environment of a STEM school can lead to a school culture that promotes a focus on the STEM commitment of the school (Bruce-Davis et al., 2014). The prevalence of informal discussions might be an indicator of this developed or developing school STEM culture. This may further indicate that teachers are overall proactive in having these STEM discussions even if, as seen from the previous findings, there may be limits to the extent to which STEM (or multi-subject teaching) comes into teachers' frequent teaching practices.

A last point of interest is that more teachers claimed to have informal discussion on STEM compared with those having informal discussion on data-use. Just as collaboration can inform data-use practices (Coburn & Talbert, 2006; Marsh, Bertrand & Huguet, 2015), discussion and collaboration can help teachers in understanding and implementing interdisciplinary education (Herro & Quigley, 2017). It is possible that since issues of data-use are more established in schools, compared with the issues of STEM, that the teachers may feel they have less need to start informal conversations on using data. Alternatively, this may be the baseline level for discussions on data and topics of STEM, being newer, prompt more discussion. It is not clear, however, if the number of teachers engaging in informal meetings on STEM is driven by resource or professional development needs the teachers have that are not being met, or if it is driven by teacher engagement in the culture of the STEM school. Further qualitative research is needed to understand the nature of collaboration in these STEM schools that have transitions relatively recently (i.e., 3 to 4 years) and to determine if such collaborations bring about changes in practices that can bridge STEM and data-use.

This section completes the quantitative discussion of this study. Following the procedures of this mixed-methods study, the final chapter contains a synthesis and concluding remarks regarding the findings that came out of my analysis of both the survey and interviews of STEM school teachers.

CHAPTER 8: SYNTHESIS AND CONCLUSION

In this chapter, I will present the synthesis and conclusions of my study. Through this study, I have sought to use qualitative and quantitative research methods to answer the following research questions:

- What are secondary educators' in STEM focused schools perspectives surrounding teaching and data-use in STEM education?
- What do secondary educators in STEM focused schools see as the role of STEM inquiry activities in informing educational decision-making?
- How do secondary educators, in STEM focused schools, describe their practices of implementing STEM education?

Following the process of a concurrent triangulation methodology, I will first present a synthesis of the qualitative and quantitative findings to highlight interesting points of comparison between these components of my study. This synthesis, combined with individual issues from the respective components of the study, will form the basis of the conclusions of this research.

Synthesis of Findings

Views of Administrators' Connections to STEM.

In the interviews, the teachers expressed that while administrators had general expectations for data-use, they did not have expectations or requirements for STEM. This perception may not be a perfect reflection of the situation in the school environments, but it is notable that the perception persisted across four different schools. This finding is interesting when paired with the corresponding survey responses regarding perceptions of administrators found in Table 9,

Table 10

Views on STEM's Influence on Student Grades and Engagement According to Mathematics Teachers (n=7)

, Table 13 and Table 14 in chapter 6. For examples, six out of 11 (54%) science teachers overall agreed in the survey that the STEM focus of the school enhances students' grades, while nine out of 11 (82%) of those same teachers overall agreed that administrators consider the STEM focus of the school to enhance student grades. As a second example, consider this truncated version of Table 14 included here (see Table 37).

Table 37

STEM Data to Inform Educational Decisions: Comparing Mathematics Teachers and Perceptions of Administrators (n=6)

	Measure of Relative Agreement				
View of Data	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
I use data from STEM lessons or activities to inform my educational decisions.	1 (17)	3 (50)	1 (17)	1 (17)	-
School administrators use data from STEM lessons or activities to inform educational decisions.	-	-	4 (67)	1 (17)	1 (17)

In the survey, the teachers generally indicated that they viewed the administrators as holding positive (or at least neutral) perceptions of the usefulness of STEM for issues such as improving grades and informing decision making. In both examples, *some* teachers agreed that administers held these views regarding the role STEM plays in their schools, while they themselves did not. These qualitative and quantitative findings do not contradict each other but instead may point to an issue of communication between teachers and administrators on the expected and desired outcomes of teaching STEM which manifests as an apparent lack of expectations for implementing STEM.

Common Components of STEM

Teachers across both the interview and survey described common aspects of STEM, discussing it in terms of the integration of content, the active learning it can allow, and the authentic context it. Differences observed in these responses, as could be expected from the structure of the study, are that teachers who were interviewed had more opportunity to flesh out and, ultimately, bring up each of these aspects of STEM. The teachers who wrote their definitions in the survey included one or more of these aspects of STEM, presumably focusing on what they consider the main aspects. Teachers in the interviews also brought up the way STEM lessons and activities can foster student engagement. While the survey participants did not include a reference to engagement in their individual definitions, the majority agreed that the STEM focus of their school served to enhance engagement in learning.

This similarity in descriptions leads me to assume that the interview and survey questions are not eliciting fundamentally different conceptions of STEM. It is under this assumption that I feel I can present the contrast and comparisons of this chapter since no teacher appears to have responded while holding an unconventional view of STEM.

Informal Collaboration on STEM

In the survey (see Table 33 and Table 34)the majority of both mathematics and science teachers claimed to have informal discussions about STEM with other teachers in and outside of their subject and grade levels. These teachers also indicated engaging in planned meetings surround STEM topics, so it seems reasonable to assume that the respondents were not conflating informal discussions for planned meetings. It is interesting, then, that only one of the teachers interviewed indicated informally interacting with teachers around STEM issues. All interviewed teachers did indicate engaging in planned meetings such as common planning times and PLCs. In some cases, they also mentioned other teachers they may talk with; for example, Greg from School A was the STEM academy leader and other teachers mentioned they would go to him if they had questions. But that is one teacher, not the wide spectrum of teacher interactions the survey would seem to imply.

The difference in the number of survey responses between the two categories make it seem unlikely that teachers are conflating the categories, so the survey is not over stating the amount of collaboration. At the same time, in the interview I asked, “Who at your school do you talk to about STEM education issues?” so teachers were given an opportunity to mention these interactions if they were occurring. Rey, from School A, was the one exception and her comment may explain this discrepancy: “I talk to my colleagues. I talk to my colleagues all the time. … Teachers like to talk about stuff, right?” It may be that that for the teachers, in these STEM schools, that issues surrounding STEM have become a normal, common part of their conversational interactions to the extent that when asked about with whom they collaborate, those interactions are overshadowed by bigger interactions such as working with academy leaders or participating on the STEM committee. If this is indicative of what is happening it implies there may be many additional decision-making interactions on STEM that were not probed by my study design. Again, using the literature on data as a template, there may be teacher collaboration that is steering teachers' to more unified views (Coburn & Talbert, 2006) that need to be explored.

Sources of data

Teachers in the interview overall described their assessment of STEM in terms of informal, formative measures connected with how students worked with an activity such as their engagement or how they reasoned and worked with evidence to make claims. Similarly, in the survey, teachers indicated they primarily focus on data from their main subject domain with science teachers sometimes including a limited focus on subject domains. However, the survey was not written with this idea of informal assessment in mind. This complicates the interpretation of questions such as the one about *how frequently teachers claimed to use specific data sources when teaching in content outside of their primary subject domain*. I had considered the wording of assessment on content outside of one's subject domain as a proxy for assessment on STEM for the purpose of that question. However, if the assessment practices of the interview participants is wide spread among teachers, then this may not be how teachers interpret that question. The survey questions may be too limited in scope to reveal the actual data-use from STEM practices. However, the teachers' near exclusive mention of applying informal assessment gives insight into the state of data-use and the two assessment pieces that are needed. To steer assessment more towards specific content, teachers may need help with both the assessment of inquiry processes of their subject domain and assessment of content (and inquiry processes) outside of their domain. In a STEM school it may be easy to assume that any assessment training should target STEM in some way. However, STEM and single subject domain teaching are different in terms of content and pedagogical content knowledge. Taking the fuller picture implied by the use of informal assessment may give a way to target data-use training more efficiently to prepare teachers to assess inquiry and content, as needed.

Comparing Mathematics and Science Teachers

The qualitative data showed a fair amount of similarity between the mathematics and science teachers in terms of their views of the basic aspects of STEM and perceptions of the STEM environment they work in (i.e. administrative influence). There were, however, also some key differences between mathematics and science teachers and differences across all teachers of different content domains (e.g., biology versus physics, or algebra versus geometry). From the interviews, one key difference between mathematics and science teachers was in the idea that their teaching was inherently integrated (for reference, this view was held by all the science teachers in the interviews, but by only one mathematics teacher). The necessity of understanding mathematics for science was mentioned by most, and some also mentioned how engineering and design is an inherent part of lab activities. In contrast, the mathematics teachers expressed a range of views with one describing that their classroom inherently integrates STEM content while another described how they see their classroom as focusing on teaching mathematics so students will have those skills to integrate with STEM in other parts of their education. As shown in Chapter 6, the quantitative data revealed even more of these differences between and within subject areas at the granular level with specific questions regarding certain practices or perspectives. The survey responses on the question of how frequently teaching focuses on single or multiple subject areas overall align with the interview responses here, but also reveal some range in the science teachers' perspectives and practices that was not evident in the interviews.

Much of the nuances of science and mathematics teachers' interactions with STEM are still unexplored. In this study, I have been able to paint a piece of the picture, but also show that these interactions are complex and involve a mixture of uniform and non-uniform perceptions. This observation naturally leads me into discussing the implications of this study.

Implications

Implications for Educational Policy Makers

STEM is still a growing focus of K-12 education and the number of STEM school continues to increase across the country. STEM schools can take different forms based on the content and student populations they focus on. The STEM schools in MWS have undergone a certification process that, on paper, indicates the school has aligned itself with components of the state's STEM framework. This focus on STEM, filtered through the unique context of individual school administrators and teachers, yields the resultant STEM education environments.

This study has revealed some of the ways teaching and data-use can come together in STEM schools. Within the classroom, teachers expressed a tension between trying to offer STEM activities while also addressing standards. While they worked to involve students in STEM activities, their assessment in these activities tended to focus on non-subject content such as student participation or engagement. Outside of the classroom, teachers at a few of the schools noted that the classroom progression and the STEM focus are not in alignment, affecting cross-curricular lesson planning and student preparation in appropriate prerequisite classes.

The number of STEM schools in MWS continues to expand. If STEM and accountability through data-use are both to continue to be part of the state education policy, it falls on the policy makers to work with teachers and administrators to address the issues arising at the intersection of these policies. A big part of this may be to identify, support, and/or accept certain kinds of assessments or process standards regarding STEM education activities. Some teachers mentioned issues in identifying relevant standards or juggling existing standards in implementing STEM. Assisting teachers in this step will help them both teach STEM and implement the assessments demanded by policy.

Implications for school administrators

The principle implication for administrators is that they should be aware of how teachers in their schools are perceiving the administrative focus on STEM. Based on the interviews, it could be the case that administrators in these STEM focused schools are not providing strong leadership on STEM. The teachers mentioned there are requirements for data-use, thus it is clear there is communication on expectations that is occurring. If the administrators have a vision of STEM teaching they can use these existing lines of communication to connect with teachers.

It is important to note that my study was limited to only teachers' impressions regarding administrators and no administrators' voices are included. Administrators at these schools may, in fact, be proactive in supporting STEM, but if there is miscommunication or perhaps a stronger emphasis on data and standards, then the leadership direction on STEM may be overshadowed.

Administrators are important drivers of helping teaching practices in the classroom align with school agendas and policies (Young, 2006), which should apply to helping teachers shape the implementation STEM in a STEM-certified school. MWS is in the process of increasing the requirements for schools to certify and re-certify their STEM designation. The changing certification will likely impose more stringent requirements on what STEM teaching activities are offered and at the same time the need to meet standards remains in place. To meet these issues, administrators in these schools will need to make sure they are connecting with teachers to give a unified direction to the schools' data and STEM focus.

Implications for STEM and data-use in Teaching.

This study has revealed some similarities, differences and inconsistencies in how teachers describe and claim to work with STEM teaching and associated data from STEM. This has implications for the focus of teacher training and support offered to teachers.

Based on this study, teachers are aware of the broad ideas of STEM, but are considering the integration and inclusion of content in different ways based on the subject domains they consider important. There are no standards for STEM, so teachers work to try to meet their primary content standards while offering STEM. The survey revealed that the mathematics and science teachers diverge on practices associated with STEM in terms of the frequency of applying different teaching methods and the use of data from those methods. At the same time, the interviews revealed all teachers primarily use informal assessments of STEM activities.

In the current environment, teachers are shaping STEM teaching both through a freedom to implement STEM as they see fit and through adherence to other policies, namely data-use and standards. If policy makers and administrators envision STEM activities as becoming a more standardized source of data for informing decisions, then teachers need further preparation in identifying standards and assessments that fit in these activities. However, top-down changes to policy may not be what is needed in growing these STEM environments. The teachers here are experiencing the early growing pains of schools that have converted to a STEM school. Their insights on issues of addressing standards, issues of student preparation and course progression, and preparation for teaching STEM could be valuable in creating the training and professional development need by teachers in these environments.

Teacher Views of Administrative STEM and Data Focus.

A difference in responses regarding administrators in the interviews and survey raises questions about teachers' views of STEM and data leadership. Interview participants expressed a lack of perceived administrative expectations regarding STEM, but survey participants generally indicated administrators perceiving STEM as useful in issues such as improving grades and informing educational decisions. This observed administrative interest in STEM data differs from other data literature where administrators tend to focus on psychometric data (Coburn & Talbert, 2006).

It could be that administrators involved in schools that applied and went through the STEM certification process are naturally more interested in data connected with the STEM aspect of the school. However, if that were the demeanor of administrators, I would not expect to see the interviewed teachers' uniformly claim there is a lack of expectations and requirement on STEM. Bruce-Davis and colleagues (2014) observed a scenario where working in a STEM environment can help align teacher and administrators' interactions on STEM. This study reveals a STEM environment where the interactions surrounding STEM and data are more ambiguous, which is a consideration other STEM schools need to account for as they develop and move towards more school wide STEM practices.

Frameworks of STEM and Data-Use

A final contribution of this study is in moving toward a proper framework for the study of STEM and data-use. Just as data-use is a mandated, core component of schools, STEM should, in theory, be a core component of STEM-certified schools. In a STEM school, both data and STEM should be present and connected. If there is no connection, then what makes it a STEM school and not simply a school that happens to do STEM? As long as performance on content standards remains the main measure of accountability, the data-use components of policy will take precedence. This was very evident in the interviewed teachers' descriptions of navigating issues of content standards in order to find opportunities to teach STEM.

Frameworks of data-use have been formulated and researched to give a solid representation of educators' decision-making processes. Currently, the main ways of talking about STEM are extremely varied and lack the defined processes found in the decision-making frameworks. Many structured conceptions of STEM have been defined (Barakos, Lujan, & Strang, 2012; Bybee, 2013; NRC, 2013; Sanders, 2008), but they describe how domain content and methods *could* be combined, not necessarily how teachers actually approach this combination. The way STEM is implemented in STEM school classrooms is ultimately based on the actions of teachers, so defining a layout for STEM that is closer to teachers' experiences may give a more valid structure for organizing and understanding STEM teaching.

One way to reconceptualize STEM practice in the classroom may be to look at it in terms of issues that shape the opportunities to engage in STEM. In this study, it was the need to meet standards and expectations for formative assessment that set the stage for teachers applying informal assessment of activities. This choice of assessment was likely further influenced by the pedagogical, content and assessment knowledge teachers brought to the STEM environment. The need to meet standards influences the content that teachers consider in their lessons, which influences what assessments are needed. Instead of starting from subject domains to define STEM, it may be useful to explore and identify a knowledge baseline of teaching perspectives and practices that can serve as a foundation to support teachers in moving to more sophisticated implementations of STEM. One part of such a baseline may be to look back how teachers are able to offer inquiry in their primary subject domains. Inquiry is a gateway to multi-disciplinary education (Crippen & Archambault, 2012) and focusing on how issues (e.g., content standards, time, student preparation via proper prerequisites) are affecting inquiry instruction can help us identify when and where teachers can make connections to offer STEM.

Next Steps and Future Work

The focus of this dissertation was in the intersection of STEM teaching and data-use as understood through teachers' perspectives of what STEM education is and how teachers claim to teach and assess STEM content. This research can be built upon in a number of ways. First, there is a need to look at how student learning and performance outcomes are affected by teacher conceptions and classroom decisions in these STEM and data-use environments. Such a study could probe the issue of how teachers' perspectives regarding STEM and data-use influence the efficacy of STEM content that is taught. This in turn could help identify ways to support teachers in improving student learning both in STEM content and in the non-STEM content that is taught through STEM lessons. Understanding this could help guide policy decisions that could support teachers while meeting educational goals of promoting the teaching of STEM content.

Second, there is a need to refine the potential framework(s) that could categorize how STEM is conceptualized and taught. Research that dives deeper into how teachers conceptualize STEM in the classroom may lead to a more relevant way of talking about STEM. In effect, an emergent set of definitions of STEM coming from teachers may be more meaningful than a top down definition imposed by policy. Related to this is the need to refine potential frameworks, such as the one in my dissertation, which look at the intersection of STEM and some other educational topic. My dissertation focused on STEM and date-use, but other interesting intersections exist such as the intersection of STEM and non-STEM content. The continued growth of STEM means that the potential of the STEM educational focus to intersect with other educational interests cannot be ignored at the classroom or policy level.

Finally, the study of STEM and data-use needs to be expanded beyond the limitations of this dissertation. This dissertation looked at mathematics and science teachers in STEM schools as defined by one state. However, there other kinds of STEM schools and STEM programs, along with STEM lessons or curricula that may be taught in absence of a policy push to teach STEM. Studies that look at a wider range of teachers and teaching context are necessary to understand the potential overall trends and outcomes associated with the increasing national focus on STEM.

Limitations of the Study

One general limitation of this study is that, while I may operationalize definitions of STEM and DDDM to discuss their presence in schools, the reality is that both of these initiatives have the potential to be implemented in a wide variety of ways. I can locate participants and schools that have policies on both these initiatives, but as someone outside of this system, my knowledge of how these policies are implemented in practice is limited to participants' claims in interviews and surveys. This research is focused on educators' perspectives of how they think they are implementing these initiatives. Future research may include direct observations to make claims about what the actual STEM and data-use process *look like* in practice compared with educators claims and recollections.

A second general limitation is in the choice to limit teacher selection to just mathematics and science. Teachers of other subjects likely could provide insight into the data-use and STEM focus of these schools as all teachers are part of the data and STEM context of these schools. However, given the prominence of mathematics and science in conceptions of STEM, a focus on mathematics and science teachers here highlights the main interactions of data use and STEM in educational decision-making and may inform future studies of STEM as a whole.

The third general limitation is with regards to the type of STEM schools covered under this study. Each of these schools was changed into a STEM school through a certification process unique to MWS. Other states have their own certification processes and some schools are founded as STEM schools instead of converting. With all the different potential STEM environments this study is meant only to be an example of what *may* be observed in a STEM school. Along with this there are further limitations tied to the qualitative and quantitative structure of the study.

Limitations of the Qualitative Aspects of the Study

The participants who agreed to be part of the qualitative portion of this study led to important limitations in this study. First, there was an issue with the school grade levels of participating cases. While the state has certified roughly a dozen secondary level schools, the participants who responded to recruitment only led to cases consisting of one high-school and three middle-schools. Second, there is the fact that the high-school case had four teachers compared with the one or two teachers in the other cases. As a result of this, the high-school case is significantly more developed than the other cases. Third, several of the teachers mentioned being active in school roles outside of teaching. In other words, some of the participants may be considering issues of STEM teaching and data-use on a more regular or higher-level bases than the average teacher.

These limitations, combined with the small sample size of the study, make it important to clarify the goal of this study. I am not looking to generalize the specific findings of these cases to other STEM education environments. Instead the goal is to look into environments that combine STEM and data policies to find issues that may arise in such environments. The cases in this study give a snapshot across a handful of schools in the state on this issue that has not been extensively researched.

Limitations of the Quantitative Aspects of the Study

At the time of this study, there were roughly 10 STEM secondary schools employing approximately 50 mathematics and 50 science teachers. Among the five schools I was able to send the survey to, there were 29 mathematics and 27 science teachers. Based on these numbers the response rate for my survey started high with 34 teachers opening the survey and 22 answering the first question. However, only 15 persisted until the end of the survey. The survey was ordered with all the STEM questions asked first and all the data questions asked second so some details may have been lost due to having a participants STEM answer but not their data-use answers. Further, the demographic questions were at the end of the survey, so that information about the participants who did not complete the survey is unknown.

I wrote the items in the survey with a very specific conception of the different ways STEM teaching could occur and the different sources of data that might be used. In light of the responses to the interviews, I now feel some of the survey items do not measure what I intended. While I have addressed this in my discussion of the findings, I would point to this issue of wording as something that needs to be considered and addressed in future surveys of STEM practices.

Final Reflection

My interest in this research was driven by questions I have regarding how STEM content could be taught and assessed. As can be said for most subjects, the development of curricula and lessons involving STEM has difficulties and nuances that need to be addressed. Coming into this research, I considered that for STEM, issues lie in what subjects are taught, how subjects are integrated (if at all) and the inclusion of either content or processes from those subjects. From my research, I am reminded that educational initiatives, such as STEM, do not exist in a vacuum. The additional issues of administrative leadership, policies on assessment and standards, and comfort with teaching and assessing the relevant content came to the forefront of this study.

The implementation of STEM education ultimately comes down to the actions of teachers. The background an individual teacher brings to the classroom along with the needs or policy requirements of the classroom, building, district, and higher serve to shape how they implement and assess STEM in the standards driven school environment.

Through my interactions with these teachers I am reminded of an important point, which I tend to ignore or overlook. That point is that theoretical frameworks, in this case both of data and STEM, are descriptive (not prescriptive) of what is observed (i.e., in this case the perspectives of teachers). These teachers are working in environments far more complex than the isolated space of STEM and data conceptualizations where my dissertation focused. Teachers discussed their desire to help students learn, promoting engagement while also ensuring their primary subject content is taught to sufficient levels.

From this observation it is worth keeping in mind that while having the frameworks and analysis to dissect the STEM and data-use issues can be meaningful for examining the state of things and establishing a point of comparison, they form only part of the story.

REFERENCES

Al Salami, M. K., Makela, C. J., & de Miranda, M. A. (2017). Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching. *International Journal of Technology and Design Education*, *27*(1), 63-88.

Apple, M. W. (2004). Schooling, markets, and an audit culture. *Educational Policy, 18*(4), 614-621.

Ashby, C. M. (2009). No Child Left Behind Act: Enhancements in the Department of Education's Review Process Could Improve State Academic Assessments. Report to the Chairman, Committee on Health, Education, Labor, and Pensions, US Senate. GAO-09-911. *US Government Accountability Office*.

Barakos, L., Lujan, V., & Strang, C. (2012). *Science, technology, engineering, mathematics (STEM): Catalyzing change amid the confusion*. Portsmouth, NH: RMC Research Corporation, Center on Instruction.

Barnett, J. & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know. *Science Education, 85*(4), 426-453.

Beaver, J. K. & Weinbaum (2015). State test data and school improvement efforts. *Educational Policy, 29*(3), 478-503.

Bequette, J.W. & Bequette, M.B. (2012). A place for art and design education in the STEM conversation. *Art Education, 65*(2), 40-47.

Berland, L.K. (2013). Designing for STEM integration. *Journal of Pre-College Engineering Education Research, 3*(1), 22-31.

Bicer, A., Navruz, B., Capraro, R. M., Capraro, M. M., Oner, T. A., & Boedeker, P. (2015). STEM schools vs. non-STEM schools: Comparing students' mathematics growth rate on high-stakes test performance. *International Journal of New Trends in Education and Their Implications*, *6*(1), 138-150.

Boesdorfer, S.B. (2017). High school chemistry teachers' views of engineering inclusion before and after a professional development program. *CET Research Brief #2*, 2(1), 1-6. Retrieved from: https://cet.uni.edu/sites/default/files/boesdorfer_brief_0.pdf

Breiner, J.M., Harkness, S.S., Johnson, C.C. & Koehler, C.M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3-11.

Brown, R., Brown, J., Reardon, K. & Merrill, C. (2011). Understanding STEM: Current perceptions. *Technology and Engineering Teacher, 70(*6), 5-9.

Bruce-Davis, M. N., Gubbins, E. J., Gilson, C. M., Villanueva, M., Foreman, J. L., & Rubenstein, L. D. (2014). STEM high school administrators', teachers', and students' perceptions of curricular and instructional strategies and practices. *Journal of Advanced Academics*, *25*(3), 272-306.

Brunsell, E., Kneser, D. M., & Niemi, K. J. (2014). *Introducing teachers and administrators to the NGSS: A professional development facilitator's guide*. Arlington, VA: NSTA Press.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. United States of America: National Science Teachers Association.

Carlson, M. O. B., Humphrey, G. E., & Reinhardt, K. S. (2003). *Weaving science inquiry and continuous assessment: Using formative assessment to improve learning*. Corwin Press.

Carmichael, C.C. (2017). *A state-by-state policy analysis of STEM education for public schools*. (Doctoral dissertation, Seton Hall University). Retrieved from http://scholarship.shu.edu/cgi/viewcontent.cgi?article=3342&context=dissertations

Carter, L. (2017). Neoliberalism and STEM Education: Some Australian Policy Discourse. *Canadian Journal of Science, Mathematics and Technology Education*, *7*(1), 32-41.

Charlesworth, R., Fleege, P. O., & Weitman, C. J. (1994). Research on the effects of group standardized testing on instruction, pupils, and teachers: New directions for policy. *Early Education and Development, 5*(3), 195-212.

Chiappetta, E. L., & Adams, A. D. (2004). Inquiry-based instruction. *The Science Teacher*, *71*(2), 46.

Coburn, C.E., & Talbert, J.E. (2006). Conceptions of evidence use in school districts: Mapping the terrain. *American Journal of Education, 112*(4), 469-495.

Coburn, C.E., & Turner, E.O. (2011). Research on data use: A framework and analysis. *Measurement: Interdisciplinary Research and Perspectives, 9*(4), 173-206.

Creswell. J.W. (2003). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (2nd ed.). London: SAGE Publications.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th. Eds.). Upper Saddle River, NJ: Prentice Hall.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into practice*, *39*(3), 124-130.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods research designs. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research*. (pp. 209-240). Thousand Oaks, CA: SAGE Publications.

Crippen, K. J., & Archambault, L. (2012). Scaffolded inquiry-based instruction with technology: A signature pedagogy for STEM education. *Computers in the Schools, 29*(1-2), 157-173.

Cross, D.I. (2009). Creating optimal mathematics learning environments: combining argumentation and writing to enhance achievement. International Journal of Science and Mathematics Education, 9, 905-930.

Cross, T. L., & Frazier, A. D. (2009). Guiding the psychosocial development of gifted students attending specialized residential STEM schools. *Roeper Review, 32*(1), 32-41.

Datnow A., Park, V., & Kennedy-Lewis, B. (2012). High school teachers' use of data to inform instruction. *Journal of Education for Students Placed at Risk, 17*(4), 247-265.

Devlin, A. S. (2017). *The Research Experience: Planning, Conducting, and Reporting Research*. Thousand Oaks, CA: SAGE Publications.

Ebbeler, J., Poortman, C. L., Schildkamp, K., & Pieters, J. M. (2016). Effects of a data use intervention on educators' use of knowledge and skills. *Studies in Educational Evaluation, 48*, 19-31.

Eekels, J. & Roozenburg, N.F.M. (1991). A methodological comparison of the structures of scientific research and engineering design: Their similarities and differences. *Design Studies, 12*(4), 197-203.

Eisenhart, M., Weis, L., Allen, C.D., Cipollone, K., Stich, A., & Dominguez, R. (2015). High school opportunities for STEM: Comparing inclusive STEM-focused and comprehensive high schools in two US cities. *Journal of Research in Science Teaching*, *52*(6), 763-789.

Erdogan, N., & Stuessy, C. L. (2015). Modeling successful STEM high schools in the United States: An ecology framework. *International Journal of Education in Mathematics, Science and Technology, 3*(1), 77-92.

Ewell, P. T. (2008). Assessment and accountability in America today: Background and context. *New Directions for Institutional Research, 2008*(S1), 7-17.

Farrell, C.C. & Marsh, J.A. (2016). Metrics matter how properties and perceptions of data shape teachers' instructional responses. *Educational Administration Quarterly, 52*(3), 423-426.

Feilzer, M.Y. (2009). Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm. *Journal of Mixed Methods Research, 4*(1), 6-16.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415.

Frykholm, J. & Glasson, G. (2005). Connecting science and mathematics instruction: Pedagogical context knowledge for teachers. *School Science and Mathematics, 105*(3), 127-141.

Gerlach, J. (2012). STEM: Defying a simple definition. NSTA Reports, p. 3. Arlington, VA: National Science Teachers Association.

Glass, K. T. (Ed.). (2009). *Lesson design for differentiated instruction, grades 4-9*. Corwin Press.

Greene, J. C. (2012). Engaging Critical Issues in Social Inquiry by Mixing Methods. *American Behavioral Scientist, 56*(6), 755-773.

Gresalfi, M., Martin, T., Hand, V., & Greeno, J. (2009). Constructing competence: An analysis of student participation in the activity systems of mathematics classrooms. *Educational studies in mathematics*, *70*(1), 49-70.

Grossman, P. L. & Stodoksky, S. S. (1995). Content as context: The role of school subjects in secondary school teaching. *Educational Researcher, 24*(8), 5-23.

Guest, G. (2012). Describing mixed methods research: An alternative to typologies. *Journal of Mixed Methods Research, 7*(2), 141–151.

Halonen, J.S., Bosack, T., Clay, S., McCarthy, M., Dunn, D.S., Hill IV, G.W., McEntarffer, R., Mehrotra, C., Nesmith, R., Weaver, K.A., & Whitlock, K. (2003). A rubric for learning, teaching, and assessing scientific inquiry in psychology. *Teaching of Psychology, 30*(3), 196-208.

Halverson, R., Grigg, J., Prichett, R., & Thomas, C. (2007). The new instructional leadership: Creating data-driven instructional systems in school. *Journal of School Leadership, 17*(2), 159-194.

Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development: implications for teacher educators. *Professional Development in Education*, *43*(3), 416-438.

Hoachlander, G., & Yanofsky, D. (2011). Making STEM real. *Educational Leadership, 68*(6), 60-65.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty- first century. *Science education, 88*(1), 28-54.

Honig, M. I., & Coburn, C. (2008). Evidence-based decision making in school district central offices: Toward a policy and research agenda. *Educational Policy*, *22*(4), 578-608.

Hurley, M. M. (2001). Reviewing integrated science and mathematics: The search for evidence and definitions from new perspectives. *School science and mathematics*, *101*(5), 259-268.

Ikemoto, G. S., & Marsh, J. A. (2007). Cutting through the "data driven" mantra: Different conceptions of data-driven decision making. In P.A. Moss (Ed.), *Evidence and decision making (National Society for the Study of Education Yearbook*, Vol. 106, Issue 1, pp. 105–131). Chicago, IL: National Society for the Study of Education.

Ingram, D., Louis, K.S. & Schroeder, R.G. (2004). Accountability Policies and Teacher Decision Making: Barriers to the Use of Data to Improve Practice. *Teachers College Record, 106*(6), 1258-1287.

International Technology and Engineering Education Association (ITEEA). (2007). Standards for technological literacy (STL): Content for the study of Technology (3rd ed.). Reston;VA: Author. Retrieved from: https://www.iteea.org/39197.aspx

Isaacs, M.L. (2003). Data-driven decision making: The engine of accountability. *Professional School Counseling, 6*(4), 228-295.

Jacobs, J., Gregory, A., Hoppey, D. & Yendol-Hoppey, D. (2009). Data literacy: Understanding teachers' data use in a context of Accountability and Response to Intervention. *Action in Teacher Education, 31*(3), 41-55.

Jennings, J.L. & Bearak, J.M. (2014). “Teaching to the Test” in the NCLB era: How test predictability affects our understanding of student performance. *Educational Researcher, 43*(8), 381-389.

Johnson, R.B., Onwuegbuzie, A.J., & Turner, L.A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, *1*(2), 112-133.

Jorgensen, M. A., & Hoffmann, J. (2003). History of the No Child Left Behind Act of 2001 (NCLB). *Assessment Report. Pearson Education: San Antonio*. Retrieved from: http://images.pearsonassessments.com/images/tmrs/tmrs_rg/HistoryofNCLB.pdf?WT.mc_id=TMRS_History_of_the_No_Child_Left_Behind

Katehi, L., Pearson, G., Feder, M. (Eds.). (2009). *Engineering in K–12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 1-11.

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246-258.

Kim, H., & Song, J. (2006). The features of peer argumentation in middle school students' scientific inquiry. *Research in Science Education*, *36*(3), 211-233.

Kumar, R. (2005). Research methodology, a step by step method for the beginner (2nd ed.). *SAGE publication*.

Lachat, M. A., & Smith, S. (2005). Practices that support data use in urban high schools. *Journal of Education for Students Placed at Risk, 10*(3), 333-349.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher, 42*(4), 223-233.

Llewellyn, D. (2010). *Differentiated science inquiry*. Corwin Press.

Llewellyn, D. (2012). Teaching high school science through inquiry and argumentation. Corwin Press.

Llewellyn, D. (2013). *Teaching high school science through inquiry and argumentation*. Corwin Press.

Love, N. (2008). *Using data to improve learning for all: A collaborative inquiry approach*. Thousand Oaks, CA: Corwin Press.

Lynch, S. J., Behrend, T., Burton, E. P., & Means, B. (2013, April). Inclusive STEM-focused high schools: STEM education policy and opportunity structures. In the *Proceedings of the annual conference of the National Association for Research in Science Teaching (NARST)*, Rio Grande, Puerto Rico.

Mandinach, E.B. & Gummer, E.S. (2013). A systematic view of implementing data literacy in educator preparation. *Educational Researcher*, *42*(10), 30-37.

Mandinach, E. B., Honey, M., & Light, D. (2006). A theoretical framework for data-driven decision making. Paper presented at the annual meeting of the *American Educational Research Association*, San Francisco, CA. Retrieved from: http://cct.edc.org/sites/cct.edc.org/files/publications/DataFrame_AERA06.pdf

Mandinach, E. B., Honey, M., Light, D., & Brunner, C. (2008). A conceptual framework for data-driven decision making. In E. B. Mandinach & M. Honey (Eds.), *Data-driven school improvement: Linking data and learning* (pp. 13–31). New York, NY: Teachers College Press.

Marsh, J.A., Bertrand, M., & Huguet, A. (2015). Using data to alter instructional practice: The mediating role of coaches and professional learning communities. *Teachers College Record*, *117*(4), 1-40.

Marsh, J. A., & Farrell, C. C. (2015). How leaders can support teachers with data-driven decision making: A framework for understanding capacity building. *Educational Management Administration & Leadership*, *43*(2), 269-289.

Marsh, J.A., Pane, J.F., & Hamilton, L.S. (2006). Making sense of data-driven decision making in education: evidence from recent RAND research. RAND Corporation. Retrieved from http://www.rand.org/pubs/occasional_papers/OP170.html

Marshall, J. C., Horton, R., Igo, B. L., & Switzer, D. M. (2009). K-12 science and mathematics teachers' beliefs about and use of inquiry in the classroom. *International Journal of Science and Mathematics Education*, *7*(3), 575-596.

McNeil, L. (2002). *Contradictions of school reform: Educational costs of standardized testing*. New York, NY: Routledge.

Mertens, D. M., & Hesse- Biber, S. (2013). Mixed methods and credibility of evidence in evaluation. *New Directions for Evaluation*, *2013*(138), 5-13.

Miller, J. D., & Benbow, C. P. (2012). Introduction to staying ahead of the gathering storm. *Peabody Journal of Education*, *87*(1), 1-5.

Nathan, M.J., Srisurichan, R, Walkington, C., Wolfgram, M., Williams, C. & Alibali, M.W. (2013). Building cohesion across representations: A mechanism for STEM integration. *Journal of Engineering Education, 102*(1), 77-116.

Nathan, M. J., Tran, N. A., Atwood, A. K., Prevost, A., & Phelps, L. A. (2010). Beliefs and expectations about engineering preparation exhibited by high school STEM teachers. *Journal of Engineering Education, 99*(4), 409-426.

National Research Council (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

National Research Council. (2007b). *Taking science to school: Learning and teaching science in grades K-8*. National Academies Press.

National Research Council. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. Washington, DC: National Academies Press.

National Research Council (2010b). *Standards for K-12 Engineering Education?* Washington, DC: National Academies Press.

National Research Council (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics.* Washington, DC: National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

National Research Council (2013). *Monitoring progress toward successful K-12 STEM education: A nation advancing*? Washington, DC: National Academies Press.

National Research Council (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: National Academies Press.

NGSS Lead States (2013). *Next Generation Science Standards: For States, By States. Appendix F - Science and Engineering Practices in the NGSS* [PDF document]. Retrieved from https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

Olszewski-Kubilius, P. (2009). Special schools and other options for gifted STEM students. *Roeper Review, 32*(1), 61-70.

Ottander, C., & Grelsson, G. (2006). Laboratory work: the teachers' perspective. Journal of Biological Education, 40(3), 113-118.

Pang, J., & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. *School science and mathematics*, *100*(2), 73-82.

Park, V., & Datnow, A. (2009). Co-constructing distributed leadership: District and school connections in data-driven decision-making. *School Leadership and Management*, *29*(5), 477-494.

Peters-Burton, E. E., Lynch, S. J., Behrend, T. S., & Means, B. B. (2014). Inclusive STEM high school design: 10 critical components. *Theory Into Practice*, *53*(1), 64-71.

Pitt, J. (2009). Blurring the boundaries - STEM education and education for sustainable development. *Design and Technology Education: An International Journal, 14*(1), 37-48.

Popham, W.J. (2009). Assessment literacy for teachers: Faddish or fundamental? *Theory Into Practice, 1*, 4-11.

Rangel, V.S., Monroy, C. & Bell, E.R. (2016). Science teachers' data use practices: A descriptive analysis. *Education Policy Analysis Archives, 24*(86), 1-33.

Richards, M. R. E., & Omdal, S. N. (2007). Effects of tiered instruction on academic performance in a secondary science course. *Journal of advanced academics*, *18*(3), 424-453.

Root-Bernstein, R., & Root-Bernstein, M. (2011, March 16). *Turning STEM into STREAM: writing as an essential component of science education*. Retrieved from https://www.nwp.org/cs/public/print/resource/3522

Ruiz-Primo, M.A. & Furtak, E.M. (2006). Informal formative assessment and scientific inquiry: Exploring teachers' practices and student learning. *Educational Assessment, 11*(3-4), 237-263.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Washington, DC: Sage.

Sanders, M.E. (2008). STEM, STEM education, STEMmainia. Retrieved from: https://vtechworks.lib.vt.edu/handle/10919/51616

Scott, C. (2012). An investigation of science, technology, engineering and mathematics (STEM) focused high schools in the US. *Journal of STEM Education: Innovations and Research, 13*(5), 30-39.

Schildkamp, K., & Poortman, C. L. (2015). Factors influencing the functioning of data teams. *Teachers College Record*, *117*(4), 1-42.

Schildkamp, K., Poortman, C.L. & Handelzalts, A. (2016). Data teams for school improvement. *School Effectiveness and School Improvement*, *27*(2), 228-254.

Schwarz, B. B., Hershkowitz, R., & Prusak, N. (2010). Argumentation and mathematics. *Educational dialogues: Understanding and promoting productive interaction*, *115*, 141.

Simon, M. A., Tzur, R., Heinz, K., Kinzel, M., & Smith, M. S. (2000). Characterizing a perspective underlying the practice of mathematics teachers in transition. *Journal for Research in Mathematics Education*, 579-601.

Simpson, R.L., Lacava, P.G., & Graner, P.S. (2004). The No Child Left Behind Act: Challenges and implications for educators. *Intervention in School and Clinic, 40*(2), 67-75.

Siskin, L.S. (1991). Departments as different worlds: Subject subcultures in secondary schools. *Education Administration Quarterly, 27*(2), 134-160.

Smith, A. (2003). Scientifically based research and evidence-based education: A federal policy context. *Research & Practice for Persons with Severe Disabilities*, *28*(3), 126-132.

Spillane, N. K., Lynch, S. J., & Ford, M. R. (2016). Inclusive STEM high schools increase opportunities for underrepresented students. Phi Delta Kappan, 97(8), 54-59.

State Educational Technology Directors Association. (2008). Science, technology, engineering, and math (STEM). State Educational Technology Directors Association (SETDA). Retrieved from http://www.setda.org/wp-content/uploads/2013/11/Science-Technology-Engineering-and-Mathematics-STEM-Report.pdf

Stinson, K., Harkness, S. S., Meyer, H., & Stallworth, J. (2009). Mathematics and science integration: Models and characterizations. *School Science and Mathematics*, *109*(3), 153-161.

Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching, 39*(8), 664-687.

Stohlmann, M., Moore, T.J. & Roehrig, G.H. (2012). Considerations for teaching integrated STEM. *Journal of Pre-College Engineering Education Research, 2*(1), 28-34.

Stubbs, E.A. & Myers, B.E. (2004). Multiple case study of STEM in school - based agricultural education, *Journal of Agricultural Education, 56*(2), 188-203.

Stubbs, K. N., & Yanco, H. A. (2009). STREAM: A workshop on the use of robotics in K-12 STEM education. *IEEE Robotics & Automation Magazine*, *16*(4).

Tashakkori, A. and Teddlie, C. (1998) Mixed methodology: Combing qualitative and quantitative approaches. London: SAGA Publications.

Tomlinson, C. A., & Allan, S. D. (2000). *Leadership for differentiating schools and classrooms*. Ascd.

Tomlinson, C. A. (2005). Grading and differentiation: Paradox or good practice?. *Theory into practice*, *44*(3), 262-269.

Turner, J. C., & Patrick, H. (2004). Motivational influences on student participation in classroom learning activities. *Teachers College Record*, *106*(9), 1759-1785.

Volante, L. & Fazio, X. (2007). Exploring teacher candidates' assessment literacy: Implications for teacher education reform and professional development. *Canadian Journal of Education, 30*(3), 749-770.

Wang, H., Moore, T.J., Roehrig, G.H. & Park, M.S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1-13.

Wayman, J.C. (2005). Involving teachers in data-driven decision making: Using computer data systems to support teacher inquiry and reflection. *Journal of Education for Students Placed at Risk, 10*(3), 295-308.

Wayman, J. C., Midgley, S., & Stringfield, S. (2005, April). Collaborative teams to support data-based decision making and instructional improvement. In Annual Meeting of the *American Educational Research Association*, Montreal, Canada.

Wiliam, D. (2010). Standardized testing and school accountability. *Educational Psychologist*, *45*(2), 107-122.

Wissehr, C., Concannon, J., & Barrow, L. H. (2011). Looking back at the Sputnik era and its impact on science education. *School Science and Mathematics*, *111*(7), 368-375.

Wiswall, M., Stiefel, L., Schwartz, A. E., & Boccardo, J. (2014). Does attending a STEM high school improve student performance? Evidence from New York City. *Economics of Education Review, 40*, 93-105.

Young, V.M. (2006). Teachers use of data: Loose coupling, agenda setting, and team norms. *American Journal of Education*, *112*(4), 521-548.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 39*(1), 35-62.

Zollerman, A. (2012). Learning for STEM literacy: STEM literacy for learning. *School Science and Mathematics, 112*(1), 12-19.

Zucker, S. (2004). Scientifically based research: NCLB and assessment. *Harcourt Policy Report. Pearson Education. Harcourt Assessment, Inc.* Retrieved from http://images.pearsonassessments.com/images/tmrs/tmrs_rg/ScientificallyBasedResearch.pdf

APPENDIX

INTERVIEW PROTOCAL

- **Preparation**
  - Arrive at the meeting room 15 minutes prior to start time, with:
    - Two recorders, extra batteries, extra memory (check to make sure the card in the recorder has enough space)
    - Paper copy of the interview script/questions
    - One copy of documents (i.e., research overview and consent form if applicable), plain paper, and one pen or pencil for the participant.
  - Set up interview room:
    - Arrange 2 tape recorders

- **Responding and Probing**
  - Use the protocol as a script - read the protocol verbatim as much as possible.
  - Dig into details of opportunities when they're mentioned – when tasks, activities, or conceptions of STEM or data-use are mentioned especially by name; ask for more details.
    - Sample probing questions:
      - "Can you tell me more about that activity?"
      - "Can you say more about that?"
      - "Is the information in a document that you can share with us or online somewhere?"
      - "You spoke about … can you elaborate?"

  - Try to keep the teacher focused on STEM and data-use; if he/she moves away from talking about these topics, ask questions such as:
    - "How is your data-use related to that task/decision making?"
    - "How does you STEM focus influence that task/decision making?"

    - Stay neutral in responses to participant answers – try to build rapport without agreeing, disagreeing or assigning value. Try not to say “good point,” “I agree,” etc. My goal is for the participants to feel comfortable.
        - Sample neutral responses:
            - “I see.”
            - “I understand.”
            - “Can you tell me more?”
            - “Can you say more about that?”

- **Post-Interview**
    - If time allows, write a brief reflection after the interview, including notable aspects of the interview (e.g., impressions, feelings, and important moments in the interview).
    - Check memory space on recorders for upcoming interviews (change SIM card if necessary).

INTERVIEW QUESTIONS

Part 1: General information

Thank you very much for agreeing to be interviewed today. Do you give permission for me to record this interview? ***[Start recording]*** Today is XXX. My name is XXX and I'm talking with (Interviewee's name). I am a graduate student and this interview is part of my dissertation work. My dissertation is investigating the intersection of STEM and data-use in your school to understand how educators (particularly secondary teachers in mathematics and science) perceive data in a STEM focused environment and the practices used to select data, extract relevant information and construct actionable knowledge to make decisions in the STEM education context of the school. My research does not intend to evaluate the STEM education or data-use practices at your school.

Main Interview Questions

<u>I'd just like to start by getting a little Background Info</u>

What are you teaching? (Or what classes do you normally teach?)

How long have you been teaching?

How long have you been teaching here at_______________?

Where you here during the time this school transitioned into the STEM certification program?

<u>First let's talk a little about what kinds of things you do in your classroom related to data-use and STEM</u>

- As a teacher, what kinds of information about students do you find most useful in teaching?
- What kinds of student assessments do you use to obtain the information you need for instructional planning/teaching?
- (If inquiry activities such as labs, research or presentations are mentioned):
    - o You mentioned _____. What are specific kinds of data can you obtain from this/these activities?
    - o In what ways do you assess students' understanding from the inquiry activities such as the _______ you just mentioned: (For what specific purposes?)

    - Are there other inquiry activities, such as [labs or guided research] that you use in your instruction?
- (If inquiry activities such as labs, research, presentation, are **not** mentioned)
    - In some interpretations of STEM education inquiry activities such as labs or guided research are considered important parts of how STEM should be taught. Do you use any inquiry activities as part of your lessons?
        - (If no)
            - Why is this the case?
        - (If yes)
            - You mentioned _____. What are specific kinds of data can you obtain from this/these activities?
            - In what ways do you assess students' understanding from the inquiry activities such as the _______ you just mentioned: (For what specific purposes?)
- The Indiana STEM certification program, of which this school is a part, seeks to create STEM classrooms.
    - From your perspective, what are the characteristics, such as activities or content, that you believe would make a classroom a STEM classroom.
    - Similarly, from your perspective, what would be the traits of a STEM lesson that would need to be present for you to say that it is a STEM lesson instead of being, just as an example, a mathematics or science lesson?
    - How closely do you feel your teaching and classroom practices mirror the ideal STEM classroom you described previously?
    - For your teaching goals, do you consider it important to become more like the STEM classroom you described? Why?
- In some interpretations of STEM, the integration of aspect from multiple domains is an important part of STEM education.
    - Do you teach lessons that combine multiple domains?
        - (if yes)
            - How frequency do you teach these lessons?

            - Can you give some examples of lessons that combined multiple domains? In these STEM lessons, specifically, how would your rank the relative importance of the domains that are present? Why?
            - What is your process when you have to assess students on a lesson that covered content from multiple domains?
            - How do you feel about these kinds of lessons, in terms of effectiveness, engagement and practicality, compared with lessons that focus just on your normal content area?
        - (if no)
            - How do you feel about these kinds of lessons, in terms of effectiveness, engagement and practicality, compared with lessons that focus just on your normal content area?

After 30 minutes on classroom practices, make sure to move on to the following:

<u>Personal perspectives around "data-use"</u>

- *(Perspective)* When you hear the word data-use, what do you think about?
- *(Use)* How do requirements of data-use influence instruction at your school?
    - Can you give me some examples?
    - What kinds of data-use do you as a teacher find most valuable when making instructional decisions in your classroom? Why?
    - Can you describe a recent example of how you have used data to adapt or alter your instruction?
- *(Social)* Who at your school do you talk to about data-use? What do you talk about? How often?
    - Do you collaborate with other teachers or administrators? If so how do these collaborations work?
    - If you have a question about how to figure something out related to data-use, who do you ask?
- *(Needs)* What would you like to learn more about in relation to using data?
    - Are there data you currently cannot obtain readily but that you would like to have?

<u>Personal perspectives around "STEM education"</u>

- *(Perspective)* When you hear the word STEM education, what do you think about?
- *(Use)* How do requirements of teaching STEM influence instruction at your school?
    - Can you give me some examples?
    - What kinds of STEM focused content do you as a teacher find most valuable when making instructional decisions in your classroom? Why?
    - Can you describe a recent example of how you have used STEM or STEM focused activates as part of your instruction?
- *(Social)* Who at your school do you talk to about STEM education issues? What do you talk about? How often?
    - Do you collaborate with other teachers or administrators? If so how do these collaborations work?
    - If you have a question about how to figure something out related to STEM education, who do you ask?
- *(Needs)* What would you like to learn more about in relation to teaching STEM?
    - Are there aspects of STEM education that you currently cannot implement in your teaching but would like to be able to implement? What is preventing you from implementing these aspects of STEM.

<u>School support for teachers' use of data and engagement in STEM</u>

- What are the school's expectations for how teachers should use data?
- How does the school support teachers' capacity for using data to drive instruction? (e.g., Professional development? Common planning time?)

- What are the school's expectations for how teachers should teach STEM?
- How does the school support teachers' capacity for using implementing STEM instruction? (e.g., Professional development? Common planning time?)

- What are the school's expectations for how teachers should teach should evaluate, assess or otherwise obtain data from STEM educational activities?

- How does the school support teachers' capacity for obtaining and using data from STEM instruction? (e.g., Professional development? Common planning time?)

Data from STEM

- From your perspective, to what extent does data from the STEM aspects of your classroom practices, lessons, and curricula inform your decision making, when compared with other data sources, such as standardized testing data, or other data types, such as mathematics or science specific performance scores?
- From your perspective, to what extent does data from the STEM aspects of your classroom practices, lessons, and curricula inform your school or district's decision making, when compared with these other data sources?

FINAL QUESTION

- Do you see a need in expanding the role of data from your STEM activities in your instructional decision making?
    - (if No). Can you elaborate on why?
    - (if Yes)
        - Can you elaborate on why?
        - What do you see as important next steps for building your capacity to use data in your STEM focused environment?