Teacher Characteristics and School-Based Professional Development in Inclusive STEM-focused High Schools: A Cross-case Analysis

By Nancy Kay Spillane

B.S, Chemistry, May 1977, The University of Vermont
M.Ed., Teacher Education, May 1980, The University of Vermont

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Sharon J. Lynch
Professor of Curriculum and Pedagogy

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Nancy Kay Spillane

Dissertation Research Committee

Sharon J. Lynch, Professor of Curriculum and Pedagogy, Dissertation Director

Karen Kortecamp, Adjunct Professor of Curriculum and Pedagogy, Committee Member

Erin E. Peters-Burton, Associate Professor of Science Education and Educational Psychology, Committee Member

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Abstract of Dissertation

Teacher Characteristics and School-Based Professional Development
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Within successful *Inclusive Science, Technology, Engineering, and Mathematics (STEM)-focused High Schools* (ISHSs), it is not only the students who are learning. Teachers, with diverse backgrounds, training, and experience, share and develop their knowledge through rich, embedded professional development to continuously shape their craft, improve their teaching, and support student success. This study of four exemplars of ISHSs (identified by experts in STEM education as highly successful in preparing students underrepresented in STEM for STEM majors in college and future STEM careers) provides a rich description of the relationships among the characteristics of STEM teachers, their professional development, and the school cultures that allow teachers to develop professionally and serve the needs of students. By providing a framework for the development of teaching staffs in ISHSs and contributing to the better understanding of STEM teaching in any school, this study offers valuable insight, implications, and information for states and school districts as they begin planning improvements to STEM education programs. A thorough examination of an existing data set that included site visits to four ISHSs along with pre- and post-visit data, provided the data for this multiple case study with cross-case analysis of the teachers and their teacher professional development experiences.

Administrators in these ISHSs had the autonomy to hire teachers with strong content backgrounds, philosophical alignment with the school missions, and a willingness to work collaboratively toward achieving the school's goals. Ongoing teacher professional development began before school started and continued throughout the school day and year through intense and sustained, formal and informal, active learning experiences. Flexible professional development systems varied, but aligned with targeted school reforms and teacher and student needs. Importantly, collaborative teacher learning occurred within a school-wide culture of collaboration. Teachers were guided in establishing open lines of communication that supported regular engagement with others and the free flow of ideas, practices, and concerns. As a result of this collaboration, in conjunction with intentional pathways to teacher leadership, teacher professionalization was deliberately and successfully fostered creating an environment of shared mission and mutual trust, and a shared sense of responsibility for school-wide decision-making and school outcomes.

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Chapter 1: Introduction

Overview

The number of *Inclusive STEM-focused High Schools* (ISHSs) in the United States has been growing in recent years, in part due to attention by the Obama administration and education policy initiatives on increasing the number of students from underrepresented groups entering science, technology, engineering or mathematics (STEM) majors in college and careers in the STEM fields. However, even though the number of schools labeled as ISHSs is increasing, to date, there is no single accepted common definition or description of an ISHS, or an understanding of the requirements for a school to be designated an ISHS (Lynch, Means, Behrend, & Peters-Burton, 2011). Several research efforts are underway to characterize these new schools. Given that ISHSs are designed to provide a rigorous education in science, technology, engineering and mathematics, and to meet the needs of groups of students who have been under-represented the STEM fields, ISHS teachers may need differential or targeted preparation and on-going support to perform their jobs effectively. This study utilized an existing database from exemplars of ISHSs (those identified by experts in STEM education research, and by national, state, and local STEM-education organizations, as successful in preparing students underrepresented in STEM for STEM majors in college and future STEM careers) to provide a rich description of the teachers who work in these ISHSs and the professional development that shapes and hones their knowledge and skills to meet the ultimate goal of preparing all students to enter STEM majors and careers.

It seems likely that a school that seeks to better meet the needs of students currently underrepresented in STEM will hire teachers and provide teacher professional development that is aligned with teachers' and students' needs. The purpose of this study was to explore that conjecture through a thorough examination of data collected for a broader set of case studies on exemplars of ISHSs.

Introduction and Statement of the Research Problem

September 2010, the President's Council on Science and Technology (PCAST), in its report entitled *Prepare and Inspire: K-12 Education in Science, Technology, Engineering and Mathematics (STEM) for America's Future,* cited as one of their primary goals, a need to "prepare all students, including girls and minorities who are underrepresented in these fields, to be proficient in STEM subjects" (PCAST, 2010, p. 11). President Obama's 2014 Budget included a call for "more STEM-focused high schools and districts" with the Department of Education investing "$300 million to support re-design of high schools . . . focusing on high-demand employment sectors such as STEM fields" (OSTP, 2014, p. 1). With the nation giving greater attention to increasing the diversity of workers in the STEM fields, more STEM-focused high schools are opening to meet this need.

ISHSs target groups of students often underrepresented in STEM majors and careers (Means et al. 2008; NRC, 2011). These groups, which include ethnic minorities, women, students from rural areas, students from lower economic socio-economic status families, and first generation college-goers, have typically demonstrated greater achievement gaps on standardized testing in mathematics and science relative to dominant groups (Hill, Corbett, & St. Rose, 2010; Nichols, Glass & Berliner, 2012; NRC, 2011). The teachers in ISHSs must teach to a diversity of students, and guide them in the development of their cognitive and non-cognitive skills to meet the high bar of college acceptance and success in STEM fields (Farrington, Roderick, Allensworth, Nagaoka, Keyes, Johnson, & Beechum, 2012; Johnson, 2009).

ISHSs represent a relatively new type of school that is currently being investigated through a variety of studies. Some examples of these studies include the following: (a) identifying models of STEM schools and the relationship between student performance and components of the models (Century & LaForce, 2012); (b) defining ISHSs and developing case studies of STEM schools that are successfully preparing students from underrepresented groups for college STEM majors (Lynch, et al., 2011); (c) comparing the effects on student outcomes for students who attend ISHSs with those who attend other types high schools as well as comparing the characteristics on STEM education in both types of schools from principals' and students' perspectives (Means, House, Young, Wang & Lynch, 2013); and (d) research to understand the effects of student supports in STEM and subsequent college major selection (Weis & Eisenhart, 2009). Understanding how these schools are designed and the factors that appear to contribute to their effectiveness can lead to a theory of action to support the development of additional STEM schools (Lynch et al., 2011). Each of these studies has identified elements that appear to be significant to the schools' success including aspects of curriculum, pedagogical approaches to student learning, school culture and environment, educational resources, support systems, administrative structures, and others. However, in-depth analyses of the teachers and the professional development in these schools have not been reported.

An aspect that could serve to further an understanding of ISHSs is a thorough exploration and investigation to characterize the teaching staff in a small carefully chosen subset of ISHSs that are successfully preparing students from underrepresented groups for college STEM majors and pathways to success in STEM careers. Understanding teacher background preparation, how teachers work as STEM-educators individually and as a staff collectively, and how and whether the ISHSs utilize professional development to support and shape teacher skills and knowledge within the context of these schools to meet the needs of the target student groups could provide a framework for educational systems seeking to develop an effective STEM teaching staff within their schools.

Conceptual Framework, Literature Review, and Deficiencies in the Literature

The teachers I studied were nested in four exemplars of ISHSs, a subset of the eight schools included in an existing data set of a larger study of the characteristics of ISHSs—the *Multiple instrumental case studies of inclusive STEM-Focused high schools: Opportunity structures for preparation and inspiration* (OSPrI) study (Lynch et al., 2011). The schools chosen as exemplars of ISHSs in the OSPrI study met a variety of selection criteria. Each was a public or public charter high school that was thoughtfully planned using community support. It self-identified as a STEM-focused school that required more or more rigorous science and mathematics courses to graduate compared with district or state requirements, or its science, technology, engineering and mathematics classes were more integrated than traditional comprehensive public high schools the students might attend. It also had generally open admissions criteria that minimized emphasis on prior academic achievement or high-stakes test scores, often coupled with active recruitment of students from groups underrepresented in STEM majors in college and STEM careers (Lynch et al., 2011). Therefore, the teachers I studied worked in 9th through 12th grade schools that prioritized some aspect of science, technology, engineering, or mathematics and sought to meet the needs of students from groups currently underrepresented in STEM majors in college and in STEM careers and professions.

To provide a foundation for understanding both these teachers and these schools, I explored literature across the continuum from teachers through their schools and classrooms to student learning. The relationships among teacher characteristics, teacher learning, classroom practices, and student performance are complex and contextualized within each school. In Chapter 2, I systematically describe and analyze the research literature to characterize current understanding of these concepts and their interrelationships. The organization I used to explore the literature is shown in the conceptual framework in Figure 1. In the next section, I provide an overview of this exploration beginning with features of teacher quality, which in the conceptual framework is characterized as *STEM Teacher Academic Background and Experience* and *Teacher Professional Development.* I then move to a discussion of the *School Collaborative Culture* and *Teacher Professionalism*, and finally to *Learning by Students Underrepresented in STEM.* In Chapter 2, where this conceptual framework is discussed in greater detail, this image is presented again and the concept being described is highlighted in the image.

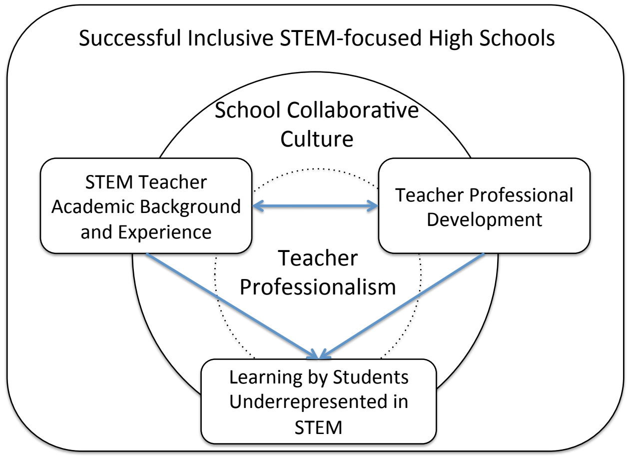


Figure 1. Teachers and teacher professional development in ISHSs conceptual framework: Situated within successful inclusive STEM-focused high schools, STEM teacher characteristics and school-based teacher professional development experiences supported by a collaborative school culture contribute to the development of teacher professionalism to enhance learning by students underrepresented in STEM college majors and STEM careers.

Teacher Quality

The search for an understanding of the factors comprising *teacher quality* exists throughout education, economics, and policy literature (c.f. Darling-Hammond, 1999; Hanushek, Kain, O'Brien, & Rivkin, 2005; Ho & Kane, 2013; NRC, 2011). The NRC (2011) suggested "teacher quality is considered the most critical factor affecting academic achievement" and yet goes on to say that while "there is no consensus on what defines teacher quality…the most common measures are content knowledge, experience, pedagogical skills, and academic skills and knowledge" (p. 79). Teacher quality has the potential to be affected by teachers' pre-service training and prior academic and professional experiences, in addition to their in-service continuing professional development once they begin teaching.

STEM teacher academic background and experience. Research studies have found correlations between individual student academic performance and the teachers who taught them (Sanders & Rivers, 1996; Slater, Davies, & Burgess, 2012) suggesting that the individual teacher matters. Other studies have identified specific teacher characteristics leading to improved student performance (Goldhaber & Brewer, 2000; Monk, 1994). Research studies on science and mathematics teachers specifically, have identified teacher certification or undergraduate coursework (Goldhaber & Brewer, 2000; Monk, 1994), a teacher's preparation route (Boyd, Grossman, Lankford, Loeb, & Wykoff, 2005), or participation in authentic scientific research experiences (Silverstein, Dubner, Miller, Glied & Loike, 2009) as factors affecting student performance. Understanding the characteristics of teacher preparation and background identified as having an effect on student performance generally, and more specifically, student performance in STEM subjects, helps establish a detailed set of descriptors to describe the teachers hired to work in the selected ISHSs. Teacher quality, however, is affected by more than the characteristics a teacher brings to the teaching position. Ongoing teacher professional development provided by the school further enhances teachers' attitudes, beliefs, skills, knowledge, and classroom practices (Desimone, 2009).

Teacher professional development. In the late 1980s, teacher professional development focused on job performance, described by Little, Gerritz, Stern, Guthrie, Kirst, and Marsh (1987) as "intended partly or primarily to prepared paid staff members for improved performance in present or future roles in school districts" (p. 1). Changes in understanding how people learn stemming from contributions from the fields of cognitive psychology, developmental psychology, and the learning sciences led to a more teacher, student, and school-centered focus (Bransford, Brown & Cocking, 2000; Newcombe et al., 2009). In 2002, Elmore articulated that teacher professional development "should be designed to develop the capacity of teachers to work collectively on problems of practice, within their own schools, and with practitioners in other settings, as much as to support the knowledge and skill development of individual educators" (p. 8).

Much research has been carried out to understand the effects of particular characteristics of teacher professional development on teacher learning, changes in classroom practice, and student performance. Kennedy (1998) directed the focus toward content and pedagogical content knowledge; Supovitz and Turner (2000) found the time duration of the professional development experience was important; Cohen and Hill (2000) explored relationships between policy, professional development, classroom practice, and student performance; and Garet, Porter, Desimone, Birman, & Yoon (2001) provided empirical evidence for characteristics of good professional development as predictors of teacher effectiveness. Darling-Hammond, Wei, Andree, Richardson, and Orphanos (2009) studied teacher professional development in countries achieving high success rates on international testing, finding teacher professional development that provided opportunities for sustained, intensive, active experiences involving collective participation, and focusing on content knowledge through a reform approach affected student performance. Summarizing and distilling these studies and others, Desimone (2009) created a framework identifying what she perceived to be the "core features of professional development" and the pathway through teachers to changes in classroom instruction and student learning (see Figure 2). Desimone suggested that professional development exhibiting these core features was more likely to change teachers, their classroom practices, and ultimately student learning. Throughout my study, Desimone's framework was used to examine the professional development experiences of teachers, and how teachers and administrators described the effects of these experiences in the selected ISHSs.

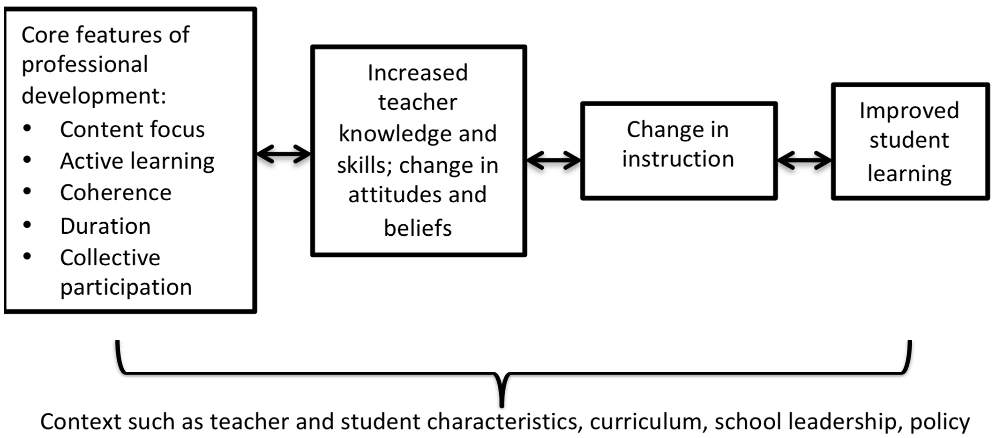


Figure 2. Desimone's (2009) conceptual framework for studying the effects of teacher professional development on teachers, classroom practices, and student learning (p. 185).

Beyond focusing on the characteristics describing effective professional development, several studies directed attention to the importance of the school context on understanding teachers' professional development experiences. Some studies explored connections between a school's culture and the effectiveness of the professional development experiences (Hamilton & Richardson, 1995; Kennedy & Smith, 2002). Others identified and explored the lesser-examined concept of teacher professionalization (Bloom & Unterman, 2013; Evans, 2002; Kennedy, Deuel, Nelson, & Slavit, 2011; NRC, 2004) as a factor resulting from, or further facilitating, effective teacher professional development. However, the ultimate goal of any school is to prepare students for their futures. The ISHSs in my study aimed to better prepare students underrepresented in

STEM for STEM majors and careers. The next section describes the research on issues or concerns found to particularly affect learning by the targeted student groups.

Learning by Students Underrepresented in STEM

The schools in this study were by design *inclusive*. Inclusive schools seek to reduce the barriers to entry with the aim of including greater numbers or proportions of students from groups underrepresented in STEM majors and careers: racial and ethnic minority groups, females, students of low socio-economic status, and students who would be first in their families to attend college. Other student groups that required additional consideration, who would be present in most schools, included students with learning disabilities and English language learners. There were several aspects of teaching and learning that were important when considering the needs of diverse learners, and by extension, the professional development that teachers might need in order to help address the needs of these students. A diverse student group has a range of prior academic preparation and experiences, cultural differences, self-perceptions of ability and capacity, and access to social capital (NAS, 2011).

Research has demonstrated that the social environment can affect student learning, different groups may experience the same environment through differential lenses, and changes to the classroom structure can lead to changes in student learning (e.g., Aronson, Fried & Good, 2000; Hazari, Sonnert, Sadler, & Shanahan, 2010; Reddy, Rhodes & Mulhall, 2007). Teachers may need targeted professional development to understand and respond appropriately to these needs (Bianchini, Cavazos, & Helms, 2000). Throughout the review of the literature on diverse learners, many studies sought to understand specific teacher characteristics or specific strategies to better meet the needs of underrepresented students (Kahle, Meece, & Scantlebury, 2000; Kanter & Konstantopoulos, 2010; Lynch, 2000). Other studies sought to understand the impacts of the social learning environment on these student groups (Durlak, Weissberg, Dymnicki, Taylor, & Schellinger, 2011; Murry & Pianta, 2007; NRC, 2011; Reddy et al., 2007).

Teachers' classroom practices can affect all students, but particular practices were found to differentially affect students underrepresented in STEM. Studies identified a number of factors beyond academic as affecting a student's interest in and choice to enter the STEM fields. Several studies found relationships between a collaborative, inquiry-based, project-based, or jigsaw type classroom-learning environments and some form of student achievement (Bowen, 2000; Geier et al., 2008; Sadler and Tai, 2007; Tai, Sadler, & Mintzes; 2006). Some studies addressed identity and the classroom practices fostering science identity development (Brotman & Moore, 2008; Carlone & Johnson, 2007; Hazari et al., 2010). Additional studies tried to understand students' mindsets regarding their abilities to be successful (Dweck, 1999), or their susceptibility to ego threat or stereotype threat (Aronson, Fried, & Good, 2002). These studies identified practices that appeared to enhance participation and engagement by students underrepresented in STEM. As such, they provided a framework for understanding the literature on classroom practices, professional development experiences, and teacher knowledge, skills, and beliefs about teaching in ISHSs.

Deficiencies in the Literature

The education research literature provides evidence that teachers affect student learning. The background preparation that teachers bring to a teaching position coupled with the professional development experienced while on the job serve collectively to shape teachers' abilities, affect the ways teachers communicate, collaborate, and cooperate, and influence classroom practices that serve to meet the needs of the ISHS's students. However, this review of the literature did not reveal an in depth understanding of the teachers who were hired to work in successful inclusive STEM-focused schools and the ways they interacted and collaborated. While the research described both the characteristics of effective professional development and professional development showing particular effectiveness in STEM, achievement and participation gaps still exist between mainstream students and students underrepresented in STEM. More focused efforts are needed to connect these studies within the realm of exemplars of ISHSs, schools that are successfully reducing achievement gaps and preparing increased numbers or proportions of students underrepresented in STEM for STEM majors and careers. This is a logical next step considering the valuable insights, implications, and information that this kind of study could offer states and school districts as they begin planning ISHSs of their own. This study yields better understanding of the relationships among the characteristics of STEM teachers, their professional development experiences, the school culture within which the teachers developed professionally, and the needs of the students served within these exemplars of ISHSs. This study may provide a framework for the creation and development of teaching staffs in ISHSs, or contribute to the better understanding of STEM teaching in any school.

Purpose Statement and Research Questions

The purpose of my study was to understand the characteristics of the STEM teachers and their corresponding school-based professional development within four schools selected as exemplars of ISHSs with a particular focus on practices that better teach and inspire students from groups currently underrepresented in STEM majors and careers. This multi-case study facilitated the analysis and interpretation of these data to understand the relationships between teacher characteristics and professional learning within each school individually, and cross-case synthesis provided increased understanding of the relationships across all four schools collectively. The following four research questions guided this study:

1. How might the backgrounds [educational, experiential, motivational] of the STEM teachers hired to work at successful ISHSs be characterized?
2. How is professional development conceptualized at each of these ISHSs?
3. How do STEM teacher characteristics relate to the conceptualization and implementation of teacher professional development at these ISHSs?
4. How do these STEM-focused schools use teachers' characteristics and professional development experiences to support STEM learning, interest, and agency of students underrepresented in STEM majors in college and STEM careers?

Theoretical Framework

This study is grounded in a constructionist epistemology, the perspective that all knowledge is "constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (Crotty, 1998, p. 42). Vygotsky's social constructivist theories point to increased learning in the presence of more experienced others within one's "zone of proximal development" who can push learning beyond what could be individually achieved (Vygotsky, 2011). Dewey speaks of education as "an active and constructive process" (1916, p. 38), which holds as true for teachers as for students. Within a school, it is not only the students who are learning. Interacting members of the school community have the potential to influence each other in positive and constructive ways. Each teacher arrives in a school with different experiences, skills, and perspectives that can contribute to the learning of others through a collaborative construction of knowledge and shaping of understanding.

Teachers come to schools with a set of prior experiences forming the basis of their subject area content knowledge and their pedagogical content knowledge (c.f. Monk, 1994, Shulman, 1986). The professional development within a school provides opportunities for the continued shaping and expansion of teachers' knowledge and skills, affecting the environment in which the entire school community learns (c.f. Khourey-Bowers, Dinko, & Hart, 2005; Ruddy & Prusinski, 2012). Teachers' skills and knowledge shape their performance in classrooms and ultimately what and how students learn and what they can achieve. The relationships among teachers, professional development, teacher classroom practices, and student performance are complex. Better understanding of how teacher characteristics interact with the ways a school perceives and shapes its professional development, and how these interplay with school culture and the development of teacher professionalism, with the ultimate goal of enhancing student experiences and performance may provide important insight into better meeting both teachers' and students' learning needs within a STEM focused learning environment.

Methodology

This qualitative research study, a multi-case study with cross-case analysis (Stake, 2006), involved a secondary analysis of an existing data set from the larger OSPrI study (Lynch et al., 2011). Data were analyzed from four of the eight ISHS school site visits completed by the OSPrI research team. Analysis focused on data on the teachers and their experiences with professional development within each of the schools as described in the conceptual framework (Figure 1).

Why Use Data From the OSPrI Study?

The OSPrI data set was ideal for this investigation for a variety of reasons. First, because the data from each site visit were collected by sets of six researchers visiting each school for three to four days in addition to pre- and post-visit data collection over several weeks, the data are rich and extensive, representing a much larger resource than a single doctoral candidate researcher could collect in a reasonable period of time. Data were systematically collected at each school using similar methods and protocols throughout the entire study that included interviews, focus groups, surveys, observations, and document analysis. Information was collected from teachers, students, administrators, parents, business partners, district personnel, and community members. This multiplicity of data types and sources contributed to the triangulation of data increasing the validity of my study. In addition, the data were coded and analyzed by all researchers participating in each OSPrI site visit, again providing a diverse set of perspectives for interpretation and crosschecking increasing my study's validity.

The collected data provided multiple windows into understanding teacher backgrounds, professional development experiences, classroom practices, and the school environment. Researchers in the OSPrI study observed several classroom lessons, recording students' and teachers' behaviors and interactions, along with uses of technology, teaching resources, and time, to help understand classroom practices and environment. Administrators participated in pre-site visit interviews, and teachers and administrators completed surveys, which additionally provided descriptive and quantitative data on staffing, staff characteristics, and professional development. Also, some of the data codes from the OSPrI study were relevant to my research questions and using data coded similarly by other researchers added validity to my study. (For additional information on the OSPrI study and data set, see sections titled: *The OSPrI study,* and *The existing data set* in the *Data Sources* section of Chapter 3.) While the OSPrI study was not designed to answer the particular questions identified in my study, the breadth of the data collected for the OSPrI study allowed my questions to be adequately investigated. The OSPrI researchers visited eight exemplars of ISHSs; the four selected for my study represented diversity in type and context, and additionally were intentionally chosen for their rich data on teachers and teaching from which both commonalities across the schools and conditions and situations unique to each were found.

My Contributions to the OSPrI Study

I have been involved with the "teacher aspect" of the OSPrI study from the start of the project, although I was not responsible for any aspect of the original proposal writing. I was a new graduate research assistant joining the team in the fall of my first term as a doctoral student, which coincided with the beginning semester of the OSPrI project. I was assigned responsibility for operationalizing the study of *Critical Component 7 (CC7): A Well-Prepared Teaching Staff* (Lynch et al., 2011; Note: The OSPrI study was designed in part to investigate the existence of *10 Critical Components* identified from research literature by the OSPrI researchers; see Appendix A for a list and brief description of the *10 Critical Components*). In collaboration with the principal investigators and research assistants on the research team, I worked on the design and validation of the Teacher Survey used in the OSPrI study, which was developed in part from existing national teacher surveys (*2000 National Survey of Science and Mathematics Education*, 2000; *Teacher Questionnaire: Local Systemic Change through Teacher Enhancement*, 2006). I also worked on the revision of classroom observation instruments, and the design and revision of teacher interview and focus group protocols to meet the specific needs of the OSPrI study. Finally, I was a member of the site-visit research teams at each of the four schools included in my study. This dissertation study went beyond the intent of the original OSPrI study to extract additional information and to interpret findings on teachers and the teaching and learning environments within each school and across all four ISHSs.

Case Study

This research fits the characteristics of a case study in that it primarily sought to answer *how* or *why* questions, was comprised of behavioral events over which the researcher had little control, and was a study of a contemporary situation (Yin, 2014). Four cases (the "quintain;" Stake, 2006), each an exemplar of an ISHS with its unique set of STEM teachers, made up the multi-case study. The unit of analysis for the case studies in the original OSPrI study was the individual school. While my study was of a subsection of the original data, focusing on the teachers and their experiences within and across the schools, the unit of analysis was still the school. The teaching staff was considered in aggregate at the level of each ISHS rather than at the individual teacher level. Individual analyses were performed for each of the school sites focusing on any and all data that pertained to teachers and school-based professional learning within each

ISHS with the goal of understanding the relationships among teachers, professional development, and the needs of the students enrolled in each school. Multi-case analysis provided an understanding of each ISHS's approach to creating a teacher community of learners to meet the needs of the student groups enrolled. Cross-case analysis across all four cases facilitated the understanding of the commonalities of the quintain while maintaining the uniqueness of each individual case (Stake, 2006).

This study involved a review of all of the OSPrI data as it pertained to teachers and the professional development in each of the four selected schools. The original OSPrI case studies were used as a resource to understand the school context and to provide an overview of the data from each school. The teachers' characteristics were primarily understood through analysis of the survey data collected prior to each site visit, although the data coded for *CC7: A Well-prepared Teaching Staff* provided teachers' voices as they came through in interviews and focus groups, and *CC9: Administrative Structure* provided information on administrators' thinking about teacher hiring, which helped to triangulate survey data (Maxwell, 2005). A characterization of teachers' professional development experiences and the teaching and learning environment in each ISHS were investigated through re-analysis of data from both *CC7* and *CC9* coded data, which included teachers' and administrators' thinking about school-wide professional development experiences and opportunities as expressed through teacher focus groups, and teacher and administrator interviews. Other data coded such as *CC2: Reform Instructional Strategies and Project-Based Learning*, and *CC10: Supports for Underrepresented Students* provided insight on classroom practices and targeted efforts to meet student needs.

All data were thoroughly read and reviewed using a constant comparative method of analysis, which allowed for the systematic generation of theory through joint coding and analysis (Glaser, 1965). Data analysis began by coding the data using open, theoretical codes arising from the research literature. Researcher memos were written throughout the coding process allowing for the redesigning and reintegration of "theoretical notions" (Glaser, 1965) as well as the emergence of additional codes and categories for analysis. Subsequent passes through the data involved pattern coding, to reduce the codes by creating larger categories; and axial coding, to understand the relationships among the categories (Saldaña, 2009). This iterative process, moving between data coding and hypothesis formation, which allowed for the development of a "theory which is integrated, consistent, plausible, [and] close to the data" (Glaser, 1965, p. 437), was carried out with data from each individual ISHS in this multiple case study in the creation of four unique case studies (Appendix C).

Cross-case synthesis followed the creation of the individual case studies to establish themes that "transcend the cases" (Creswell, 2007). Validation was sought through reinforcement throughout the four cases. To the extent possible, these data on teachers and their teaching and learning environments in four ISHSs were analyzed and interpreted to understand how and whether professional development experiences related to teacher characteristics and the needs of the student groups served by these ISHSs.

Limitations, Delimitations, and Assumptions

This study was delimited to the analysis of the data previously collected in the preparation of eight ISHS case studies as part of the larger OSPrI study (Lynch et al. 2011). Four data sets from the schools I visited were selected for analysis in my study. As a result of these delimitations, there are limitations in the data. This set of schools is but a small representation of ISHSs throughout the U.S., although they were chosen to provide some urban, rural, and suburban, geographical, and student diversity. All were public schools, but all were also schools of choice requiring an application to attend. Although these applications for admission required minimal information and the selection process was primarily by lottery, this process could have resulted in student populations that were not fully characteristic of the demographics of their districts. Among the schools selected for my study, magnet, charter, and networked charter schools were represented; none were traditional neighborhood public schools. Their structures included stand-alone schools, schools on campuses with other networked schools, and networked schools sited separately. All schools were relatively small with student populations ranging from mid-200s to fewer than 600 students.

Because my study took advantage of a previously collected set of data, it was not possible to create finely tuned instruments to directly target my study's research questions. Instead, the data were scoured to uncover the desired information. In the original OSPrI study, even though the study was at the school level, there were many opportunities for teacher voices to be captured, including teacher focus groups, teacher interviews that followed classroom observations, and the pre-visit Teacher Survey. Additionally, information about professional development could be extracted from document reviews, the administrator survey, and pre-visit and on-site administrator interviews. I believe that the richness of the data provided by this data set over-rides concerns about designing instruments to specifically respond to the research questions.

One noteworthy feature of the OSPrI study was that *exemplars* of *successful* ISHSs were intentionally selected for the study, and as a result an important goal of the study was to create a theory of action (Lynch et al, 2011) for successful ISHSs. An assumption of the OSPrI study was that these ISHSs were working well, and the aim was to understand the commonalities across the schools to shape a description of practices appearing to support successful ISHSs. The OSPrI study, therefore, was not evaluative and did not seek to differentiate among the schools to identify more or less effective practices, but instead to identify those common practices appearing across all schools.

My study of teachers and teacher professional development also sought to understand common practices among the four ISHSs in my study in order to gain an understanding of teacher characteristics, teacher professional development, classroom practices, and school environments that may better support successful school and student outcomes. Each individual Teacher and Teacher Professional Development in ISHSs case study (Appendix C) written for this study included information unique to each school. However, the cross-case analysis sought to understand the teacher-related commonalities across the four schools, occasionally describing different interpretations or representations of common practices, but it did not intend to evaluate the differences between schools.

Definitions of Key Terms

Several terms are used throughout this study that may have more general or alternate definitions in common practice. The definitions used for these terms throughout the remainder of this study are described below.

Teacher characteristics: Aspects of teacher's pre-service experiences that have the potential to influence student learning. Research points to a number of factors including content knowledge, pedagogical content knowledge, academic coursework and degrees, and teacher certifications, along with various teaching, professional, and research experiences (Goldhaber & Brewer, 2000; Monk, 1994; Silverstein et al., 2009).

Professional development: For the purposes of this study, the term, professional development, is used when referring to all professional learning experiences that are facilitated or enabled by the school or school system for the continued advancement of teachers employed by the school (Desimone, 2009; Elmore, 2002).

Groups underrepresented in STEM: This term is used to refer to different demographic groups that to date are not represented in STEM majors in college or in STEM jobs and careers in the same percentages that they are present in the U.S. population. At the time of this study, these groups included women, Blacks, Hispanics, Native Americans, Alaska Natives, Native Hawaiians, students from families of lower socio-economic status, students who would be first in their generation to attend college, English language learners, and students with disabilities (NRC, 2011).

Inclusive STEM-focused high schools (ISHSs): This term is used extensively in this study because the four school sites explored are exemplars of this type of school. By design these schools focus additional attention on some aspect of science, technology, engineering, or mathematics, which may arise as integration across these disciplines, a greater intensity or depth of study within one or more of the disciplines, or extension from these disciplines into the real world. These schools also seek, through reduced barriers to entry, to prepare students underrepresented in the STEM fields for STEM majors in college and STEM careers (Lynch et al., 2011). Because the specific schools for this study were intentionally selected as those effectively preparing increased numbers or proportions of students from underrepresented groups for STEM majors and pathways to STEM careers, throughout this study these specific ISHSs may be referred to as “successful ISHSs” or “exemplars of ISHSs.”

The literature base that supports both these definitions and the research questions for my study are described and explored in Chapter 2, *Review of the Literature.*

Chapter 2: Review of the Literature

Introduction

This study used data collected from four successful Inclusive STEM-focused High Schools (ISHSs) to investigate their teachers and the teaching and learning environments. The teachers who were the focus of this study taught in 9^{th} through 12^{th} grade schools that prioritized learning in science, technology, engineering, and mathematics (STEM) and sought to meet the needs of students from groups underrepresented in STEM majors in college and in STEM careers and professions. These student groups included racial and ethnic groups such as Blacks and Hispanics, people of lower socioeconomic status, and females. Also included were students who would be first in their families to attend college, students with disabilities, and English language learners. The exemplars of ISHSs in this study were smaller schools with student populations under 600 and were public charter, public magnet, or otherwise public schools of choice. These ISHSs graduated increased percentages of students underrepresented in STEM relative to their towns, districts, or states, and more successfully prepared these students to enter college STEM majors and STEM careers (Behrend, Ford, Ross, Han, Peters-Burton, & Spillane, 2014; Lynch, Spillane, Peters-Burton, Behrend, Ross, House, & Han, 2013; Peters-Burton, Ford, Ross, Behrend, Spillane, & Han, 2014; Spillane, Kaminsky, Lynch, Ross, Means, & Han, 2013). Understanding the characteristics and professional development experiences of teachers in these successful ISHSs provided insight into the development of teaching staffs to better meet student needs in similar schools. This knowledge may also be extrapolated to STEM teachers in high schools more generally. While there is extensive literature on teachers and teacher professional development, and there is some understanding of learning by student groups currently underrepresented in STEM, there is not a strong literature base examining teachers and teaching in successful ISHSs, and the relationships among teacher characteristics and teachers' professional development opportunities, particularly focusing on learning by students underrepresented in STEM in these schools. My study sought to fill this gap.

Overview of Topics

This review of the literature provided a framework for the development of my study. Four major domains of knowledge and one sub-domain were explored, synthesized, and analyzed to build a foundational understanding from which to examine the teachers and their teaching and the learning environments in four exemplars of ISHSs. These domains of knowledge provided background for the development of the conceptual framework that guided my study (see Figure 1). The four major domains reviewed included: (a) *STEM teacher academic background and experience*; (b) *teacher professional development* [Note: these first two domains were initially conceptualized at *teacher quality* and were later separated into these two separate domains.]; (c) *school collaborative culture*; and (d) *learning by students underrepresented in STEM.* Also reviewed as a sub-domain of school collaborative culture, was *teacher professionalism* or *teacher professionalization*. This sub-domain was much less pronounced in the literature and referenced far less frequently than the four major domains. However, it appeared in subtle but unique ways that suggested its potential to be increasingly significant as this study unfolded, and was therefore included in this review and in the study's conceptual framework.

An examination of the research literature on STEM teacher academic background and experience provided a base of knowledge on the relationships found between teacher characteristics and measures of student performance, achievement, or success. An exploration of the teacher professional development literature identified characteristics of teacher professional development found to change or expand teachers' thinking and/or classroom practices, and/or to affect student performance. An investigation of the literature on the school environment led to the establishment of the more focused domain of school collaborative culture highlighting its influence on teacher effectiveness, the effectiveness of professional development experiences, and various measures of student performance. Literature on teacher professionalism identified conceptualizations of this construct; the different ways it was measured and characterized; and some relationships with teacher characteristics, professional development experiences, school collaborative culture, and student performance. Finally, a review of the research literature on learning by students underrepresented in STEM characterized differential learning effects of classroom practices, and school social and emotional environments on diverse student groups. To the extent possible, studies that focused on some aspect of STEM in high schools, and public schools were reviewed. However, where there was a lack of target literature, this review referenced tangential or broader domains and extrapolated to the desired targets.

The Literature Search Process

This review of the literature began as a non-linear exploration into a variety of topics that appeared to have the potential to inform the fields of teacher quality, teacher professional development, and student learning. Once the domains identified above were established, I focused my review by reading the recently published books currently being used to inform the design of pre-service teacher programs, teacher professional development, and processes for teacher evaluation (Darling-Hammond, 2013; Darling-Hammond & Bransford, 2005; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). I then read a series of reports from the National Academy of Sciences that characterized current issues in schooling, teaching, and learning (NRC, 2000a; NRC, 2000b; NRC, 2004; NRC, 2011; NRC, 2012). Next, I examined the research studies that were referenced in the books and reports that made up my foundational reading. These books, reports, and preliminary research studies allowed me to create sets of keywords that I could use to explore the peer-reviewed research literature in each of the identified domains. However, throughout my literature review process, I continued to refine both keywords and concepts, and to let the conceptual framework for my study evolve as I acquired new knowledge and new understanding.

I examined the peer-reviewed research literature using various combinations of the keywords in Table 1 to find studies that would contribute to the development of each identified knowledge domain. I began with keyword searches of relevant online literature databases, including ERIC (EBSCO), JSTOR, PsycARTICLES, PSYCinfo, and PolicyFile, initially prioritizing meta-analyses and review articles. From these search returns, I screened the articles by title to identify those with potential to inform the domains. From this collection, I read abstracts and further collected and culled the selections, downloading and saving articles that appeared to fit the desired categories. I entered all literary works into a Zotero file [Zotero is an online tool for collecting and organizing research literature]. I read these articles beginning with those with abstracts suggesting the greatest relevance to the research domains, and giving some emphasis to more recent research studies. I coded each article with "tags" that would allow the article to be found in the Zotero file by searching using identified words; notes were entered for future reference. As I read each article, I reviewed their lists of references for relevance, and downloaded, saved, read, categorized, and tagged them as appropriate. I continued this process of searching, collecting, reading, reviewing, and coding articles in an ongoing, iterative process until I felt that I had reached an adequate level of information saturation for each of the identified domains. At this point, in an effort to make sure that the most current studies were included in my review, I performed targeted keyword searches of recently published journals that were highly regarded for their relevance to my study (e.g. JRST, JSTE). Finally, in a similar search, I performed keyword searches of the recent literature in GoogleScholar to ensure that I was not overlooking appropriate research outside of the anticipated journals or fields. Ultimately, I reviewed in full over 110 research studies and over 70 scholarly works, although the list of all studies examined is far larger.

Table 1

Keywords for Literature Search

Topic	Sources Consulted[a]	Keywords
STEM Teacher Academic Background and Experience	NRC studies Education Journals Economics Journals Policy Journals	• Teacher: − quality − effectiveness − preparation − evaluation − background − performance − cosmopolitanism
Keyword modifiers targeting student		• student: − achievement

performance		− performance − test scores − outcomes − standardized testing
Teacher Professional Development	Books on pre-service, in-service, teacher evaluation program development Education Journals Subject Area Journals Administration or Leadership Journals	• teacher: − professional development − learning − quality − effectiveness • teaching reform • classroom reform • reform practices
Keyword modifiers targeting specific characteristics of teacher professional development		• collaboration • collective practice • collaborative learning • school-wide reform • content focus (also science, mathematics, engineering technology, STEM, specific sciences) • coherent, sustained, intensive, and active learning • high school or secondary school
Keyword modifiers targeting classroom practices		• project-based or problem-based (PBL) • inquiry, or inquiry-based classroom practice • peer-mediated, peer-to-peer
School Collaborative Culture	Education Journals Leadership Journals	• School: − culture − environment − climate • positive, supportive, collaborative, collective
Keyword modifiers for particular types of schools		• themed schools • magnet schools • charter schools • schools of choice • small schools

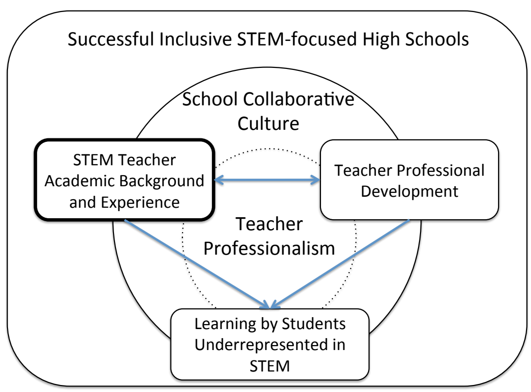
Teacher Professionalism	Education Journals Leadership Journals	• professionalism • professionalization • autonomy • distributed leadership • flattened hierarchy • decisional capital
Learning by Students Underrepresented in STEM	Education Journals Psychology Journals	• underrepresented • minority • race • ethnicity • girls • women • [low] socioeconomic status, SES • first generation • English language learners, ELL • disability • STEM

[a]Sources identified are those beyond the research databases described in this section.

Over the course of my review of the literature, I refined the domains to address the concepts highlighted in my conceptual framework (see Figure 1). In the following sections, I synthesize and analyze the research literature to provide a description of the state of current understanding and to identify the direction and focus of my study. To provide a visual focus for the flow of ideas in this review, I present a graphic of my conceptual framework at the beginning of each section with the relevant concept highlighted.

I begin this literature review with a description of the characteristics of teachers, STEM teachers in particular, that were found to affect student learning. This content, *STEM Teacher Academic Background and Experience,* falls under the umbrella of teacher quality, but will focus primarily on the characteristics a teacher brings to a particular teaching position. In this discussion I provide definitions of teacher quality found in the literature and explain the choices in my conceptual framework. I review the literature on *Teacher Professional Development*, focusing particularly on professional development that might affect student learning in STEM. Next, I introduce the concept of S*chool Collaborative Culture* and examine its relationship with collective practice, effectiveness of professional development, sustaining reform, student performance, and the overall school environment. Within the section of *School Collaborative Culture*, I include a description and discussion of *Teacher Professionalism*. In a final section on *Learning by Students Underrepresented in STEM,* I describe studies on teacher and classroom practices that may affect student learning—particularly by students from underrepresented groups, and where possible in STEM—and how these may relate to teacher professional development.

STEM Teacher Academic Background and Experience



Teacher quality is related to the knowledge and skills that a teacher brings to a teaching position, often acquired in part, through a program of formal pre-service teacher preparation. In-service training, learning that takes place after a teacher is situated in a school, also plays a role in teacher quality and are addressed in the section of this chapter on *Teacher Professional Development*.

Beyond an understanding of how the more easily measured teacher characteristics of academic preparation, certification, and years of experience are predictive of student performance, there is increasing attention focused on assessing teachers' effectiveness in the classroom. The NSB, *2012 Science and Engineering Indicators* report characterizes teacher quality in two ways: one that is easily measurable, and a second that is less so. The first includes "educational attainment, professional certification, participation in practice teaching, self-assessment of preparation, and years of experience" (NSB, 2012, p. 1-22). The second includes teachers' "abilities to motivate students, manage the classroom, maximize instruction time, and diagnose and overcome students' learning difficulties" (NSB, 2012, p. 1-22). The NSB recommends that STEM teachers' preparation should provide them with "adequate STEM content knowledge that is aligned with what they are expected to teach" (NSB, 2012, p. 1-24), but there are no specifications about how this should happen.

Research studies over the years have found correlations between individual teachers and student performance, suggesting that teachers do make a difference in student learning (Sanders & Rivers, 1996; Slater, Davies, & Burgess, 2012). More targeted studies have identified specific teacher characteristics such as academic preparation and teacher training as influencing student performance (Goldhaber & Brewer, 2000; Monk, 1994). The more measurable teacher-specific characteristics are addressed in the following section. Classroom practices found to influence student learning are discussed in a later section on *Learning by Students Unrepresented in STEM*.

Teacher Quality and Student Performance

Two studies found correlations between student performance and the teachers who taught them. The first (Sanders & Rivers, 1996) looked at student performance on standardized tests in elementary school, and was a longitudinal study that disaggregated teachers into quintiles by their effects on students, and students into quartiles by the incoming academic performance. The second study (Slater et al., 2012) connected secondary subject area teachers with students' high school subject-area performance measures.

The Sanders and Rivers study of elementary school teachers and students described significant effects of teacher quality on subject-specific student performance that is somewhat relevant to the secondary level because of its focus on mathematics alone. In this large quantitative study, Sanders and Rivers (1996) used a multivariate, longitudinal statistical analysis of mathematics achievement test performance by nearly 4,000 students in Tennessee from grades 3 through 5. These students were second graders in 1992-1993 and fifth graders in 1994-1995. The research found evidence that teachers' effects on students were both *additive and cumulative*, [which the researchers described as teacher effects adding from year to year, but independent of the previous year's teacher effect, as well as cumulative across a student's entire years of schooling] and there was little evidence that a good teacher could compensate completely for previous poor ones. Students who had had several lower quality teachers in a row performed significantly lower than their peers who had a series of higher quality teachers. This study also found that an increase in teacher quality resulted in the most significant gains on standardized tests for the lowest performing quartile students, with greater gains being noted for each successively higher quintile teacher. One interesting finding was that, on average, students in the highest quartile of achievers only met the targeted academic gains when in classes taught by the top quintile of teachers. Also, although this study found a disproportionate number of Black students compared to White students in classes taught by the lower performing quintiles of teachers, student performance within a quintile was comparable across both Black and White student groups—a poor teacher did not have a disproportionate effect on one ethnic group over another. Likewise, there were no disproportionately positive effects on either Black or White students by a particularly effective teacher.

Slater et al. (2012) carried out a large study of 7,305 students and 740 teachers in 33 state secondary schools in England between 1999 and 2002. The researchers performed a statistical regression analysis to link students' high-stakes English, math, and science exam performance at age 16 with their teachers for these subjects, and were able to control for students' prior academic performance. This study found that having a high quality teacher had a significant effect on student test scores. A student taught by a teacher in the top 75th percentile of teacher quality would add 0.565 of a General Certificate of Secondary Education (GCSE) point per subject over a student taught by a teacher in the 25th percentile, an increase the researchers described as a "not trivial" (Slater et al., 2012, p. 42) effect. However, while student performance was found to correlate with teacher quality, the researchers were not able to identify specific teacher characteristics as being responsible for the observed effects.

These two studies described teacher effects—a good teacher could have a greater impact on student learning than a poor teacher, and a series of poor teachers could set a student on a trajectory that was challenging for future educational experiences to remedy. When considering student performance, the quality of the teacher emerged as a significant factor. However, these studies did not identify *particular* teacher characteristics as being responsible for this teacher quality effect. In the following section, several studies are described that explored connections between specific teacher characteristics and student performance.

Teacher Characteristics and Student Learning

Several studies sought to find relationships among specific teacher characteristics and student performance. These studies focused on characteristics of academic background (Monk, 1994) and teacher preparation (Boyd, Grossman, Lankford, Loeb, & Wykoff, 2005; Goldhaber & Brewer, 2000) that are generally acquired before a teacher begins working in a school, as well as years of teaching experience (Harris & Sass, 2011).

Monk (1994) ran regression models to understand the effects of secondary school teachers' mathematics and science subject matter preparation on students' performance gains in these subjects. Using data from the *Longitudinal Survey of American Youth*, Monk studied 2,829 students entering 10th grade in the fall of 1987, selected through a stratified random sampling of public schools to represent U.S. geographic regions and community types. Survey data were collected between 1987 and 1991 from students, their teachers, and their parents; mathematics and science achievement test data were collected from 1987, 1988, and 1989. Monk was able to match teacher data with student data. This study found positive relationships between the number of undergraduate mathematics courses a teacher took and student improvement in mathematics, with the most significant effects being associated with the addition of each mathematics course up to five. Undergraduate mathematics pedagogy courses were also significant, and in fact, were found to be more significant than mathematics courses themselves. Having earned a major in mathematics was not found to be significant. It was found that teachers having a science major and the number of science education courses were significant predictors of student performance in science, but there was no relationship found between the number of science courses taken and student performance. This study did not find that the number of years of teaching experience had a significant effect on student performance. Although not consistent across subjects, in general, Monk found that teacher subject area content and educational preparation as measured by teachers' college major, courses taken in the subject-area, and courses taken in pedagogical content positively affected student learning in mathematics and science.

Using the *National Educational Longitudinal Study of 1988* (NELS:88), Goldhaber and Brewer (2000) studied 12th grade mathematics students (N = 3,786) and science students (N = 2,524) matched with their mathematics teachers (N = 2,098) and science teachers (N = 1,371) using multiple regression analysis to understand the relationship between teachers' type of teaching certificate and students' performance on standardized tests in science and mathematics. Significant findings from this study indicated that mathematics students who had teachers holding either bachelor's or master's degrees in mathematics performed better than students of teachers with degrees in other subjects; however, there were not similar findings for science. Although there were no significant differences between teachers with emergency and traditional certifications, students of teachers who were not certified in mathematics performed worse than those of teachers who were certified. In addition, the researchers found some evidence that teachers holding certificates from states with higher certification standards showed positive effects on student performance in both mathematics and science; however, these relationships were not strong.

Several studies found relationships between student learning and teacher certification. Boyd et al. (2005) studied the relationship between student performance and teacher preparation by traditional or alternate routes to certification. Using data from students and teachers in grades 3-8 in high-poverty urban schools in New York City, Boyd et al. found teachers who entered through alternate pathways to certification demonstrated smaller initial student gains in both mathematics and English language arts compared with teachers entering through traditional pathways. Desimone and Long (2010) found that a student's academic growth in first grade was significantly slower if the student's teacher had less than a bachelor's degree, and the academic growth happened significantly faster if the teacher had permanent, long-term, or alternative certification, rather than an emergency certificate or no certification to teach. However, both of these studies are of earlier grades than my target groups and it is less common that a secondary teacher will not minimally hold a bachelor's degree. Finally, content area preparation is often very different for secondary teachers than primary teachers. Therefore, these two studies may be less relevant to my investigation; however they do suggest that there may be differential effects arising from teachers' certification routes and preparation pathways.

While not measuring teacher characteristics directly, Darling-Hammond (1999) reported that states (Connecticut and North Carolina, and to a lesser extent, Kentucky, Arkansas, and West Virginia) that sought to improve teacher quality by investing in research-based reforms such as teacher pre-service education, licensing, teacher mentoring, and raising their teacher certification requirements between 1992 and 1996 showed some of the most significant gains in student performance on the NAEP 4th and 8th grade assessments over this time period. States that focused instead on student and teacher accountability through investments in high stakes achievement testing (Georgia and South Carolina) showed, at best, flat performance, but more often a decline in student performance over the same time period.

Harris and Sass (2011) carried out a large statistical analysis to understand the relationships between a teacher's background training and other measures of teacher quality, and student achievement. A large data set from Florida allowed the researchers to match students (between 160,000 and 260,000 students) and their performance on state standardized math and reading tests with teachers, and teacher education programs. Aside from some professional development effects, this study found the only teacher characteristic having a significant positive effect on student performance across subjects was a teacher's years of teaching experience. For middle school mathematics teachers, teachers' professional development experiences were found to have a positive and significant effect on student achievement. The effect was negative, but non-significant, for the year the professional development was experienced, but positive and significant for the following 2-4 years. While there is an appeal to the comprehensiveness of studies such as Harris and Sass (2011), with few standardized tests assessing student learning aligned with teaching in all subject areas, it is difficult to convincingly demonstrate the relationship between teacher characteristics and student learning in high school courses.

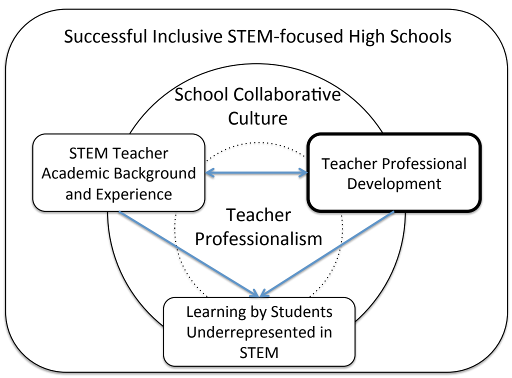
Similar problems are likely an explanation for a lack of studies relating teacher preparation and types of certification at the secondary level.

One characteristic Bryk, Sebring, Allensworth, Luppescu, and Easton (2010) studied that reflected a collective characteristic of a teaching staff rather than of an individual teacher was that of *teacher cosmopolitanism*, as assessed by the extent to which teachers brought a diversity of learning experiences to the school by coming from geographically diverse locations and educational backgrounds. Although, on its own, a strong teacher cosmopolitanism was not found to have a significant effect, a *weak* teacher cosmopolitanism combined with either a weak commitment to school reforms or weak professional community within the school significantly increased the likelihood of school failure.

Summary

These studies on teacher characteristics and teacher quality identify the importance of teachers in student learning. High quality teachers have more positive effects on student learning than lower quality teachers. While an absolute measure of teacher quality is difficult to quantify, these studies suggest, particularly in science and mathematics, that several factors should be considered. Subject-content preparation and pedagogical-content preparation, teacher certification in the subject area being taught, higher standards for that certification, and years of teaching experience all have the potential to positively affect student academic performance. Teacher cosmopolitanism within a teaching staff may also play a role. In my study, an exploration of teachers' academic backgrounds and teacher certifications relative to the subjects taught, along with their years of teaching experience, both in their current school and overall, provided some evidence of teacher preparation and teacher quality. In addition, examining data on the locations and types of colleges and universities the teachers attended allowed the derivation of a level of teacher cosmopolitanism within each school. The teacher surveys along with data from teacher interviews and focus groups provided much of this information. In some of the literature described above, teacher professional development also emerged as contributing to and enhancing teacher effectiveness beyond the effects of individual teacher characteristics. In the next section, the effects of teachers' professional development experiences on student learning are explored in greater detail.

Teacher Professional Development



Teacher professional development, or in-service teacher training, is in part the school-based teacher learning that begins or continues after a teacher is hired. Teacher professional development has the potential to affect teachers' knowledge, skills, attitudes, beliefs, classroom practices, and ultimately student learning (Desimone, 2009).

Changes in Thinking About Teacher Professional Development

Recent changes in the thinking about the design and function of professional development stem from contributions from the fields of cognitive psychology, developmental psychology, and the learning sciences reflecting new understanding about how people learn (NRC, 2000b; Newcombe et al., 2009). Along with these changes, questions about the content of the curriculum have undergone transformation from Spencer's (1894) "What knowledge is of most worth?" (p. 11; content driven) to Charters' (1920) "By what means should we determine what we will teach?" (Pinar, Merriam, Slattery & Taubman, 2008, p. 101; methods driven), to more currently Apple's (2004), "whose knowledge is of most worth?" (p. xxvi; culture and hierarchy driven). Reflected here are changes in thinking about the academic content being taught in schools, the methods of teaching and learning, and the socio-political drivers of curriculum. If classroom learning for students is to undergo transformation, there must be concurrent changes in classroom instruction, which must involve teacher learning (Cohen & Hill, 2000; Desimone, 2009). In addition, demographic shifts in the student population in the U.S. have influenced thoughts about teaching to a diversity of learners (NRC, 2011). Hawley and Valli (1999) described these fluctuations in educational expectations as moving from teaching *some* students to teaching *all* students, and replacing "teaching by telling" with "teaching for understanding" (p. 132). Thoughts about schooling are influenced by increased focus on the learner, the content to be learned, how learning will be assessed, and how learning fits within the social context. As articulated in *How People Learn* (NRC, 2001), there is an advantage to educational practices being *learner-centered, knowledge-centered, assessment-centered,* and *community-centered.* These changes in thinking about student and teacher learning have influenced changes in what is perceived as high-quality professional development experiences for teachers.

Characteristics of High-Quality Teacher Professional Development

Teacher professional development is a broadly used term to describe experiences that enhance teachers' performance. Current conceptions acknowledge that these experiences do more than improve the knowledge and skills of individual teachers; they recognize the importance of the coherence and contextualization of teacher learning along with collective or collaborative practice (Elmore, 2002).

Teacher professional development has been described and analyzed through a variety of lenses including its *structure*, *format*, *audience*, *outcomes,* and *theoretical basis*. Structure refers to the method of delivery through experiences such as conferences and workshops, college coursework, summer institutes, research work, and in-school coaching and mentoring. Format might refer to professional development as a single event, an intense short-term experience, sustained reoccurring meetings, or regular online connections. The audience might be novice or experienced teachers, teachers of a specific subject, a collaborative group, an entire faculty, or a single teacher. Targeted outcomes might include gains in teacher knowledge, culture change, changes in classroom practices, or changes in student attitudes or achievement. And theoretical basis might refer to a theory of learning, a theory of instruction, or a theory of change. In exploring the research on teacher professional development, I used Desimone's (2009) framework (see Figure 2) to organize the vast network of literature in this field. This framework articulates the progression from teacher professional development to changes in teacher knowledge, skills, attitudes or beliefs, to changes in classroom instruction, to improvement in student learning. It also identifies the "core features"—the research-based characteristics—of effective professional development that are described in the next section (Cohen & Hill, 2000; Garet, Porter, Desimone, Birman, & Yoon, 2001; Kennedy, 1998; Supovitz & Turner, 2000).

Studies supporting a professional development framework. Many studies provided the research basis to support Desimone's (2009) framework for effective professional development. One of the first studies to identify a particular characteristic of teacher professional development as having a significant effect on student learning was a secondary analysis of 12 studies that linked professional development experiences of K-12 science and mathematics teachers with student achievement (Kennedy, 1998). Four of the studies included middle or high school teachers; all others were at the elementary level. The experiences represented a variety of forms and varied in intensity, length of time, format, in-class observation, and mentoring. Kennedy found the single greatest factor affecting student learning was whether the teacher professional development was focused on subject area content. The majority of the studies dealt with teachers' knowledge of the subject and on how students learned particular content—the pedagogical content knowledge (PCK; Shulman, 1986). These were both categorized as subject area content in Kennedy's study. Kennedy concluded that the content focus of the professional development experience had more significant effects on student achievement than the method of the delivery, or the time span or intensity of the experience.

Supovitz and Turner (2000) explored characteristics of professional development that led to teachers changing their classroom practices. The study surveyed 3464 K-8 science teachers and 666 principals who participated in the *Local Systemic Change* (LSC) initiative in 1997, an initiative designed to prepare teachers to implement exemplary instructional materials in the classroom. The surveys asked teachers to report on the frequency of their use of reform-based teaching practices such as whether they facilitated student discussion, asked students to supply evidence, explain concepts, etc., (what the researchers referred to as promoting an *investigative classroom culture*). Findings from this study demonstrated that increasing hours of professional development significantly increased teachers' use of inquiry-based practices and levels of investigative classroom culture. Teachers who participated in fewer than 40 hours of professional development engaged in more traditional practices than the average teacher, and those who participated in more than 80 hours of professional development reported significantly more frequent use of inquiry-based practices and had more investigative classroom cultures than the average teacher. This study is the source of the recommended "80 hours of professional development" (Supovitz & Turner, 2000, p. 973) that is often cited by subsequent studies as the tipping point for successful professional development experiences. Supovitz and Turner also found a positive correlation between the level of investigative classroom culture and a teacher's attitude toward reform, a teacher's content preparation, and support from the school principal.

A study by Cohen and Hill (2000) sought to understand the relationships among state education policy, teacher professional development, classroom practices, and student achievement during a time of statewide curricular change in mathematics. While the participants in this study were teachers in the higher grades in elementary school, the results of this study could be extrapolated to subject area teachers in secondary school because of the focus on single subject-area (mathematics) instructional change supported through content-specific curriculum-targeted professional development experiences.

In 1985, California introduced a new *Mathematics Framework* that "called for intellectually much more ambitious instruction" (Cohen & Hill, 2000, p. 296) and sought to encourage the change by providing approved classroom resources, teacher professional development, and standardized assessments to match the curriculum. The reformed student assessments were ultimately administered to students during the 1993 and 1994 school years. Cohen and Hill used the results from a 1994 statewide teacher survey along with student test scores aggregated at the school level to understand the relationships. This study surveyed a stratified random sample of 975 California teachers. Throughout the state, teachers were offered relevant professional development that targeted content and pedagogy associated with the new policy-driven curriculum. The study explored two relationships: first, between teacher professional development and classroom practices, and second, between the effects of the knowledge of and use of the state assessments and teachers' classroom practices. After characterizing these relationships, Cohen and Hill calculated school-level scores of classroom practices, professional development participation, and other school-environment factors and compared these with student achievement at the school level.

Cohen and Hill (2000) found that teachers who had the opportunity to engage in professional development that was specifically focused on the targeted curricular changes reported engaging in more reform-oriented practices in their classrooms. The amount of time spent in professional development positively affected teachers' use of reform-oriented practices. Teachers who participated in professional development for an average of two days reported nearly one-half of a standard deviation higher, and those who attended a one-week-long workshop reported a full standard deviation higher frequency in the use of reform-oriented practices in their classrooms over the average non-participant. Additionally, teachers who had an average amount of participation in curriculum workshops reported the use of fewer conventional classroom practices than non-participants. Thus this study found that the teachers who participated in reform-oriented professional development both increased their use of reform-oriented practices and decreased their use of conventional practices in their classrooms; they did not simply add new practices. In comparison, there was almost a zero correlation between changes in reform practices or conventional practice and teachers' participation in "special topics" math-specific workshops, which the researchers described as those professional development experiences that were not directly related to the school reforms. Cohen and Hill concluded that content-level, curriculum-related, sustained professional development was correlated with the most significant changes in teachers' reform practices in the classroom.

In the second part of their study Cohen and Hill (2000) examined how policy decisions affected teachers' classroom practices. California sought to influence classroom practices through the use of reform-practice-related standardized assessments, and this study explored the relationship between a teacher's knowledge of the reform-assessments and their use of these assessments on their classroom practices. This study found that teachers who knew about the standardized assessment tests were more likely to administer them and were also likely to include more reform-based practices in their classrooms. However, these teachers were not more likely to reduce their use of conventional practices, so they were adding new practices, but not otherwise changing. Teachers who were aware of the standardized assessment tests did make efforts to change their practices. Cohen and Hill suggested that knowledge of the standardized assessments encouraged teachers to seek information or instruction on new practices. Both the reform-based assessments and teachers' opportunities to participate in relevant professional development were found to be significantly related to changing classroom practices and generally independent of one another. The researchers concluded that "teachers' opportunities to learn were a crucial link between instructional policy and classroom practice" (Cohen & Hill, 2000, p. 319) as long as these experiences were relevant to the curriculum studied by the students, connected to curriculum and assessment, and involved sustained experiences over time.

Finally, Cohen and Hill (2000) sought to understand the relationship between changes in teachers' classroom practices and student achievement on the reform-related assessments. Cohen and Hill reported on relationships between school-level student test score averages and aggregated teacher professional development participation, exposure and use of standardized assessments, use of particular curricular units, teachers' perception of school environment, and other school variables. Findings included increased student performance with (a) increased use of reform-practices in classrooms, (b) increased teacher professional development opportunities to learn the new curriculum, (c) teachers' use of new curriculum materials in their classrooms, and (d) teachers' knowledge of and use of the standardized assessment. Another significant finding was that there was no correlation between teachers' participation in "special topics" workshops and student performance on reform-related assessments.

From this extensive study, Cohen and Hill (2000) concluded that teachers must have opportunities to learn about new curriculum and how to implement it. This can lead to changes in classroom practices, changes in student learning, and improvement in student performance on relevant assessments. This study supports the progression of change described in Desimone's (2009) framework. Cohen and Hill also argued for the "importance of consistency among the elements of instructional policy … and professional learning" (2000, p. 330) articulating the importance of coherence between the content of teacher professional development and the desired school reforms in curriculum and instruction.

Garet et al. (2001) explored the effects of teacher professional development experiences on teacher learning using a national sample of 1027 mathematics and science teachers who, in 1997, participated in workshops offered through *The Eisenhower Professional Development Program, Title II of the Elementary and Secondary Education Act*. The researchers designed a survey to capture characteristics identified in the literature as those of "high-quality professional development" (Garet at al., 2001, p. 917), which included both the *structure* and *core features* of the experience. Measures related to structure assessed (a) the form, such as study group, network, workshop, or conference, (b) the duration including total contact hours and the time span of the activity, and (c) the extent of collective participation of groups or departments from the same school as opposed to individual participation. Measures of the core features assessed (a) the extent to which the professional development addressed math or science content, (b) the extent to which the activity included active engagement with analysis of teaching and learning, and (c) the extent to which the activity emphasized coherence with standards, curricula, and assessments, and encouraged ongoing teacher communication. To gather data on teacher learning, teachers were asked to assess and report the impact of their professional development experiences on changes in their knowledge and skills, and changes in their classroom practices.

The study found several factors that affected changes in teacher self-reports of knowledge, skills, and classroom practices. Working backwards from classroom practice, correlational analysis found teachers' classroom practices were significantly affected by coherent professional development experiences that led to increases in teachers' knowledge and skills. Also significantly correlated were increases in teachers' knowledge and skills with professional development that had greater content focus, offered opportunities for active learning, and again, were coherent experiences. The study also found that opportunities for active learning and coherent experiences were positively and independently affected by both measures of duration—contact hours and the time span—and opportunities for collective participation. From these results, Garet et al. (2001) concluded that an increase in teachers' reform practices in the classroom depended in part on their gaining knowledge and skills through intense and sustained professional development that was content-focused, coherent with teacher and school needs and involved opportunities for active learning, and engagement with others in a collaborative experience. The results of this study support several of the core features of teacher professional development described in Desimone's (2009) framework.

Summary. These research studies on teacher professional development provided support for attributing changes in teacher learning, changes in classroom practices, and improved student achievement to specific characteristics of professional development experiences. Based on these studies, when the described core features of teacher professional development are present, it is anticipated that the professional development experiences will better contribute to the progression of change from teacher learning to student learning. Effective professional development experiences should be coherent with school reform efforts and teacher and student needs. Teachers should be engaged in active, collective learning processes that are of sufficient duration for teachers to learn, and sustained over time to support implementation and changes in practice.

The previously described professional development studies represented professional development for broad areas of science or mathematics content across elementary through high school grade levels and appear to be generally applicable to the teachers and teaching in the ISHSs I studied. However, because my study used data from STEM-content teachers and teacher professional development experiences in secondary schools, a few studies that focused more narrowly on specific academic content targeting high school science, mathematics, engineering, or technology teacher professional development were reviewed. These studies are described in the next section.

Professional Development for the STEM Fields

I reviewed a few studies that more finely targeted professional development experiences in secondary mathematics and science (Ostermeier, Prenzel and Duit, 2010), engineering and technology (Felder, Brent, & Prince, 2011; Hoepfl, 2011; NRC, 2009). More recently, due to the release of the *Next Generation Science Standards* (NGSS), educators and researchers have been weighing in on how to affect teacher learning, either through pre-service programs or in-service professional development, to facilitate the implementation of the science and engineering practices identified in the NGSS. (Duschl & Bybee, 2014; Windschitl, Thompson, Braaten, & Stroupe, 2012). These studies helped to identify more subtle features of complex science content learning and integration through teacher preparation or professional development experiences that may be important for a study of teachers in ISHSs.

Science and mathematics. Ostermeier et al. (2010) carried out a large study of a German national effort to improve professional development to enhance student learning—the SINUS project. The German government, in response to mediocre student performance on the *Trends in International Mathematics and Science Study* (TIMSS), sought to improve classroom instruction in mathematics and science with a goal of improving student learning and understanding. The government supported the development of about 15 modules that related to content areas where German students had shown weak performance on the TIMSS test. These modules were not curricula, but rather resources to "outline central aspects of the problem area and provide examples of how to overcome the identified shortcomings" (Ostermeier et al., 2010, p. 306). Teacher groups at each school could use these modules as a starting point to begin discussions on particular science or mathematics content that they found to be problematic with their students. The professional development experiences involved teachers at 170 schools. Within each school, groups of teachers, collaborating at a school level, were provided opportunities to work with the selected modules and work also within a network of about five other schools. Each school collectively determined its own working goals and chose how to develop new materials or make modifications to existing practices. Teachers also engaged in self-evaluation to determine how to proceed. Each school was assigned a coordinator, and the teachers worked collaboratively, receiving support from education researchers and other consultants.

Findings from this study showed positive effects on student performance as measured by the PISA test [this test was used to facilitate comparison between the SINUS schools and a sample that was representative of all German schools], improvements in student attitudes and interest, and higher perceptions of the classroom teaching as being “cognitively activating” (Ostermeier et al., 2010, p. 320) in comparison with non-program schools. Additionally the effects of the professional development program had a greater effect in the lower track schools [German schools are academically tracked]. On surveys, teachers gave positive ratings to their contentedness with the program, and these positive ratings showed a significant increase between the beginning and end of the program. Teacher surveys showed a significant increase of both teachers’ appreciation of the experience as well as personal gain in professional competence through participation in this particular program.

The relationships between the NGSS and STEM teacher professional development have not yet been extensively researched, but education researchers proposed some areas that are likely to need targeting as the NGSS becomes increasingly accepted. Duschl and Bybee (2014) highlighted the importance of making sure that teachers can help students “unpack” the complexities of scientific or engineering investigations to help them better understand the struggle involved in these investigative processes. They propose a “5D” (p. 5) model of (a) Deciding, (b) Developing, (c) Documenting, (d) Devising, and (e) Determining, as a way to structure complex modeling and explanation building. Windschitl et al., (2012) described helping teachers learn to use “model-based inquiry” (p. 884). This process serves to facilitate students’ active engagement in discourse, expressing and developing their thinking by constructing and revising models that explain their understanding of complex scientific concepts using everyday experiences and common language. These two papers focused on the importance of teachers learning to develop academic discourse, explanation, and model building to help students clarify their thinking and make their conceptions of complex scientific concepts visible.

Engineering and technology. In describing professional development for engineering education, the NRC study, *Engineering in K-12 Education* (2009), identified three dimensions of teacher content knowledge for engineering that included (a) subject area knowledge, (b) a knowledge of the materials and programs available to assist in delivering engineering content, and (c) pedagogical content knowledge for helping others learn engineering content. The NRC further recommended making connections among science inquiry, mathematical reasoning, and engineering design, with a particular focus on understanding how engineering design could be used as a pedagogical strategy in science and mathematics, and how professional development could be structured to support teachers in making changes. This report supported professional development that lasted for at least a week, continued in the classroom or online after the end of the formal training, and provided opportunities for continuing education. Also supported was coherence in professional development where standards, curricula, student assessments, and school leadership collectively supported the needed changes. These characteristics of professional development are aligned with the core features identified in Desimone's (2009) framework.

In a study of engineering professional development (Felder, Brent & Prince, 2011) focused around Raymond Wlodkowski's theory of adult learner motivation and *How People Learn* (NRC, 2001), the researchers identified the importance of (a) the expertise of the presenters, (b) the relevance of the content, (c) choice in how the content will be applied, (d) opportunities for practice of and reflection on new methods, and (e) groupwork. Four of the five professional development characteristics identified in this study overlap with those in Desimone's (2009) framework with (b) and (c) being relevant to the coherence and content focus, (d) relating to active learning, and (e) reflecting collective participation. Only (a) the expertise of the presenters is not explicitly characterized in Desimone's framework. This may be significant to more specialized areas of STEM content learning where the presenter's expertise plays an important role in the teachers' content learning.

In a report on teacher professional development for technology and engineering education for the Council on Technology Teacher Education, Hoepfl (2011) identified specific content knowledge and pedagogical content knowledge as necessary. She characterized the creative design process as central to the field, along with the discussion of what it meant to help teachers promote creativity and design in their classrooms. She described specific content: the multiple "languages" used in engineering design including "verbal and textual, graphical representations, and mathematical models" (Hoepfl, 2011, p. 294). Hoepfl pointed to a consensus in the field that for "creativity to be productive it must be demonstrated to have relevance and effectiveness in a broader context, and thus must be effectively communicated to others" (2011, p. 294). She continued to describe the necessary questioning and problem solving abilities that contributed to effective technology design. In these words were seeds of the ubiquitous *21st century skills* that are described throughout teaching reform literature (Farrington et al., 2012). Hoepfl explained that technology design teachers must successfully lead students to question and seek solutions, and they must guide students' creativity and model the process in more of an apprentice-expert relationship than a typical student-teacher dynamic.

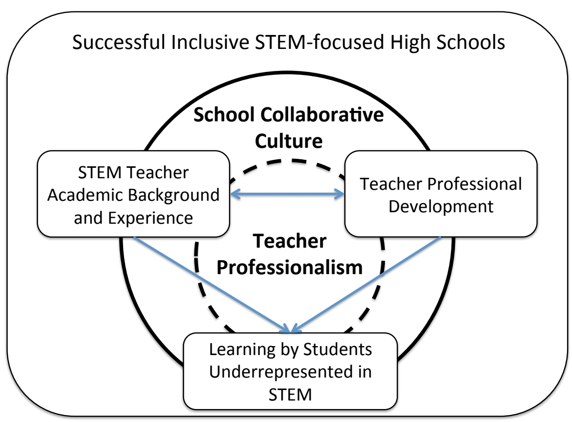
Not surprisingly, research studies on professional development in science, technology, engineering, and mathematics focused more specifically on STEM content knowledge or STEM pedagogical content knowledge than on the delivery process of that professional development. However, where professional development characteristics beyond pedagogical and content knowledge were described in this body of literature, they aligned with characteristics of effective professional development featured in Figure 2.

Summary

Ideas about the characteristics of effective teacher professional development have evolved over the past few decades and educators appear to have come to some consensus. These characteristics are summarized and organized in Desimone's (2009; Figure 2) framework describing high quality professional development as focused on content that is coherent with school, teacher, and student needs; on active learning by teachers working collectively; and of adequate intensity and duration to support teacher learning. Teacher learning can lead to changes in classroom practices, and ultimately to improvement in student learning. Professional development specifically targeting the needs of secondary STEM teachers may require a greater emphasis on particular STEM content, STEM pedagogical content, and the science and engineering processes of the NGSS, and the expertise of the teacher educators may play a more prominent role. This review of the literature helped to direct exploration of teacher professional development for my study of teachers, teaching, and learning in ISHSs. It was important to examine the relationships among desired school reforms as expressed by school leaders, teachers' perceptions of their own and students' needs, the professional development opportunities available and provided by the school, and the strategies and approaches to learning used in the classrooms.

Several of the reviewed studies identified collective practice or teacher collaboration as an important feature in the effectiveness of teacher professional development, which was also acknowledged as a core feature in Desimone's framework. Teaching and teacher professional development occurring within the context of a school, and collective practice and teacher collaboration appear to be intertwined with aspects of a school's culture or environment. Many studies examined interrelationships among the broader school culture or environment and teaching and learning effectiveness. The literature on collective or collaborative practices, teacher professional development, and the school environment is reviewed in the next section.

Collective Teacher Practice, Collaboration, and Teacher Professionalism



There is a bit of a chicken-and-egg confounding that occurs when investigating teacher collaboration in schools. Collaboration emerged from the research literature in three slightly different, yet overlapping ways. As described in the previous section, collective practice was identified as one of the core features in the design of effective professional development, and this might have involved collaboration. Collaboration within a group was described in some studies as a pre-requisite for the ultimate success of professional development and it was also presented as an outcome of collective professional development experiences. It was difficult to disentangle the connections—whether collaboration was a cause or an effect, or both—although it is probably safe to say that individuals must have opportunities to work together in collective fashion before any kind of true collaboration can result.

Several research studies explored relationships between the existence of collaborative teacher practices in schools and the effectiveness of professional development leading to changes in teacher knowledge, skills, attitudes and beliefs, changes in classroom practices, and ultimately, affecting student performance (De Vries, Jansen, & van de Grift, 2013; Goddard, Goddard, & Tschannen-Moran, 2007; Hamilton & Richardson, 1995; Johnson et al., 2007). Other studies sought to describe the process by which collaboration effected changes in schools (Garet et al., 2001; Johnson & Marx, 2009; Ruddy & Prusinski, 2012; Sun, Penuel, Frank, Gallagher, & Youngs, 2013). Still other studies documented the conditions or social environments present in schools that were rich in collaboration often describing interrelationships with aspects of teacher professionalism or teacher professionalization (Bloom & Unterman, 2013; Bryk et al., 2010; Evans, 2002; Kennedy et al., 2011; Kennedy & Smith, 2013).

Teacher Professionalism and Teacher Professionalization

Because teacher professionalism and teacher professionalization became increasingly salient in my study, these terms are described and defined here. Many people and organizations have contributed to discussions of teachers as professionals. The following descriptions are drawn from sources that reflect these concepts both from the general teacher perspective (Agarao-Fernandez & de Guzman, 2006) and more specifically from the literature on science teachers and teaching (NSTA, 2010; Tobias & Baffert, 2009).

The National Science Teachers Association (NSTA) Board of Directors adopted a position statement (NSTA, 2010) describing the characteristics of teacher professionalism. This document outlined the personal responsibilities of a teacher for "promoting the growth of all students" (p. 1), seeking individual professional growth, and being a leader in the profession. This document also outlined a school's responsibility for supporting the development of teachers as professionals, which included the importance of providing time for teachers to plan, interact, and collaborate with colleagues, and to pursue continuous professional development opportunities. Building on a list of characteristics produced by the National Education Association, Tobias and Baffert (2009) created their own list of 12 "essential elements" (p. 39) to describe the science teaching profession. Most relevant to my study were the identified elements of a teacher having strong content-level academic and pedagogical backgrounds; the provision of time for teachers to collaborate, to engage in professional development, and to stay current in their fields; and the importance of teacher autonomy and decision-making capacity in classrooms and schools.

In describing the dimensions of teaching professionalization, Agarao-Fernandez and de Guzman (2006) cited the importance of adequate pre-service and in-service training and opportunities for advancement. They described a professionalized teacher as having expertise in the subjects taught, having been well supported as a new practitioner, having opportunities to continuously update skills and knowledge and to collaborate and engage with colleagues. They also explained that professionalized teachers should be provided with "formal avenues of promotion and mobility" (p. 215), and should have the capacity and autonomy to make decisions in the best interest of their students.

Even in these few descriptions, teacher professionalism and teacher professionalization seem somewhat conflated. For my study, I use the term teacher professionalism to describe characteristics a teacher brings into the teaching role, and the term teacher professionalization to describe those features created or shaped by the school to serve the development of teachers as professionals.

Collaboration and Change

De Vries et al., (2013) explored the effects of teachers' collaborative practices on how teachers thought about student learning. This study used teacher self-report survey data from 260 secondary teachers in four secondary schools in the Netherlands. Most significantly, in comparison with teachers who reported low participation in continuing professional development, De Vries et al. found that teachers who reported greater participation in all kinds of continuing professional development possessed more student-oriented beliefs [student-oriented beliefs overlap somewhat with "*autonomy supported teaching*" (AST; Roth & Weinstock, 2013, p. 402) that is discussed later in a study on teacher epistemologies]. Teachers in this group reported believing in the importance of classroom activities that supported students' autonomous learning, cooperative learning, and student development of skills and competencies, as opposed to engaging in activities that were more teacher mediated. These teachers were also more likely to report relating course content to students' own knowledge and experiences, and seeking to accommodate differences in student aptitudes and interests. Thus teachers in this study who engaged in continuous professional learning experiences were more likely to think about learning from the students' perspective and to use reform practices in their classrooms. It should be noted that for the teachers in this study, professional development was considered a professional duty, but participation was not mandated as part of the teaching role. As such, the findings may be that teachers who participated (voluntarily) in continuing professional development were those who already had student-oriented conceptions of learning, rather than the professional development itself being the cause of this thinking.

Two other studies examined the effects of school-level teacher collaboration on student academic performance. Goddard et al. (2007) sought to understand this relationship through a large survey study of 47 elementary schools, 452 teachers, and 2,536 fourth-grade students from the same Midwestern school district. Each school had at least four teachers responding to a researcher-designed survey to assess teacher collaboration. The survey asked teachers to characterize the extent to which they worked collectively to influence such decisions as planning school improvement, selecting instructional methods, evaluating curriculum, and determining or planning professional development experiences. These measures are similar to those that will be discussed in a later section in a study by Evans (2002) where she sought to understand *teacher professionalization* in magnet schools. Student achievement was assessed through math and reading scores on 4th grade standardized tests. This study found that teacher collaboration was a statistically significant predictor of student mathematics and reading achievement in the school even after correcting for student characteristics and school context. The researchers concluded that when teachers had opportunities to collaborate, the experiences and knowledge that were shared among a teaching staff promoted learning to improve instruction.

Johnson et al. (2007) performed a three-year longitudinal study of two middle schools—one involved in a collaborative professional development experience in science, and a second, non-participating comparative school as a control. The professional development included a summer two-week intensive of standards-based initiatives and inquiry teaching followed by collaborative monthly meetings to plan curricular changes and to modify lessons. In the first year of the study student performance on the state science assessment at both the intervention and control schools were similar with student cohorts of approximately 200 at each school. However, student performance in the intervention school showed statistically significant improvement for each of the following two years of the study relative to the control school, with similar effects for both White and "minority" students, whom the authors described as including African American, Hispanic, Asian, and multi-racial students.

These studies identified positive effects on teacher and student learning as a function of collaborative professional development. The act of collaboration appeared to contribute to changes in teachers' beliefs, the implementation of classroom reforms, and student academic performance. Although the researchers hypothesized explanations for the observed relationships, these studies themselves did not explain the process by which teacher collaboration affected change. Several studies follow that sought to understand the process by which collaboration worked.

How Collaboration Works

In their study exploring the characteristics of effective professional development described earlier in this review, Garet et al. (2001) suggested processes through which collective participation in professional development involving groups of teachers from the same school, department, or grade level might effect change. The researchers hypothesized three distinct advantages: (a) teachers could work together to address issues that arose during the professional development experience, (b) teachers from the same institution were likely to be working with similar course materials, and therefore there would be coherence in how the professional development could integrate with other aspects of their instruction, and (c) teachers would have similar students and therefore could discuss how the professional development could be used to address the needs of these teachers' targeted groups. Garet et al. (2001) also identified an increased likelihood of reform being sustained over time when a critical mass of teachers from a single institution was involved in a professional development experience together, explaining that the common understanding reached through collective professional development could lead to a "shared professional culture" (p. 922) of support.

To understand the dissemination of new knowledge throughout a school, Sun, et al. (2013) investigated what they called *spillover effect*, a term taken from economics. Their study examined the spread of knowledge and practice through the teachers in a school after a few teachers had engaged in professional development experiences. Sun et al. followed two comparable groups of about 20 schools—each assigned to either participate in professional development or to be delayed for a year before participation. Information was collected through two years of survey data from 434 participating and 400 non-participating teachers to determine the extent to which teachers were indirectly exposed to professional development through interactions with teachers who had participated, and the extent of expertise acquired as a result of this networking. While this was not a study of science or mathematics teachers, it is significant in understanding how collaborations among teachers subsequent to professional development experiences have the potential to affect the dissemination of new knowledge and skills throughout the staff.

Sun et al. (2013) suggested that collegial networks among teachers within schools provided opportunities for teachers to learn from one another as they engaged and interacted over challenges involving pedagogy and content. Statistical survey analysis found that teachers were more likely to help others if their professional development experiences had been intense, of greater duration, included a broader range of relevant content, and provided teachers with active-learning experiences—the same characteristics identified as significant in previous studies of effective professional development and supported in Desimone's (2009) framework for professional development (see Figure 2).

Sun et al. (2013) found that opportunities to collaborate within a school provided two paths for school improvement. Teachers who had engaged in professional development together and had acquired similar language to speak about new or different classroom practices could continue to share their knowledge and experiences while implementing reforms. For teachers who did not participate in the professional development, opportunities to collaborate with teachers who had participated enabled them to learn about the experiences and to learn of applications to their own classrooms and content areas. Opportunities for collaboration allowed for the flow of ideas among faculty members, and thus the dissemination of new knowledge and new practices could expand beyond those directly influenced by the professional development experience.

To study the effects of *transformative professional development*—described as professional development in line with previously established characteristics of effective professional development—Johnson and Marx (2009) followed middle school teachers from two schools. Eight middle school science teachers from one school engaged in a collaborative professional development intervention—an intensive summer program followed by monthly day-long meetings for two school years. These teachers were matched with seven control teachers from a second school who did not participate in the professional development intervention. Data were collected over the subsequent fifteen months through interviews, focus groups, teacher journals, and classroom observations. Using the *Local Systemic Change Classroom Observation Protocol* (LSC), researchers observed teachers' classroom practices each month. The study also focused on the formation of three kinds relationships: (a) among teachers as they developed a professional learning community, (b) between teachers and students in the classroom, and (c) between teachers and the program leaders for the professional development program. This study found that four teachers in the professional development group made significant gains in their teaching of science as assessed by the LSC, in comparison with only one in the control group showing similar gains. The researchers concluded, however, that the opportunity for a collective professional development experience alone did not appear to cause change. This study found that the development of trusting relationships among the participating teachers as they worked in this professional collaboration facilitated learning. Describing it as "the linchpin that held the [professional development] experience together" (Johnson & Marx, 2009, p.125), the relational trust formed in this professional learning community appeared to be a necessary condition. As Johnson and Marx (2009) explained: "Trusting relationships between the program leaders and the teachers … were essential for promoting buy-in among the teachers" (p. 122), and trust between teachers enabled them to share ideas and provide constructive feedback to one another, to ultimately improve their classroom teaching, develop better relationships with students, and create more positive learning environments in their classrooms over the fifteen month professional development experience, in comparison with the seven isolated control teachers.

These studies suggest that collective participation enhances the effectiveness and maintenance of reforms implemented through professional development experiences. However, teachers must have multiple opportunities to interact, to exchange ideas and practices, to form trusting relationships, to provide feedback and guidance to one another, and to collectively collaborate in order to support enduring reform in their classrooms. These studies suggest that whole-school reform can be enhanced through collaborative teacher professional development experiences that support teachers as they initiate change in their classrooms. However, subsequent opportunities for faculty-wide interactions that allow for collaboration between both participating and non-participating teachers appear to provide a conduit for increased dissemination and perpetuation of reform strategies and practices throughout the extended faculty community contributing to more pervasive and lasting change in classroom learning environments. The Johnson and Marx (2009) study introduces the idea of relational trust as an important feature to support reform, and relational trust appears to have the potential to be influenced by the existing culture in a school. Several studies are discussed in the next section relating to a collaborative school culture.

A Culture of Collaboration

Seeking to better understand the relationship between a school's culture and the effectiveness of a professional development experience, Hamilton and Richardson (1995) studied groups of teachers at two schools as they engaged in a year-long professional development experience designed to help them examine their own beliefs about teaching and learning with respect to current research. Hamilton and Richardson documented changes in interactions among the participants along with their changing beliefs and practices in teaching and learning. This study found that teachers' interactions were in large part influenced by school-wide cultures of congeniality (not wanting to cause dissention) and individualism, which both had substantial negative effects on teachers' willingness to collaborate, to discuss ideas and practices, and to ultimately benefit from the professional development experience. Hamilton and Richardson concluded, "failure to recognize participants' beliefs and understandings and the influence of school context can strongly affect the results of a staff development program" (1995, p. 367).

Several studies viewed school-wide collaboration as a function of school culture or an offshoot of school leadership. Teacher professionalization also emerged along-side discussions of a school-wide collaborative culture. The studies that follow articulate some of the complexity of the collaborative relationship.

Kennedy & Smith (2013) explored the relationships among ideas of collective and collaborative practices that characterized effective organizational behaviors in professional learning communities (PLCs), and teachers' self-efficacy as assessed by their levels of comfort with peer and supervisor interactions. Surveys were administered to 661 elementary and secondary teachers in 42 public, private, and charter schools.

Survey items based on organizational behaviors within PLCs loaded onto five factors: 1) learning from peers, 2) collective learning, 3) collective reflective practice, 4) collective leadership/vision, and 5) collective decision-making. Items exploring teacher self-efficacy loaded onto two factors: physiological internal (most items related to feelings of discomfort in teaching or content level capability in comparison with other teachers), and physiological external self-efficacy (ideas of discomfort, nervousness, feelings of inadequacy when being observed, working with outside experts, or sharing ideas with colleagues). Kennedy and Smith found organizational behaviors explained significant percentages of the variance in teacher self-efficacy. They concluded "teachers who work in buildings that support more collective reflective practice have more comfort with external input such as administrative observations, student outcome data, or colleague observation" (2013, p. 140). Additionally, they explained that time for collective learning "in a positive, trusting, professional environment" provided "the opportunity for *reflection* within the *community of peers,*" enabling collective learning and "ultimately transformational change of professional practices" (Kennedy & Smith, 2013, p. 141). This study characterizes the contributions of a collaborative school culture on teachers' abilities, comfort level, or willingness to assist and be assisted by each other in their professional endeavors.

In a study of whole-school reform in Chicago elementary schools, Bryk et al. (2010) examined teacher and school characteristics related to school-wide improvement and student performance on mathematics and reading scores. Bryk et al. characterized a "strong professional community" through measures assessing several collaborative practices that included public classroom practice, reflective dialogue among staff, peer collaboration, new teacher socialization, and a sense of collective responsibility for student performance and school improvement. These measures are aligned with Kennedy and Smith's effective organizational behaviors in PLCs previously described. Bryk et al. (2010) found a strong professional community coupled with high quality professional development and a strong work orientation resulted in increased student performance in math. In addition, when these characteristics were aligned with the curriculum, there was a significantly increased likelihood of school improvement. The results of this study highlight the importance to school reform of collective practice, aligned professional development, and a trusting environment providing opportunities for community participants to learn from each other.

Several studies examined teacher experiences and school culture in smaller schools of choice or themed schools. Because the schools in my study are such schools, this literature proved to be relevant, and is discussed in the next section.

Teachers in charter, magnet, small, or themed schools. In reviewing literature on teachers in charter, magnet, small or themed schools, a fairly consistent message of collaborative practice emerged. In comparison with traditional schools, teachers in these schools identified stronger and more sustained relationships between students and teachers, greater teacher collaboration and greater autonomy, and generally greater job satisfaction (Bloom & Unterman, 2013; Evans, 2002; NRC, 2004). Teachers "reported more collaboration with their colleagues, more adequate resources, a greater influence over instruction and administrative policies, more opportunities to learn, more colleagues who emphasized personalized attention to students, and generally higher levels of job satisfaction and efficacy" as well as belonging to "communities of support and learning for both students and teachers" (NRC, 2004, p. 178). Teachers reported liking being part of a team.

Evans (2002) used a national-level data set to carry out a comparison study between schools of choice, particularly magnet schools, and traditional schools on four measures of "teacher professionalization" which she described as: (a) autonomy, both in the individual classroom and with respect to broader school decision-making authority, (b) participation in professional development, a (c) competitive salary, and (d) teacher certification. Evans explained that a general requirement of magnet schools was that they reduced racial segregation of the district by 5% and had a balanced mix of race and ethnicities, or had a racial make-up that matched the district (2002, p. 318). Using the 1993-1994 Schools and Staffing Survey (SASS), 5,909 secondary school teachers' responses were analyzed which included 1,353 teachers working in urban magnet schools. Responses to relevant items on the SASS were aggregated to characterize each of the four measures of professionalization. Evans (2002) found teachers in magnet schools scored significantly higher on professional development, salary, and two aspects of autonomy: influence over school policy and control in the classroom. Teachers in secondary magnet schools experienced greater levels of professionalization than their colleagues in traditional public secondary schools with a greater say in school budget and curriculum, and greater decision-making in their own classrooms; they were also more likely to engage in professional development opportunities, and were better paid.

These studies articulated the connectedness among collaborative practice, teacher autonomy and self-efficacy, and teacher professionalization. Some of the measures of teacher autonomy were characterized by factors that could be considered aspects of teacher leadership. Additional studies identified teacher empowerment arising from collaborative practices as leading to a greater sharing of the school leadership responsibilities across multiple participants in the school community. These studies are described in the next section.

Collaborative practice and the distribution of leadership. From a five-year study of five middle and high schools undergoing change from voluntary to compulsory participation in professional learning communities (PLCs), Kennedy et al. (2011) described the characteristics that resulted in successful creation of a school environment that fostered continuing professional learning. Kennedy et al. explained that providing time for teachers to meet and to work together was necessary but not sufficient. For these PLCs to be successful, this study found that teachers needed reinforcement through high-quality professional development that focused on issues critical to classroom practice and within the range and scope of teachers' abilities to effect change. Teachers also needed to have responsibility for articulating the goals of these PLCs rather than goals being assigned to the group by an administrator. Kennedy et al. (2011) identified the importance of a community wherein dialogue and inquiry were expected, a "questioning and wondering stance toward student learning" (p. 23) was encouraged, and where colleagues pressed each other in intellectually significant ways to facilitate the deepening of collective understanding. Kennedy et al. (2011) explained, "When the adults in a school continually engage in dialogue and inquiry to support student learning, a re-culturing takes place" (p. 23) that allows teachers to take risks and to put themselves in vulnerable positions as they work together to make productive change.

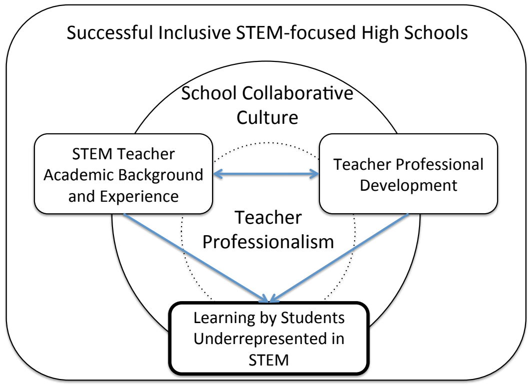
Extrapolating these observations to the broader construct of school leadership, Kennedy et al. (2011) explained “leadership is more effective when it’s stretched over knowledgeable individuals in an organization,” (p. 22). They added that schools with *distributed leadership* demonstrated a flattened hierarchy with experienced faculty members including teachers, coaches, and specialists contributing actively to decision-making relating to school improvement activities, and also accepting accountability for decisions and outcomes. Schools where institutional knowledge and expertise were distributed among all staff members and where each individual felt a sense of responsibility toward achieving desired outcomes, created an environment of shared mission and mutual trust. Spillane, Halverson, & Diamond (2004) characterized an alternate way of thinking about school leadership as a collective and distributed property of the school rather than of an individual leader. They explained “*collective* cognitive properties of a group of leaders working together to enact a particular task leads to the evolution of a leadership practice that is substantially more than the sum of each individual’s practice” (p. 18), identifying the advantage of multiple individuals within a school sharing and collaborating to lead.

Summary

These studies of collective practice and collaboration suggested that whole-school reform could be enhanced through collaborative teacher professional development experiences that supported teachers as they initiated and worked to maintain changes in their classrooms. Subsequent ongoing opportunities for faculty-wide interactions allowed for dissemination and perpetuation of reform strategies and practices throughout the extended faculty community. The formation of a community-wide sense of relational trust provided space for risk-taking and vulnerability. Collaboration on school decision-making could lead to the development of shared goals and a mutual sense of responsibility for decisions and results. A school environment that provided space for the development of relational trust could facilitate collaboration that expanded the impact of professional development through diffusion and reinforcement. This collaborative space could allow for the development of a distributed leadership where teachers and others felt a sense of collective responsibility for school outcomes. This progression, beginning with collective and collaborative practices and leading to distributed leadership and collective responsibility lays the groundwork to support the intentional professionalization of teachers.

To this point, this review has explored the research literature on how the characteristics and interactions of teachers, teacher professional development, and the broader school environment could affect student learning. In addition, the progression from teacher professional development through teacher learning to student learning was examined. However, the differential effects that teacher characteristics, classroom practices, or school environment could have on the diversity of learners that are likely to be present in a school that describes itself as inclusive were not extensively explored. The next section examines the literature on learning by students underrepresented in STEM college majors and STEM careers.

Learning by Students Underrepresented in STEM



The schools targeted in my study were by design *inclusive*. This term refers to the inclusion of students underrepresented in STEM majors and careers: racial and ethnic minority groups [groups identified within these categories often include Blacks or African Americans, Hispanics or Latinos, and Alaska Natives, Native Americans, Native Hawaiians and other Pacific Islanders, and students belonging to two or more racial or ethnic groups], females, students of low socio-economic status, and students who would be first in their families to attend college. Specific groups also included were students eligible for special education services and English language learners. This section focuses on student learning with specific attention to differential learning by students underrepresented in STEM.

The literature on student learning seems to fall into two broad categories: general learning, not specific to any particular subject area including social, emotional, and environmental aspects of learning; and learning that can be contextualized within the development of a student's STEM identity, relating to learning in science, technology, engineering, and mathematics. The literature in each of these categories is synthesized and analyzed in two separate sections to follow: (1) *Social and Emotional Learning*, and (2) *STEM Identity*.

Social and Emotional Learning

An NRC report (2011) articulated "research finds that the most promising approaches to improving the low performance of certain groups of students pay as much attention to the social forces operating in schools and in classrooms as they do to skill and knowledge development" (NRC, 2011, p. 58). These social forces can be broad and far-reaching and include the social and emotional learning environments in schools, noncognitive factors of learning, and individual teacher or student characteristics that affect teaching and learning.

Noncognitive factors. Noncognitive factors have emerged as a body of knowledge within the research literature. Farrington et al., (2012) carried out an extensive review of research on the role of noncognitive factors and their effects on school performance across all subject areas. This review sought to understand the "interplay between cognitive and noncognitive factors" and how intelligence and learning is embedded "in both the environment and in socio-cultural processes" (Farrington et al., 2012, p. 2). The authors identified five categories of noncognitive factors: 1) academic behaviors, 2) academic perseverance, 3) academic mindsets, 4) learning strategies, and 5) social skills. This study aimed to establish if there was adequate evidence to determine whether each identified noncognitive factor had the potential to be changed within a student, and if and how the classroom environment could affect student achievement and the gender or race/ethnicity achievement gap. Their most significant generalized findings related to improving *student perseverance* and *academic behaviors*. This study found that trying to effect *direct* change on either of these factors was generally not productive. Each was better addressed through *academic mindsets* and *learning strategies.* Academic mindsets were defined as "beliefs, attitudes, or ways of perceiving oneself in relation to learning and intellectual work that support academic performance" (Farrington et al., 2012, p. 28). Dweck (1999) has written extensively about the importance of a *growth mindset* based on an incremental theory of learning—that intelligence is malleable and the brain can get stronger through work. Learning strategies were defined to encompass "metacognition, self-regulated learning, time management, and goal setting" which constituted a "group of learner-directed strategies, processes, and 'study skills' that contribute to academic performance" (Farrington et al., 2012, p. 39). In particular, this review found that "mindsets are shaped by school and classroom contexts, but they also are malleable at an individual level through experimental interventions" (Farrington et al., 2012, p. 38). Farrington et al. also cited evidence that women and minority students tended to have more negative mindsets in science and math, and interventions designed to target student mindsets produced differential effects for these groups. With respect to learning strategies, this review cited evidence that the explicit instruction about learning strategies, especially targeted to the specific learning occurring in a particular classroom, had significant impact on student achievement. A learning strategy was more likely to be transferrable to another subject area or course when learned specifically at first for later generalization. The authors also noted that the relationship between gender or race and learning strategy use was an "under-investigated area about which we currently know very little" (Farrington et al., 2012, p. 47). One particular conclusion identified classroom level intervention that had the potential to effect changes in student achievement. Farrington et al. (2012) suggested "classrooms are important both as sites for the explicit teaching of learning strategies and as contexts that set motivational conditions for learning and strategy use" (p. 47).

Farrington et al.'s review of the research on noncognitive factors clarified aspects of the complex interplay among social, emotional, environmental, and academic facets of student learning across all subject areas. For my study, this work suggested that it would be important, to the extent possible, to listen for voices expressing student self-perceptions and the development of learning strategies, especially with respect to learning by students underrepresented in STEM. In the next section, I summarize several studies that focused on social and emotional learning environments and perceptions, attitudes, or performance by students underrepresented in STEM.

Student Social and Emotional Learning

A meta-analysis carried out by Durlak, Weissberg, Dymnicki, Taylor, and Schellinger (2011) provided a fairly comprehensive overview of 213 K-12 school-based research studies on the impacts of school-wide social and emotional (SEL) interventions on student outcome measures. To be included in this study, the SEL interventions had to be universal programs for all students, targeting students between the ages of 5 and 18 without learning or adjustment problems that also emphasized the development of at least one SEL skill. Durlak et al. (2011) characterized SEL skills as encompassing "self-awareness, self-management, social awareness, relationship skills, and responsible decision making" (p. 406). Student outcome measures included "social and emotional skills, attitude toward self and others, positive social behavior, conduct problems, emotional distress, and academic performance" (Durlak et al., 2011, p. 407). Schools implementing these programs demonstrated significant improvement in social and emotional skills, attitudes, and behaviors, along with an 11% increase in academic performance. SEL programs were found to be successful at all educational levels and in urban, suburban, and rural schools. Also, even though the social and emotional learning may not have directly targeted student academic performance, improvements in academic performance appeared to parallel improvements in SEL skills. Durlak et al.'s findings suggest that SEL programming has the potential to effect change in student performance, which may suggest that the SEL environment in a school may affect student learning.

This study suggested that when considering student learning in ISHSs in my study, it would be important to examine programming in these schools designed to target students' social and emotional learning, the school SEL environment, and teacher professional development related to SEL. Durlak et al.'s study, however, did not examine *how* the social and emotional learning environment affected student academic learning, or how teachers operated within the SEL sphere of influence to effect change. A review of studies that examined specific social or emotional learning relative to the targeted groups of students underrepresented in STEM is covered in the next section.

Student well-being and ability to learn. Some studies articulated the needs of students underrepresented in STEM as being different from mainstream students. One group of students underrepresented in STEM includes students with disabilities. According to Murray & Pianta (2007), students with "high-incidence mental illness," which includes learning disabilities, emotional and behavioral disorders, and mild mental retardation [all terms used by the authors], are more likely to experience depression, anxiety, and other adjustment problems. Students who are depressed or have low self-esteem may also struggle more to perform academically in the classroom. Conditions that serve to alleviate student incidence of depression and to increase self-esteem have the potential to affect student academic performance. In their study to understand school and teacher characteristics that specifically contributed to the academic performance of students with disabilities, Murray and Pianta (2007) identified the formation of good teacher-student relationships as most significant.

A study by Reddy et al., (2007) examined the relationship between student perceptions of teacher support and student sense of well-being. This longitudinal study followed 2585 (healthy, typical, not unusually depressed) middle school students from 6^{th} through 8^{th} grade, recording their perceptions of teacher support and self-reports of depression and self-esteem three times during the period. Reddy et al. found that student perceptions of teacher support were significantly inversely correlated to students' reports of depression and lower self-esteem during middle school. On average, all students reported perceiving decreases in teacher support over the three years. Both boys and girls indicated initial levels of depression that were not statistically different from each other. There were statistically significant differences in measures of self-esteem between boys and girls, with boys rating higher. This study found that initial levels of perceived teacher support were significantly positively related to self-esteem and negatively related to depression. Also, when adolescents perceived an increase in teacher support during the three years of middle school, their ratings of self-esteem increased and their ratings of depression decreased. The researchers did reverse the variables to see whether changing perceptions of depression and self-esteem would predict perceptions of teacher support, and no statistically significant relationships were found. The overall results of this study suggest that students' perceptions of initial and increasing teacher support have the potential to lead to higher self-esteem and a lower incidence of depression.

Reddy et al.'s (2007) findings suggest that schools creating increased opportunities for students and teachers to develop supportive relationships may see increased student perceptions of teacher support, especially during the challenging middle school transition years. The researchers suggested that structures such as homeroom or advisory groups, students working with the same teacher for multi-year placements, and opportunities for teachers to work with smaller groups of students (as might be the case in project-based learning environments or peer-learning experiences) could contribute to increases in perceived teacher support. Increasing opportunities such as these could contribute to the increased well-being of all students. Students with high-incidence mental illness, whom Murray and Pianta (2007) described as potentially having a greater tendency toward low self-esteem and depression, may be more positively affected by increased opportunities to develop such relationships. In my study, teacher practices and professional development experiences in ISHSs were examined with respect to student social and emotional learning to help explore whether and how these schools considered SEL as a potential contribution to increased academic performance by students underrepresented in STEM.

Perceptions, stereotype threat, and student mindsets. Several studies were reviewed that examined relationships between perceptions of student ability—either by the teachers or the students themselves—and student performance; sometimes student diversity played a role. This first study examined challenges experienced by pre-service teachers' working in diverse classrooms. Florian (2012) described a study in Scotland of pre-service teachers' challenges with the "increasing [student] cultural, linguistic, and developmental diversity, along with the pressure to achieve high academic standards for everybody" (p. 275) similar to those found in the United States. This three-year study focused on teacher educators and the struggles they experienced in helping pre-service teachers develop skills and knowledge to teach to diverse populations. Florian found that pre-service teachers had three essential challenges: (a) replacing a deterministic view of student ability with a concept of transformability, (b) viewing difficulties students experienced in learning as dilemmas for teaching rather than problems with the students, and (c) modeling new ways of working with and through others. This study suggested there is a need to help teachers change their mindsets about their students' abilities to improve regardless of the differences among them, to treat challenges through problem solving rather than dismissing them as student-based, and to make sure teachers are provided with opportunities to work through problem solving with others, especially more experienced others. While this study was of pre-service teachers and their teacher educators, the identified challenges in teaching diverse groups of students seem relevant to in-service teachers as well. For my study of teachers in ISHSs, Florian's (2012) study suggested the importance of paying attention to how teachers in the ISHSs spoke about students' abilities and their potential to change and improve, and how teachers spoke of their own abilities to influence changes in student performance.

A second study (Aronson et al., 2002) examined classroom environmental factors and their effects on students' beliefs about their potential for success. Changing students' mindsets about their own learning led to a reduction of the negative impacts of these environmental factors. Aronson et al., sought to create a "lasting and influential" change in students' attitudes about the malleability of their intelligence. The study followed three groups of approximately 25 African-American and Caucasian male and female college students: one experimental group (Intervention Pen Pal) learned about the malleability of intelligence and wrote letters to a pen pal about this malleability; one control group (Control Pen Pal) wrote letters with a pen pal about aspects of intelligence, but not about the malleability of intelligence; and a third control group (Control, No Pen Pal) neither wrote letters nor learned about the malleability of intelligence. Students in the Intervention Pen Pal group, after learning about the malleability of intelligence themselves, were asked to write a letter to a middle schooler (fictitious, but the study participant did not know this) encouraging him or her to work hard and to consider that his/her brain was like a muscle that could get stronger with effort (therefore malleable). The Control Pen Pal group participants also wrote letters to students and were asked to write about the diverse talents that make up intelligence. This group did not learn about the malleability of intelligence. Both Intervention and Control Pen Pal groups were asked to include personal messages relating to their own struggles with school. In an effort to make these messages as durable as possible, students were asked to write an additional letter to another student and to then turn the letter into a speech to be videotaped. Subsequent to this part of the intervention, all students, intervention and both control groups, completed a survey assessing their understanding of the malleability of intelligence. At a later date, all students were surveyed again about the malleability of intelligence and were also asked to respond to surveys rating their enjoyment of academics and the extent to which they identified with academics. They were also asked to respond to measures designed to access their perceptions of stereotype threat.

Participation in the Intervention Pen Pal group emphasizing the malleability of intelligence was found to have significant effects on students' own theory of learning. More of the students in this group adopted an incremental rather than entity theory of learning in comparison with either control group. Using analysis of covariance (ANCOVA) to compare the three experimental conditions and controlling for SAT score, the researchers found significant positive effects from the Intervention Pen Pal group on students' academic performance that were more significant and persistent for the African American students than for the Caucasian students. Thus, students who experienced reinforcement of an incremental theory of intelligence (a growth mindset; Dweck, 1999), especially students who were more likely to experience stereotype threat, were also more likely to subsequently perform better academically than similar students in a condition that did not emphasize the malleability of intelligence. This study suggests that helping students develop an incremental theory of intelligence may lead to greater resilience by students who are more likely to experience stereotype threat.

One interesting study (Roth & Weinstock, 2013) evaluated the effects of teachers' personal epistemological beliefs about students' "autonomous internalization of prosocial behavior" (p. 405) and their perceptions of teachers' support of their autonomy. Surveying 622 Israeli junior high school students and their homeroom teachers, Roth and Weinstock found teachers who believed that "multiple, possibly legitimate perspectives exist and that knowing is a process of choosing the apparently best explanation among alternatives" (Roth & Weinstock, 2013, p. 405)—teachers holding *relativistic* epistemological beliefs as opposed to *objectivistic* beliefs—were more likely to use practices in the classroom that supported student autonomy and prosocial behaviors [*autonomy supported teaching* (*AST;* Roth & Weinstock, 2013, p. 402)]. Thus teachers' personal epistemological beliefs were found to affect students' perceptions of classroom autonomy and their autonomous behaviors.

SEL summary. These discussions of social and emotional learning looked at the potential for student academic performance to be affected not only by teachers' content knowledge and skills, but also by the classroom environment as it served to enhance teacher-student relationships, student sense of well-being, and teacher or student perceptions of knowledge or learning. Professional development that increases teachers' awareness of these issues and provides knowledge of processes to both identify and react to these effects may increase student academic performance.

A study that is reviewed later in this chapter (Kanter & Konstantopoulos, 2010) on teacher classroom practices that have the ability to influence student learning, noted that student interest can influence the likelihood that a student will pursue a STEM major or a STEM career in different ways than academic success alone. *Interest* is identified as one of the four factors in the development of a student's *science identity*, which includes *interest*, *competence*, *performance*, and *recognition* (Aschbacher, Li, & Roth, 2009; Brotman & Moore, 2008; Carlone & Johnson, 2007; Hazari, Sonnert, Sadler, & Shanahan, 2010). Science identity appears to be one outcome of a number of activities and conditions found to affect student learning in STEM. In the next section, I review the literature on science identity leading to a description that is used for the remainder of this review. I follow this with an exploration of several studies that examine classroom learning experiences found to affect one or more of the four factors that contribute to the development of a student's science identity.

Science (or STEM) Identity

Research studies support the relationship between the strength of a student's science identity and the likelihood of selection of, and persistence in, a STEM-major in college. There was also evidence that some of the characteristics of the high school classroom learning environment could support the development of science identity including (a) interest in science, (b) perceived competence in science, (c) ability to perform science, and (d) recognition by others as science savvy.

Identity. The formation of an identity involves more than an individual's own actions. Several descriptions of identity leading to science identity more specifically follow. Gee defined identity as "being recognized as a 'kind of person,' in a given context" (2000-1, p. 99). Chatman, Eccles, and Malanchuk (2005) described identity formation as something that happens in the context of everyday situations, viewing identity as "an ongoing dynamic process whereby individuals establish, evaluate, reevaluate, and reestablish who they are and are not relative to others in their environments" (p. 117). With respect to an identity as a student, Hänze and Berger (2007) used the term "academic self-concept" to describe "a generalized, domain-specific feeling of competence that is determined by the student's experience of competence in specific domains of the curriculum, or school subjects" (p. 30). These definitions suggest that the formation of a student's science identity could occur, in part, as the student worked to acquire new knowledge and demonstrate an understanding of this knowledge within the community of learners and instructors in the everyday context of the high school.

Science identity. Two studies were used to establish a working definition of science identity—later generalized to *STEM identity*—that is used throughout the remainder of this literature review and in my study. One was a study of women who were successful in science careers, and a second examined the relationship between college freshmen's sense of science identity and their high school experiences. Together these studies helped define the concepts comprising my construct of science identity.

Carlone and Johnson (2007) performed a longitudinal study of 15 women of color who were successful in pursuing careers in science. Through ethnographic case studies, the researchers sought to understand how these women, who all "expressed a strong connection to science" (Carlone & Johnson, 2007, p. 1209) made sense of their science experiences. This study found that even though the women reached different endpoints in their science trajectories, the importance of being recognized by others was a significant feature in the development of a strong and positive science identity, and the development of a science identity appeared to be a significant precursor for choosing to pursue a career in the sciences.

Hazari, Sonnert, Sadler, and Shanahan (2010) studied the physics identities of 3,829 college freshmen who had taken high school physics and were currently enrolled in college English at one of 34 randomly selected U.S. colleges and universities. The findings included equivalent increases in both boys' and girls' physics identities when students reported having had high school teachers who provided support and encouragement and focused on conceptual understanding, labs that addressed students' beliefs, a high frequency of student questioning and commenting, and discussions of relevant issues in science and the benefits of being a scientist. Girls benefitted differentially and positively when their teachers engaged in explicit discussion of female underrepresentation in STEM, which had no impact on boys' science identity. It is interesting to note that the girls less often reported that their high school classes focused on conceptual understanding or made contextual or real-world connections. Since these girls were likely to have been in the same classes as the boys, it may be noteworthy that these same learning environments were perceived differently by the girls and the boys.

In characterizing "science identity," both of these studies (Carlone & Johnson, 2007; Hazari et al., 2010) identified the importance of the concepts of *performance, recognition,* and *competence*. Carlone and Johnson's model articulated the significance of the "socially constructed nature of science identity," suggesting that "one cannot pull off being a particular kind of person (enacting a particular identity) unless one makes visible to (*performs* for) others one's competence in relevant practices, and, in response, others *recognize* one's performance as credible" (2007, p. 1190). Hazari et al. (2010) developed their model of science identity to specifically understand the physics identities of college students enrolled in first year English classes. The researchers used the three components from Carlone and Johnson's model, and also included *interest* as suggested by social-cognitive career theory. Unlike Carlone and Johnson's participants—15 women of color who were already established in careers in science fields thus already indicating interest—the participants of Hazari et al.'s study were students who had not yet committed to a particular field of study, so interest could not be assumed. For my study of teachers and teaching in ISHSs, I could not assume that the students had already established interest in and a trajectory toward the STEM fields; therefore the model I used for STEM identity included the four concepts: (a) interest, (b) competence, (c) performance, and (d) recognition (see Figure 3). I also used the term STEM identity as a more general form of science identity to suggest that students may identify with science, technology, engineering, or mathematics or some combination of these fields.

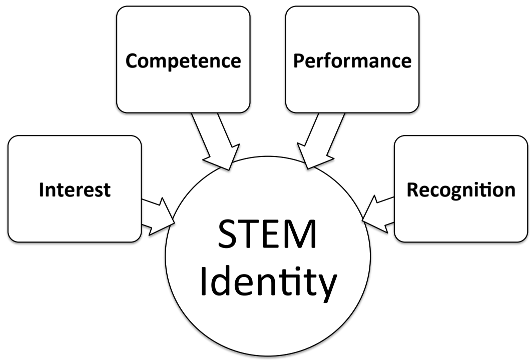


Figure 3. Factors contributing to the development of a student's STEM identity (cf. Carlone & Johnson, 2007; Hazari et al., 2010).

In the following section, I review research that related student learning in STEM to the concepts of interest, competence, performance, and recognition—those significant in the development of a student's STEM identity. Studies relating to student interest in STEM examined both the effects of early interest on subsequent persistence, college grades, and degree attainment, as well as how features of the high school and classroom environments contributed to interest. Further studies investigated the effects of classroom environments and experiences on students' competence in STEM, opportunities to perform or demonstrate their competence, and opportunities to be recognized for their knowledge, skills, and abilities in STEM.

Student interest and persistence in STEM. A number of large-scale correlational studies examining students' college STEM course performance or persistence in STEM found relationships with students' prior secondary school classroom experiences. Maltese and Tai (2011) examined students' STEM persistence (how likely it was that a student would continue to study in a STEM field once started along this pathway) using a NELS:88 longitudinal data set that compiled five sets of responses from 4,700 students—in 8th, 10th, and 12th grades, and following up 6 and 12 years after an original 8th grade survey. This study found correlations between a student's STEM persistence and their 8th grade interest in science, and 12th grade major intent (the major the student anticipated studying in college). Upon examining high school classroom effects, the study found positive correlations between increased student interest in science between 8th grade and 12th grade, and students reporting that their teachers clearly emphasized future study in science, discussed science careers, and used inquiry-type learning over lectures and bookwork. Maltese and Tai (2011) suggested the potential advantage of exposing students to STEM careers earlier in their schooling, helping them understand the utility of STEM courses for future careers by making "science personal, local and relevant" (p. 900), and ensuring that students were actively engaged in "investigating the world around them and thinking about how to solve science and mathematics problems" (p. 900).

Sadler and Tai (2007) compared chemistry grades of 3,521 college students and student reports of classroom practices in their high school chemistry classes. This study found college chemistry course grades were positively associated with the time that students reported spending in peer teaching and being exposed to everyday examples in their high school classrooms, and were negatively associated with the percentage of time students reported spending on individual work.

To understand the effects of pre-college career expectations on the likelihood of a student earning a science degree Tai, Liu, Maltese, and Fan (2006a) examined NELS:88

data to study 3,359 students who earned baccalaureate degrees from 4-year colleges or universities. Studying the same students in grade 8 and at age 30, Tai et al. (2006a) found that a science career goal in eighth grade at least doubled the probability that a student would earn a life science or physical science degree over a non-science degree. Even more significantly, while high mathematics achievement significantly increased the probability of a student earning a physical science degree, having a science career goal in 8th grade had a greater effect.

To understand relationships between course grade and prior high school experiences and academic performance in college science courses, Tai, Sadler, and Mintzes (2006b) studied 8,178 students attending a stratified random sampling of 55 four-year colleges and universities, enrolled in 128 first semester college introductory chemistry, biology, or physics courses. The study found that students earning higher grades in college and university science classes were more likely to report that their high school science courses emphasized understanding (as opposed to rote work), and spent time on critical concepts (those that the students identified as being relevant to their lives and beliefs).

These several correlational studies suggested the importance of exposing students to STEM careers well before high school, helping them connect the science learned in class with their own lives and the world beyond the classroom, and providing opportunities for students to engage with peers to learn through inquiry-based study. A range of collaborative learning experiences—peer-mediated learning, explaining understanding to peers, and inquiry-based learning—surfaced in a number of studies as a potential influence on students' attitudes toward science, future interest in a STEM career, grades in college STEM courses, and student STEM identity. In the following section I review the research studying the effects of collaborative and cooperative learning environments on student performance and attitudes toward STEM.

Cooperative student learning environments. Several studies examined effects of cooperative classroom practices on student performance and attitudes toward STEM. In a meta-analysis of 37 experimental studies of cooperative learning experiences in comparison with traditional learning experiences in SMET [science, mathematics, engineering, technology—this was an earlier version of what is now known as STEM] classrooms, Bowen (2000) found increases in student achievement (mean effect size of 0.51 with a standard deviation of 0.35), persistence (a 22% increase), and a positive effect on student attitudes toward their SMET classes.

Some collaborative, inquiry-based learning activities are referred to as project, or problem-based learning. While these two terms are used both interchangeably and uniquely, I have used the term *PBL* in this review to generally represent small group problem-solving activities. A significant majority of the research on PBL has taken place in medical and veterinary schools where the PBL learning approach has been in use for a much longer time than in K-12 classrooms where it represents a more recent adoption. In a large meta-analysis study, researchers looked at the effectiveness of PBL in comparison with traditional classroom experiences primarily in the field of medicine, but also including economics and computer science. Strobel and van Barneveld (2009) performed a synthesis of seven large meta-analysis studies that collectively reviewed more than 100 studies on PBL, focusing on learning outcomes. The meta-synthesis found that the PBL approach was significantly better whenever "the method used to assess basic science knowledge required a level of elaboration beyond multiple-choice or true/false questions" (Strobel & van Barneveld, 2009, p. 54), as well as the retention of knowledge for the long term. In addition, both students and staff reported greater satisfaction with the PBL approach.

In comparing the effects of a cooperative experience (a jigsaw learning experience) with a traditional classroom experience for 137 twelfth grade physics students, Hänze and Berger (2007) found that while there was no direct effect on physics achievement, positive effects from the cooperative experience were noted on students' "autonomy, competence, [and] social relatedness" (p.29). Of particular note was the finding that students who had positive physics self-concepts experienced little difference in feelings of competence between the cooperative and the traditional learning environments, but students holding negative physics self-concepts demonstrated statistically significantly more positive feelings of competence when participating in the collaborative experience. In addition, there was a strong correlation between physics self-concept and gender. Girls, who in this study were more likely to have held negative physics self-concepts, demonstrated statistically significantly greater feelings of competence in the collaborative learning environment. Overall, students in the cooperative learning experience reported greater involvement in learning, a stronger sense of intrinsic motivation, and a greater interest in the topics that were studied.

Summary

The studies reviewed in this section suggest that there are many factors beyond the teaching of STEM content knowledge that have the potential to affect a student's STEM academic performance and their interest in and choice to enter the STEM fields.

While the teacher's individual influence is important, classroom practices and the school environment can also play important roles. Students underrepresented in the STEM fields appear to need an opportunity to become interested through exposure to science content, applications of science content to the real world, and knowledge of STEM careers. In addition, they need opportunities to try out the practice of science and become competent, to share this competence with others through peer-to-peer interactions, and to perform their understanding in a way that facilitates validation and acknowledgement of their competence by others. These needs are in line with characteristics of identity development outlined by Hazari et al. (2010) and Carlone and Johnson (2007). Students belonging to groups underrepresented in the STEM fields must come to identify as STEM learners and this may place different demands on the teachers and their classroom practices. These students need teachers with strong content knowledge and pedagogical content knowledge so they have the guidance to become competent. Project-based, inquiry-based, small-group learning experiences provide opportunities for students to engage collaboratively with others to construct their knowledge and make strides toward proficiency (Bowen, 2000). Additionally they provide students some ownership and autonomy in the learning process (Hänze & Berger, 2007; Strobel & van Barneveld, 2009). Also important are social and emotional learning environments in the classroom and the school, student mindsets about their own abilities to learn, and stereotype threat might affect student learning (Aronson et al., 2002; Durlak et al., 2011; Dweck, 1999; Farrington et al., 2012). A classroom that utilizes small-group instruction might allow the teacher to interact more frequently and proficiently with students creating more opportunities for the formation of teacher-student relationships (Murray & Pianta, 2007;

Reddy et al., 2007). While all students stand to benefit from opportunities to demonstrate their competence and gain peers' and teachers' recognition, there appears to be the potential for students underrepresented in STEM fields to experience greater benefits, which may provide additional pathways toward increasing participation in STEM.

Through these many studies, both classroom practices and the socio-cultural environment in a school appear to have the potential to affect student performance, and some factors seem to stand out as being more important to improvements in STEM education for students from underrepresented groups. Teacher professional development that aims to help teachers understand these factors or conditions and to address them through relevant changes in instructional practices or classroom environments could affect participation by these students. In studies reviewed in this chapter, student collaborative group work such as project-based learning is identified as a way to increase teacher-student relationships, opportunities for peer-to-peer interactions, and student autonomy in their learning. Beyond the collaborative practices that can occur among students within an individual classroom, collaboration appears to be both a condition for and a result of the school culture and environment demonstrating a complex interplay with teachers, teacher professional development, and teacher professionalism.

Chapter 2 Summary

My review has examined literature ranging from characteristics associated with teacher quality and effective professional development to the effects of a school-wide collaborative culture and the professionalization of teachers. I have looked at the effects of social and emotional learning and features of classroom practice found to be differentially effective for students underrepresented in STEM, and have explored the development of students' STEM identity. What follows is a brief summary of these ideas.

Summary of STEM Teacher Academic Background and Experience

The research has been hard-pressed to demonstrate consistently identified causal relationships between specific teacher characteristics and student performance. It is possible to find both examples and counter-examples identifying specific teacher characteristics as those that can guarantee STEM teacher quality. That said, several characteristics have been repeatedly identified as increasing the likelihood that a teacher will be well prepared to help students achieve in STEM. Higher quality STEM teachers are more likely to have teacher certifications and degrees in their subject areas (Goldhaber & Brewer, 2000; Monk, 1994). Mathematics teachers, in particular, appear to be better prepared if they have had five mathematics courses and have participated in math-specific professional development (Harris & Sass, 2011; Monk, 1994). Engineering and technology teachers appear to be better prepared if they have a good understanding of the design process, which is often provided through targeted professional development experiences led by experts (Felder, Brent, & Prince, 2011; Hoepfl, 2011). In addition, teachers appear to produce greater effects on student learning when they have had more than three years of teaching experience (Harris & Sass, 2011). Viewing teacher quality from a staff-level perspective, quality teachers work collaboratively, are collectively cosmopolitan, and have a voice in decision-making at the school level as well as in their classrooms (Bryk et al., 2010; Kennedy et al., 2011).

Summary of Professional Development

Research has identified a number of characteristics of professional development as having an influence on teacher learning and student performance. Desimone's (2009) framework (Figure 2) provides a structure for their organization. Effective professional development needs to be focused on relevant content and pedagogical content knowledge, should involve active learning, be intense and sustained, be coherent with teacher and student needs or school reforms, and should involve collective or collaborative practice. Additionally, the alignment of specific content and pedagogical content with the teacher's disciplinary focus, along with the involvement of experts as resources or mentors, appears to be particularly important for STEM-related professional development (Felder et al., 2011; Hoepfl, 2011). For *inclusive* STEM schools, however, the content of the professional development that could be important hinges on classroom practices designed to enhance a student's STEM identity and to affect students' conceptions of their own learning (e.g., academic mindsets, Dweck, 1999; stereotype threat, Aronson et al., 2002). At the practice level, this might involve learning that may facilitate collaborative approaches to student learning including peer-mediated learning, and project-based or problem-based small group learning. It also may involve reform-based, inquiry-based student learning experiences that allow students to actively engage with the course content and take ownership for their learning, to explain their understanding to each other, and to design and carry out investigations of their own design. Professional development opportunities helping teachers understand these pedagogical approaches have the potential to influence classroom practices that may significantly affect the learning of students underrepresented in STEM.

The effectiveness of professional development is also contingent on more than the described characteristics. All learning takes place within the context of the school, and the school culture can play a role in whether teachers are supported as they endeavor to reform classroom practices and aim to make positive change. Teachers in environments with strong relational trust appear more likely to both be supported by collective learning and to support their peers in learning (Johnson & Marx, 2009). In addition, schools with strong collaborative cultures appear to support increased teacher professionalization and distributed leadership (Kennedy et al., 2011; Kennedy & Smith, 2013).

Summary of Learning by Students Underrepresented in STEM

Both classroom practices and the socio-cultural environment in a school have the potential to affect student learning. Student learning can be enhanced when teachers hold student-oriented beliefs (DeVries et al., 2013), engage in autonomy supported teaching practices (Roth & Weinstock, 2013), support student development of a growth mindset (Dweck, 1999), and when schools have active social and emotional learning programs (Durlak et al., 2011). The development of a student's positive STEM identity can lead to greater participation in STEM. Classroom practices that better support the development of STEM identity involve opportunities for students to become interested and competent in STEM and also provide contexts to facilitate student performance and recognition of their STEM abilities (Carlone & Johnson, 2007; Hazari et al., 2010).

Final Thoughts on The Continuum: Teachers, Professional Development, Classroom Changes, Student Learning

All of the research and reports reviewed for this study to better understand the continuum from teachers' academic preparation, through teacher professional development, to changes in teacher learning and classroom practice, to student learning and performance, point to a pervasive theme of *coherence* across the continuum. Teachers should be prepared with solid content knowledge and pedagogical content knowledge for the subject areas they will teach. Teacher professional development should be aligned with teacher and student needs and school reforms. It should provide opportunities for teachers to collaborate in order to reinforce, share, and disseminate learning and expertise. And classroom practices should be aligned with desired changes in student learning. These steps provide a coherent pathway for the transfer of knowledge and skills leading ultimately to improved student performance (Desimone, 2009). This coherence has the greatest possibility of being effective if it is occurs within a school-wide culture that allows and encourages the spread of knowledge and skills leading to teacher autonomy, responsibility, and distributed leadership (Evans, 2002; Kennedy et al., 2011; Sun et al., 2013).

The research literature identifies particular teacher characteristics and professional development characteristics as important to support teacher effectiveness and student learning. The ISHSs in my study are successfully preparing students to enter STEM majors in college, and for pathways to STEM careers. My study sought to provide a rich description of the teachers and teaching and learning experiences within these successful ISHSs, helping to bridge the gap between knowledge about aspects of teachers and their professional development experiences that support student learning, and the particular efforts of ISHSs in the development of their teaching staffs to meet the needs of their student populations.

In carrying out this study to generate information useful in understanding teachers and their professional development experiences in successful ISHSs, it was important to examine schools that were effectively preparing students from groups underrepresented in STEM to enter STEM majors in college and STEM careers. The process by which the four schools were selected for this study, in addition to the approach used to gather and analyze the data, is described in the Methodology chapter that follows.

Chapter 3: Methodology

Overview of Methodology

The purpose of this study was to come to an understanding of the teacher characteristics and the teaching and learning environments in and across four successful ISHSs using a preexisting data set collected for a larger and more expansive study of ISHSs (OSPrI; Lynch et al., 2011). For inclusion as an exemplar of an ISHS in the OSPrI study, the ISHSs had to demonstrate successful preparation of increased numbers or percentages of students from groups underrepresented in STEM for STEM college majors and pathways to jobs in STEM fields relative to comparison schools, districts, or states (for a more detailed description of school selection for the OSPrI study, see section titled, *The existing data set* under *Data Sources* later in this chapter). My study sought to provide a rich description of the characteristics of the teachers hired to work in these ISHSs and the characteristics of the school-based professional development experienced by these teachers within the context of the ISHS school environment. Further, this study sought to understand if and how the characteristics of the teachers in the ISHSs related to the professional development opportunities provided to and experienced by the teachers, and if and how the needs of students underrepresented in STEM were considered. Providing descriptions and analyses of these characteristics and relationships across these four successful ISHSs may offer a framework or structure to guide school districts interested in designing an ISHS from the ground up, or for school leaders seeking to develop or strengthen the existing STEM teaching staff in their schools.

The method chosen for this qualitative research study was a multiple case study with cross-case analysis (Stake, 2006). It was first a qualitative study because it aimed to elicit understanding and meaning using the researcher as the primary instrument of data collection and analysis to produce richly descriptive findings through fieldwork and an inductive analytic approach (Merriam, 1998). Second, it fit the criteria of case study where each case, bounded by the limits of each individual ISHS, represented the *bounded system*, which Yin (2014) described as "a contemporary phenomenon … in its real world context" (p. 2), whose issues "reflect complex, situated, problematic relationships" (Stake, 2006, p. 10). This type of case study would be best described as an *instrumental* case study (Stake, 2006), because rather than understand each case for its intrinsic value, the goal was to understand the phenomenon of teachers in successful ISHSs through the study of teachers in exemplars of successful ISHSs intentionally chosen as schools that worked. To "strengthen the precision, the validity, and the stability of the findings" (Merriam, 1998, p. 40), this study examined as four cases, the teachers and teaching in four unique schools that were thought to represent the similar phenomenon of exemplars of ISHSs, in the creation of four individual case studies. These four cases made up the *quintain* (Stake, 2006) of the multiple case study where each case offered a distinct opportunity and context to study the phenomenon of teachers and the teaching and learning environment in an ISHS. This study aimed to acquire an understanding "beyond the case" (Stake, 2006, p. 8), beyond a description of teachers and the teaching and learning environment, to analyze the relationship of teachers and learning in successful ISHSs more broadly. Cross-case analysis followed within-case analysis with the aim of understanding both the commonalities among the schools within the quintain and the differences from case to case (Stake, 2006), which led to the development of findings and cross-case assertions that cut across all cases, and gave rise to an "understanding of the aggregate" (Stake, 2006, p. 39).

The data sources for this study were selected from the existing data set collected for the OSPrI study (for a more extensive description of the OSPrI study, see section titled *The OSPrI study* under *Data Sources* later in this chapter; Lynch et al., 2011). The OSPrI study gathered data from eight exemplars of ISHSs from which eight complete *OSPrI Case Studies* were developed (Behrend et al., 2014; Behrend, Lynch, Peters-Burton, Spillane, Han, & Ross, 2015; Ford, Kaminsky, Lynch, House, & Han, 2014; Han, Lynch, Ross, & House, 2014; Lynch et al., 2013; Peters-Burton et al., 2014a; Peters Burton, Kaminsky, Lynch, Behrend, Ross, House, & Han, 2013; Spillane et al., 2013). I analyzed the OSPrI Case Studies along with selected analogous raw and coded data from four of the eight ISHS school site visits focusing particularly on data from those schools that appeared to have the best potential to lead to a richer understanding of the teachers, professional development, classroom practices, and learning by students underrepresented in STEM and the relationships among them (Behrend et al., 2014; Lynch et al., 2013; Peters-Burton et al., 2014a; Spillane et al., 2013). The teachers and the teaching and learning environment within each ISHS represented a single case, and a short *Teachers and Teacher Professional Development Case Study* was written for this dissertation to analyze and interpret the data from each individual school. These four new case studies (see Appendix C) comprised the multiple case study; and cross-case analysis was used to better understand the quintain—"both its commonality and its differences across manifestations" (Stake, 2006, p. 40).

The remaining sections of this chapter describe the research process for this study. This methodology begins with a restatement of the research questions followed by a description of the epistemology and theoretical perspectives that guided the study. Next, the OSPrI study and the subset of schools selected for my study are described along with an explanation of the criteria for selection. Following this, the subset of the existing OSPrI data that was used for my study is described along with the analytical method I followed to organize and analyze the data for the four cases in the quintain and for the cross case analysis. Finally, validity and reliability issues in this study are addressed.

Research Design

Research Questions

The following research questions guided this investigation of teachers and teaching at four exemplars of ISHSs—those that have been determined through a variety of measures to be better preparing larger numbers or proportions of students underrepresented in STEM for STEM majors in college and pathways to STEM careers by providing stronger backgrounds in STEM coursework, increasing graduation rates, and increasing college admission rates relative to comparison schools, districts, or states.

1. How might the backgrounds [educational, experiential, motivational] of the STEM teachers hired to work at successful ISHSs be characterized?
2. How is professional development conceptualized at each ISHS?
3. How do STEM teacher characteristics relate to the conceptualization and implementation of teacher professional development in these ISHS?
4. How do these STEM-focused schools use teachers' characteristics and professional development experiences to support STEM learning, interest, and

agency of students underrepresented in STEM majors in college and STEM careers?

Epistemology

This cross-case analysis is grounded in the constructionist paradigm, which makes the ontological assumption that there are multiple realities, determined by multiple participants; along with a subjectivist epistemology, which assumes that knowledge is co-created between and among all participants, including the researcher (Denzin & Lincoln, 2000). Both Piaget (constructivism) and Papert (constructionism) view knowledge as constructed in interactions with the world; however, Papert views the process as the individual's transformation of ideas through engagement and public interaction with these external objects and ideas, while Piaget focuses primarily on the individual's changing knowledge (Ackermann, 2001). Crotty (2007) differentiates constructionism from constructivism as the development of collective knowledge through social interaction as opposed to the development of one's own knowledge as one interacts with the world. In line with the constructionist paradigm, the aim of this inquiry is to *understand* a situation, and the nature of this knowledge involves "individual reconstructions coalescing around consensus" (Lincoln & Guba, 2000, p. 166). Embracing a constructionist perspective implies accepting that people's understandings are shaped through their interactions with the individuals, objects, and symbols that make up their circumstances. Teachers construct their understanding through multiple and varied interactions with colleagues, administrators, students, and the extended school community within the context of the school. Likewise, as a researcher, my understanding of the teachers' experiences was constructed through my interactions with them, their symbols, and their environments. In addition, I interacted with data previously collected, co-constructed, and co-analyzed by the OSPrI researchers who performed the site visits at each ISHS. In interpreting the teachers' experiences, I had to socially construct my understanding of the teachers' socially constructed understandings, as well as of other researchers' constructed understandings. Crotty (2007) refers to this as the "double hermaneutic" (p.56) of social science research (and could even be considered a triple hermeneutic, given the additional level of interpretation, in this case). It was important, therefore, for me to acknowledge my own subjectivity and to ensure that adequate data were collected to support the themes or theories developed through this study.

In the creation of a valid case study, it was important use the data as a means to hear and acknowledge the voices of the individuals involved in the experience of teaching and learning in ISHSs in the telling of their story. Therefore, this study used data gathered from a diversity of participants—teachers, administrators, staff, students, parents, and community members—and across multiple situations and activities within four schools in total. The teachers' voices were accessed through the Teacher Survey, teacher focus group, and post-observation interview data. Administrators who may have been responsible for conceiving, planning, organizing, and supporting teacher professional development articulated their insights and perspectives through interviews and the Administrator Survey. Student and parent voices from focus groups helped characterize their perspectives on classroom practices, learning experiences, and the school environment. Data from classroom observations provided on-site researchers' observations and perspectives on teacher and student interactions, as well as the application of teacher skills, knowledge, and professional development. Data from post-observation interviews between teachers and researchers allowed some consensus or common understanding of what transpired during classes. Descriptions of teacher characteristics along with an understanding of the teaching and learning environments in these ISHSs were developed using these many and varied data sources from multiple and diverse participants. In addition, the interpretations of the participants' voices and other researchers' interpretations were visited and revisited in the iterative actions that comprised the development of the cross-case analysis.

For the OSPrI study, at each school, sets of six researchers (not necessarily the same six researchers) participated in interactive and observational data gathering with multiple school personnel, which provided a diversity of voices contributing to a rich socially constructed description of the teacher experience. Also, researcher observations coupled with teacher, student, administrator, parent, and partner self-reports and commentary allowed some triangulation of data to reduce validity threats. Each single case was bounded by the limits of an individual ISHS. The four schools, perceived to represent a similar phenomenon of exemplars of ISHSs, comprised a multiple case study (Stake, 2006). These four similar, but unique cases were analyzed both individually (within case) and collectively (across cases) to develop an understanding that resonated among all cases while still allowing the unique characteristics of each school to come through to tell the entire story.

Participant Selection

The bounded system in this study representing the individual case was the ISHS, which included its teachers, administrators, students, parents, and community, along with the infrastructure that contributed to its functioning during the year the data were collected. Eight ISHSs made up the original OSPrI multiple case study. I selected four of the eight schools from the OSPrI study for my study based on two criteria. The first criterion was that I participated as one of the researchers on the school site visit, and the second was that there was reason to believe that the data on teachers and teaching was adequately rich and extensive to allow my research questions to be answered. In four of these schools, the discussions of teachers and their teaching and learning experiences within the schools rose to relative prominence in focus groups, administrator and teacher interviews, and on the school websites. The schools selected for my study included Manor New Tech High School in Manor, Texas (MNTH; Lynch et al., 2013); Gary and Jerry-Ann Jacobs High Tech High School in San Diego, California (GJJ-HTH; Behrend et al., 2013), California; Denver School of Science and Technology at Stapleton in Denver, Colorado (DSST: Stapleton; Spillane et al., 2013); and the Urban Science Academy in Boston, Massachusetts (USA; Peters-Burton et al., 2014a). All future references to these schools use the indicated acronyms, although when the OSPrI Case Studies for these schools are specifically referenced, typical APA citation format is followed. Table 2 provides some general information about each of the selected schools.

Table 2

Selected Schools for the Multiple Case Quintain[a]

School	Student Population	Attendance Zone/ School Site/ School System	Affiliations	Site Visit Dates
MNTH	333	small town/exurbia/ small public school system	State-level STEM network: T-STEM National-level network: New Tech Network	May 2012
GJJ-HTH	578	large metropolitan area/ suburban neighborhood/	Public charter network (K-12): High Tech High	Dec 2012

		networked charter school system		
DSST	508	large metropolitan area/ suburban neighborhood/ networked charter school system	Public charter network (6-12): Denver School of Science and Technology; also Denver Public Schools	Feb 2013
USA	576	large metropolitan area/ suburban neighborhood/ large, academically tiered public school system	Boston Public School Magnet School Teachers Union	Mar 2013

[a] Data were collected during 2012-2013 school year for MNTH; all others during 2013-2014 school year.

Data Sources

The OSPrI study. The OSPrI study was an NSF-funded research study to understand the characteristics of exemplars of ISHSs with respect to *10 Critical Components* identified through the research literature (Lynch et al., 2011; Appendix A). A collection of referrals from state education organizations, experts in the fields of STEM and education, and policy documents identified potential exemplars of ISHSs from throughout the United States. Each recommended school was evaluated using publically available data that included graduation and attendance rates, student demographics, and standardized test scores to establish suitability for the OSPrI study. Eight schools were selected that fit the OSPrI study's selection criteria of being STEM-focused, inclusive, and an exemplar of an ISHS. Each school demonstrated student achievement at or above their respective comparison schools, districts, or states; sent a greater percentage of their students to college, more often in STEM majors; and was seen by the education and research fields as "successful" (Lynch et al., 2011). Each school had student selection criteria that were not dependent upon students' prior academic success or high stakes test scores, usually involving a simple application and a lottery selection. These schools often enrolled greater numbers or percentages of students from groups underrepresented in STEM majors and STEM careers, or enrolled a more diverse school population than surrounding schools or districts. None of the schools was the only school in its district, and there was some element of selection by choice in each case. A range of geographic locations and school types were represented among the eight schools selected for the OSPrI study.

Teams of six researchers that included professors, researchers, and research assistants from George Washington University, George Mason University, and SRI visited each school for three to four days between May 2012 and June 2013. Data collected included pre-visit information from school websites, school-provided documents, survey data from school administrators and teachers, and administrator interviews. School and student outcome data were sometimes provided by the schools and also accessed from school system, state, and national publically available online resources. On-site data were collected from classroom observations, student, teacher, and parent focus groups, interviews with teachers, administrators, and school partners, and school tours, and usually at least two researchers participated in each activity. All data were systematically collected following the same research protocols for each school for pre-visit, site visit, and post-visit data collection.

After each site visit, the two researchers who participated in each activity coded and crosschecked the collected data according to the *10 Critical Components* and any additional themes that emerged from the data. All coded data were subsequently entered into NVivo software and organized by the *10 Critical Components* and emergent themes

[NVivo is a software tool for organizing and analyzing qualitative research data; http://www.qsrinternational.com/]. Using the NVivo collected and coded data, individual researchers wrote narratives analyzing and interpreting the data for each Critical Component. A team of a lead researcher and lead research assistant wrote a first draft of each OSPrI Case Study that included the narratives of each of the *10 Critical Components* and emergent themes along with a description of the school context, and a discussion of the school and student outcomes. All researchers participating in the site visit read and edited each case study before it was sent back to the participating school for member-checking and acceptance by school administrators. Finally, the accepted OSPrI Case Studies were published on the OSPrI research website (www.ospri.research.gwu.edu). Additional publications related to the case studies were published in *Theory into Practice*, and *School Science and Math* (Peters-Burton et al., 2014b; Peters-Burton, Lynch, Behrend, & Means, 2014).

The existing data set. Data for my study were derived from three different levels of the OSPrI study data sets for each of the four selected schools. The highest level included the complete OSPrI Case Studies written for each of the four selected ISHSs (Behrend et al., 2014; Lynch et al., 2013; Peters-Burton et al., 2014a; Spillane et al., 2014). The next level included the NVivo files of the data coded for the OSPrI *10 Critical Components* and emergent themes by the site-visit researchers. These files represented preliminary data analyses of classroom observations, interviews, focus groups, open-ended and narrative responses from the Teacher and Administrator Surveys, and documents collected from each school and from the school website or other online sources. Finally, some quantitative raw data were collected, but not coded or analyzed for the OSPrI study. These included Likert-style responses from the Teacher Surveys and some time-related data from the Lesson Flow Classroom Observation Instrument (LFCOP; Lynch & Hanson, 2005). A copy of the LFCOP instrument is included in Appendix B). Pairs of researchers completed the LFCOP instrument during each classroom observation, and a teacher interview usually followed each classroom observation to validate the observations and to collect data on the teacher's perspective of the experience. Table 3 provides a list of the type and number of data collection activities carried out at each school site.

Table 3

Raw Data Sources Collected From Each ISHS

School	Admin Survey	Teacher Survey [a] All/STEM (?)[b]	Interviews School Personnel	Interviews Non-School Personnel	Classroom Obs. (LFCOP/ Interview)	Teacher Focus Groups	Student/ Parent/ Alumni Focus Groups
MNTH	1	21/10	5	4	11	5	7
GJJ-HTH	1	30/14(2)	2	7	9	5	6
DSST	1	22/11(1)	3	8	8	5	5
USA	1	22/11	6	4	12	5	4

[a]Teacher participation was voluntary; approximately 30% of teachers from each school chose to participate.
[b]Parentheses identify the number of teachers who were difficult to characterize as either STEM or non-STEM.

Selections from the data set. Some data from the OSPrI data set were identified as likely to contribute more substantially than others to answering the research questions for my study. As previously mentioned, all of the data from each school in the OSPrI study were coded by the researchers involved in each of the site visits according to the *10 Critical Components* and a few additional emergent themes (Behrend et al., 2014; Lynch et al., 2013; Peters-Burton et al., 2014a; Spillane et al., 2014). These coded data were collected in an NVivo database. There was overlap between some of the Critical Components in the OSPrI study and the research questions in my study. Therefore, in addition to using the selected narratives for the targeted Critical Components from the OSPrI Case Studies, I also returned to the NVivo coded data files that contained additional information relevant to my research questions that did not play as important a role in responding to the OSPrI research questions. Using these previously coded data also served to enhance the validity of the coding process because at least the two OSPrI researchers who collected the data reviewed and agreed with each assigned code.

Using the conceptual framework created for my study (Figure 1) and the OSPrI study's 10 Critical Components (Appendix A), I cross-referenced concepts between the two sets of ideas. Data coded for *CC7, Well-prepared Teaching Staff*, were likely to include information on teacher characteristics and teacher professional development. Data coded *CC9, Administrative Structure*, were likely to contain information about how administrators thought about hiring teachers as well as the design and implementation of professional development in their schools. Data related to classroom practices or teacher professional development opportunities that might support the needs of students underrepresented in STEM were likely coded into *CC2, Reform Instructional Strategies and Project-based Learning*, or *CC10, Special Supports for Underrepresented Students*. Finally, a couple of the themes that emerged while analyzing the OSPrI data—*21st Century Skills* (Lynch et al., 2013) and *School Culture* (Behrend et al., 2013; Lynch et al., 2013; Peters-Burton et al., 2014a; Spillane et al., 2013)—were likely to include information that could be helpful in understanding the interrelationships among teachers, teacher professional development, and classroom practices that support the needs of students underrepresented in STEM.

The first data analyzed were the original OSPrI Case Studies, followed by the NVivo critical component files described above. However, because the Critical Components coding by the researchers involved in the OSPrI site visits may not have adequately captured all of the data that would be useful in answering my research questions, additional raw data sources were revisited. The Teacher Surveys were not fully analyzed before writing the OSPrI case studies except to answer very specific questions, plus there was no analysis of the collected Teacher Surveys across all schools. While most of the questions from the survey that had narrative-style responses were coded and analyzed for the OSPrI study, I took time to more closely examine the survey questions with Likert-type responses for additional information they might provide. In each school, all classroom observations included data collected using the LFCOP instrument, along with researcher notes maintained throughout the lesson, and a follow-up teacher interview. All narrative data were coded according to the Critical Components, but the more quantitative data from the LFCOP were not collectively analyzed. Data from this instrument provided insight into classroom practices that were not elucidated by other means.

Table 4 aligns the research questions for my study with the Critical Component coded NVivo data and additional school data sources from the OSPrI study.

Table 4

Research Questions and Aligned Data Sources

	Research Question	Data Source(s)
1	How might the backgrounds [educational,	• *NVivo coded data: CC7*[a]

	experiential, motivational] of the STEM teachers hired to work at successful ISHSs be characterized?	• Teacher Survey[b]
2	How is professional development conceptualized at each ISHS?	• *NVivo coded data: CC7, CC9*
3	How do STEM teacher characteristics relate to the conceptualization and implementation of teacher professional development at an ISHS?	• *NVivo coded data: CC2, CC7, CC9, 21st Century Skills, School Culture* • Teacher Survey • LFCOP
4	How do these STEM-focused schools use teachers' characteristics and professional development experiences to support STEM learning, interest, and agency of students underrepresented in STEM majors in college and STEM careers?	• *NVivo coded data: CC2, CC7, CC10,* • *21st Century Skills, School Culture* • Teacher Survey • LFCOP

[a] Italicized data sources represent coded data from the original OSPrI study.
[b] Non-italicized data sources represent raw or unanalyzed data from the OSPrI study.

Data Analysis

The data for this study were analyzed in a progression from the individual case through multiple cases, and finally to cross-case analysis of the quintain. The process of analysis iteratively and cyclically progressed through "describing, classifying, and interpreting" (Creswell, 2007, p. 153) the data. Researcher memos, a series of notes, ideas, and thinking about the data and evolving theory, were maintained throughout the entire process as "a way to facilitate reflection and analytic insight" (Maxwell, 2005, p. 12).

Coding

The first step in analysis after collecting all of the relevant OSPrI Case Studies, coded NVivo data sets, and raw data from the OSPrI study was to re-code the data. The first cycle involved *structural coding* that "initially categorizes the data corpus" (Saldaña, 2009, p. 67). This initial step served to organize the large data set into subsets that related to the targeted concepts identified in the review of the literature and in the conceptual framework for this study: (a) STEM teacher academic background and experience, (b) teacher professional development, (c) school-wide collaborative culture, (d) teacher professionalism, and (e) learning by students underrepresented in STEM. (See Table 5 for conceptual and operational definitions for each of these concepts.)

Table 5

Conceptual and Operational Definitions for Concepts in the Conceptual Framework

Aspect of Model	**Conceptual/Theoretical Definition (Literature-based)**	**Codes, Coding Names, Operational Definition (keywords, phrases and concepts)**
STEM Teacher Academic Background and Experience	Teachers prepare to teach STEM courses by completing academic coursework, earning degrees in STEM, participating in teacher preparation programs and becoming certified to teach. Teaching experience and professional STEM experience also contribute to teacher quality.	Content coded under this aspect of the model focused on the training and experience that teachers brought to their positions in the ISHS to include: • Academic background including subject-area coursework, college or university attendance, degrees, majors, content knowledge • Teacher training including college or university programs or degrees, certification, type of certification including traditional, emergency, alternative, special programming, in-house certification programs • Teaching experience, years of teaching, pedagogy, pedagogical content knowledge • Teacher cosmopolitanism as measured by type of college or university attended, location of college relative to ISHS, collective diversity across all teachers in the ISHS • Professional experience including former non-academic positions and research experience

Teacher Professional Development	Effective professional development is focused on relevant content and pedagogical content knowledge that is coherent with teacher and student needs or school reforms, involves active learning, is intense and sustained, and involves teachers in collective or collaborative practice (Desimone, 2009). The content focus and educator expertise of STEM-targeted experiences may be important.	Content coded for this aspect of the model included descriptions of the actual professional development experiences including: • Administrators' perceptions of professional development—what was offered, why it was offered, intent of the experience, school reforms tied to professional development • Teachers' perceptions of professional development experiences—how they related to their needs or student needs, how they related to school-wide mission or reform goals, relevance to subject-area content • Duration and extent of provided professional development; type of learning experience • Time available and/or scheduled for meeting with other teachers to discuss teaching and learning • The existence of collective or collaborative practices among teachers
School Collaborative Culture	A collaborative school culture may contribute to the enhanced effectiveness of teacher professional development through greater diffusion or professional learning and the perpetuation of desired school reforms. A collaborative culture may provide greater opportunities for such activities as reflective dialogue, visible classroom practice and group decision-making.	Content coded under this aspect of the model included both descriptions of how collaboration occurred at the ISHS as well as participant's perceptions of the school environment as collaborative or supportive, to include: • Teachers', administrators' or students' perceptions of the school environment • Relational trust, support for trying out new activities, procedures, lessons; feelings of autonomy (but not necessarily independence) • Reform practices in the classrooms, student-centered learning, student dialogue • Collective participation, collaborative decision-making • Student perceptions of collaborative

		culture, relational trust, teacher support, autonomy supported teaching, student-centered teaching
Teacher Professionalism	Teacher professionalism or professionalization may involve teacher autonomy and decision-making capacity both in the classroom and in the school, opportunities for leadership positions or involvement in a distributed leadership capacity within the school.	This aspect of the model was partially subsumed under school collaborative culture, but data specifically reflecting teachers' autonomy, decision-making, and opportunities for leadership were additionally coded. This could include: • Collaboration in decision-making • Collective responsibility for decisions and results • Leadership structure, distributed leadership, flattened hierarchy, • Teacher empowerment and autonomy both in the classroom and in the school
Learning by Students Underrepresented in STEM	Both classroom practices and the socio-cultural environment in a school have the potential to affect student learning. Student learning can be enhanced when their teachers hold student-oriented beliefs (DeVries et al., 2013), engage in autonomy supported teaching practices (Roth & Weinstock, 2013), support student development of a growth mindset (Dweck, 1999), and when schools otherwise have active social and emotional learning programs (Durlak et al., 2011). The development of a positive STEM identity can lead to greater participation in STEM. Classroom practices that better support the	Content coded under this aspect of the model included those social and emotional factors or classroom practices identified as having the potential to influence learning by students underrepresented in STEM. These could include: • Classroom practices related to project-based or problem-based learning, inquiry learning, student dialogue, student-designed investigations or projects • Collaborative or cooperative classroom activities • Professional development that targeted social and emotional learning, mindsets, theories of learning, stereotype threat • Classroom learning that focused on STEM careers, applications of classroom content to real world issues, or underrepresentation in STEM • Experiences that particularly encouraged students to be successful in STEM fields • Student perceptions of classroom

	development of STEM identity involve opportunities for students to become interested and competent in STEM and also provide contexts to facilitate student performance and recognition of their STEM abilities (Carlone & Johnson, 2007; Hazari et al., 2010).	activities they found particularly supportive and encouraging

However, coding, which is the assignment of a short term or phrase to some portion of data, should do more than simply describe or categorize the data (Saldana, 2009). While an initial pass through the data served to sort it into categories determined by my conceptual framework, I made use of *open* or *initial coding* designed to provide space for the development of new codes representing information emerging from the data itself. Saldaña (2009) explains that a code should represent "a summative, salient, essence-capturing and/or evocative attribute" (p. 3) as a step in "a transitional process between data collection and more extensive data analysis" (p. 4). Coffey and Atkinson (1996) suggest that codes are "tools to think with" (p. 32), and describe this first coding pass through the data as "essentially heuristic" (p. 30) providing an opportunity for the researcher to interact with and to think about the data, to engage in creative thinking with the data, and to ask questions of the data while positing theories and frameworks. Coding should be more than labeling; it should link the data in ways that allow for the codes to be organized and grouped into categories that will help the researcher see patterns in the data. The data for this study were first organized by school, and by theme within each school for the within-case analysis, and later organized by theme across the four schools for the cross-case analysis.

Subsequent cycles of coding were used to "develop a sense of categorical, thematic, conceptual and/or theoretical organization" (Saldaña, 2009, p. 149) from the exercises carried out during the first cycle of coding. Several processes were utilized including *pattern coding,* which aimed to reduce the number of codes into "a more meaningful and parsimonious unit of analysis" (Saldaña, 2009, p. 152) by creating larger categories; and *axial coding*, which involved the search for relationships among categories and sub-categories to better understand the "conditions, causes, and consequences of a process" (p. 159). Corbin and Strauss (2008) describe *process coding* which serves to identify "consequences of action/interaction" among participants and structures within the data. While there appear to be many names for slightly different permutations of the coding process, all allowed the search for connections and interactions among the different data and provided a platform for the development of research findings. Coding, analysis, and interpretation occurred simultaneously and iteratively throughout the data review process along the lines of the constant comparative method (Glaser, 1965). The processes of coding and analysis were carried out one school at a time, with each school representing a single case study.

After coding and analysis, a short case study—*Teachers and Teacher Professional Development in ISHSs Case Study*—was written for each school (see Appendix C for the complete case studies). These four single case studies responded to the four research questions as they applied within each individual school. These case studies were then used for the cross-case analysis.

Cross-case Analysis

The four cases in this study were thought to represent a similar phenomenon, and therefore analysis across the quintain could provide a more robust set of findings on teachers and the teaching and learning environments in exemplars of ISHSs. Stake (2006) advocates for the completion of all individual cases before beginning formal analysis of the quintain suggesting “each [case] needs to be heard while the other is being analyzed” (Stake, 2006, p. 46). Stake’s concern is related to the “case-quintain dialectic” (p. 39) wherein he encourages attention to both common features of the quintain as well as the unique contextual characteristics of the individual case. Throughout the development of each individual case, evidence from the data were sought to support the development of findings responding to the “themes” (Stake, 2006, p. 42) of the study, or the research questions. Also while findings were developed for individual cases, findings that showed the potential to be present across all four cases were collected as researcher memos for consideration when cross-case analysis began in earnest.

Cross-case analysis began after the data from each individual ISHS were analyzed and summarized in the Teachers and Teacher Professional Development in ISHSs Case Studies (Appendix C). This analysis followed the general guidelines of Stake’s (2006) “Track I” (p. 46) cross-case procedure, which called for the development of tentative assertions based on the findings of each individual case, maintaining situationality rather than merging findings across the quintain at the outset. Using Stake’s recommended worksheets, these tentative assertions were then analyzed, examined for prominence, interpreted across all cases, and revised and reworked to better represent the quintain. As the cross-case assertions evolved, there was a search for replication, where subsequent cases supported a similar theory (Yin, 2014). Further analysis examined findings from each case that supported or provided counter-examples of the assertions. Ultimately "theme-based assertions" (Stake, 2006, p. 47) were made for the final cross-case analysis report.

Limitations of Study

Validity and Reliability

As with any research, it was important to ensure that the conclusions drawn were (a) representative of the data collected, and (b) the data collected were representative of the breadth and depth of the concern. In quantitative studies, these criteria are referred to as validity and reliability. In qualitative research, which looks at a study's trustworthiness or authenticity, these criteria are better replaced with the terms: "*credibility, transferability, dependability,* and *confirmability*" (Denzin & Lincoln, 2000, p. 21). Credibility, a qualitative correlate of internal validity, asks whether participants would find the results believable. Transferability asks whether the context and assumptions for the research site are adequately identified so that a reader might make an assessment of a study's applicability to a different situation (Trochin, 2006), and is the qualitative correlate of external validity. Dependability, related to reliability, asks whether the research protocol is appropriate for the study and whether it has been consistently and appropriately followed during data collection and analysis. Finally, confirmability, a correlate of objectivity, asks whether it is likely that others would corroborate the study results.

Lincoln and Guba (2000) explain that the credibility of a study can be enhanced if the study is *fair*, providing a balanced representation of all of the voices that make up the story. Multiple sources of evidence can lessen the threat to construct validity by ensuring that the data are not one-sided and that *all* perspectives, to the extent that they can be identified, are represented in the original plan. During data analysis and interpretation, the researcher must be mindful that the story being attributed to the data is in fact the one being told. Repetitious data gathering allows data to be continuously compared with developing themes to ensure that themes are appropriately supported and that negative cases, those where the data contradict the developing theory, are also documented. Maxwell (2005) uses the term *validity* to refer to "the correctness or credibility of a description, conclusion, explanation, interpretation" (p. 106) suggesting that each aspect from data selection, data collection, coding, and analysis, and finally, to report writing must be monitored for threats to accurate representation. Many qualitative researchers identify processes that may serve to minimize validity threats (c.f., Creswell, 2007; Lincoln & Guba, 2000; Maxwell, 2005; Saldaña, 2009; Stake, 2006; Yin, 2003). Table 6 introduces several potential threats to validity in my study and identifies strategies I used to reduce particular validity threats.

Table 6

Validity Threats and Strategies for Alleviation

Process Step	Validity Threat	Strategies to Reduce Validity Threats
Data Selection	Not hearing all of the voices	• Multiple participants Multiple data sources throughout the school Multiple types of data: survey, interview, focus group, observation (Lincoln & Guba, 2000) • Collection of "rich data" (Maxwell, 2005) • Data set includes primary (raw data), secondary (OSPrI Critical Components and emergent themes

		data coded by on-site researchers), and tertiary (OSPrI Case Studies) data
Initial OSPrI Data Collection	Researcher bias; selective data collection	• More than one researcher present for each activity. Two researchers agreed on accuracy of notes taken (cross-checking; Creswell, 2009) • Where collected, audio files were consulted to ensure accuracy of quotes • OSPrI Case Studies (thus the interpretations from collected data) cross-checked with all participating researchers and member-checked with schools (Maxwell, 2005) • Both teacher interviews (as self-reported data) and classroom observations by the researcher used for triangulation of data • Multiple coders coding original data provided multiple perspectives and intercoder-agreement (Creswell, 2009)
Data Coding	Coding bias	• Using coded data from the OSPrI study where categories of data aligned with the research questions for my study (intercoder-agreement; Creswell, 2009)
	Consistency of codes	• Use of a code-book or code definitions that was referenced throughout the coding process (Saldaña, 2009) (see Appendix D for codes used in this study) • Multiple coding passes through the data—doing rough coding of the data as data were initially collected, and again on each subsequent reading (Saldaña, 2009)
Thematic Analysis	Internal validity	• Pattern matching, explanation building, addressing rival explanations (Yin, 2003) • Constant comparison of new data

	with evolving themes (Glaser, 1965)
Researcher bias	• Maintained a reflective journal with "copious analytic memos" (Saldaña, 2009, p. 28) • Triangulation through repetitious data gathering and critical review of multiple data sources to verify the repeatability of an observation or interpretation (Stake, 2006) • Multiple cases, validation through cross-case analysis, replication logic (Yin, 2003) • Peer debriefing through consultation with OSPrI researchers who attended the site visits 2009)

Subjectivity

Lincoln and Guba (2000) observe, "The *way* in which we know is most assuredly tied up with both *what* we know and our *relationships with our research participants"* (p. 183) leading to standards that include positionality, reflexivity, and voice. Positionality reflects the need to understand and identify the researcher's orientation toward or personal interest in the study. Reflexivity acknowledges that a researcher comes to the research experience with a set of subjectivities, and voice refers to the importance of ensuring that readers of the text "hear" the voices of the participants. Lincoln and Guba (2000) identify a researcher's multiple "selfs" derived from academic, experiential, and situational perspectives and suggest a researcher's continuous mindfulness of the influence of each of these selves on interactions throughout the research and writing processes.

My interest in this study has been influenced by my many years as a science teacher and science department head. From my teaching experience I know how much professional development and school environment influenced my teaching practices. I also know that when I felt valued for the expertise I bought to a teaching position, I utilized my skills to greater capacity, felt a greater sense of responsibility to my students and school, and ultimately became a better teacher. When I worked collectively and collaboratively as part of a team of teachers seeking to solve common challenges, both teachers and students appeared to benefit—teachers by sharing collective expertise, and students by better classroom practices. While I was hopeful that the data would show this was true of the teachers in the ISHSs I studied, I was constantly mindful of my bias toward this outcome and worked to ensure that the data, and not my hopes and expectations, would bear out this hypothesis.

As I began this research study, I was mindful that I stepped into the researcher's role having been a teacher of middle and high school science students, a department head in a high school, a parent of students, and a volunteer science teacher in elementary schools. While I had worked with many teachers and many types of school leaders, I had never been a school administrator. Because of my experiences, there was the potential that I would find myself being more sensitive to the challenges experienced by the teachers, or thinking of the effects of teachers' efforts on their students. I had to make sure that I listened carefully to *all* of the voices and made sure to weigh them as I heard them rather than how they triggered my own memories and experiences. As I came to the end of my exploration of the data, and started feeling that I knew the whole story because all of the aspects with which I was familiar had been explored, I made sure that I had fully examined *all* participant contributions represented in the OSPrI data, even those where I anticipated that I would learn nothing new, so I could be sure I had included all of the voices that should be heard in the presentation of a balanced study.

With respect to students from underrepresented groups, the only group of which I can claim membership is that of a woman in a science field. There was the potential that I would find myself more sensitive to the experiences of the girls in their STEM classes or their female teachers, and I made sure to listen carefully to all voices to fully understand their experiences and their perspectives. I am hopeful that I entered this study adequately cognizant of the possible effects of my own personal life history. It was only in doing so that I could successfully explore the existing data from the four ISHSs to present a full and balanced description of the teachers and their teaching and learning experiences as they educated all students in preparation for STEM majors in college and STEM careers.

Chapter 4: Cross-Case Analysis Findings

Introduction

This chapter seeks to make meaning of a study of the STEM teachers and their professional development experiences at four successful Inclusive STEM-focused High Schools (ISHSs; note that a complete and detailed definition of these schools is included in Chapter 1), through a cross-case analysis of the findings from individual case studies. The four schools were intentionally selected from a more comprehensive study of eight ISHSs (Lynch et al., 2011; selection criteria can be found under *Selection Criteria* in Chapter 3). Data were collected and analyzed and individual Teachers and Teacher Professional Development in ISHSs case studies were written for each ISHS according to the methodology described in Chapter 3. The four case studies are included in their entirety in Appendix C, and all data referenced in Chapters 4 and 5 come from these case studies unless otherwise noted. This chapter presents findings across the four cases in response to the four research questions that guided this study:

1. How might the backgrounds [educational, experiential, motivational] of the STEM teachers hired to work at successful ISHSs be characterized?
2. How is professional development conceptualized at each of these ISHSs?
3. How do STEM teacher characteristics relate to the conceptualization and implementation of teacher professional development at these ISHSs?
4. How do these STEM-focused schools use teachers' characteristics and professional development experiences to support STEM learning, interest, and agency of students underrepresented in STEM majors in college and STEM careers?

This chapter begins with a brief introduction to each ISHS included in this study. Following this, data across the four schools are described and analyzed as they relate to each of the four research questions. In Chapter 5, responses to the four research questions are summarized, conclusions based on these findings relative to the larger literature base on teachers and teacher professional development are presented, and the implications for practice and research are discussed. The four schools selected for this cross-case analysis included: Manor New Tech High School (MNTH) in Manor Texas; The Gary and Jerri-Ann Jacobs High Tech High School (GJJ-HTH) in San Diego, California; The Denver School of Science and Technology at Stapleton (DSST: Stapleton) in Denver, Colorado; and The Urban Science Academy (USA) in Boston Massachusetts. All data for this study came from a preexisting data set collected for the OSPrI Study (Lynch et al., 2011), which involved six-person research teams performing three-day site visits to each of the four schools. During these visits, the teams collected data through focus groups, interviews, and classroom observations. Additional data were collected before each visit through teacher and administrator surveys, Internet searches, and the analysis of documents provided by the schools (see Chapter 3, *The OSPrI study* and *The existing data set* for a more detailed description of the OSPrI data collection and data set). The particular data selected from the OSPrI study for use in this study were described in Chapter 3, *Selections from the data set*.

Using the selected data, four individual case studies on Teachers and Teacher Professional Development in ISHSs (Appendix C) were written following the conceptual framework hypothesized for this study (Figure 1). Each case study examined STEM teacher academic background and experience, teacher professional development experiences, and the use of classroom teaching strategies shown in the literature to have the potential to support learning by students underrepresented in STEM. In addition, the school collaborative culture and other factors related to teacher professionalism or professionalization were described.

The Four ISHSs

MNTH

Manor New Tech High School, one of three public high schools in the Manor Independent School District (MISD) in Manor Texas, first opened as a school of choice for the 2007-2008 school year with 160 ninth and tenth grade students, fourteen teachers, and three administrators. During 2011-2012, the year of the OSPrI visit, the school had 332 students in grades 9-12, and 28 teachers. Two classes had graduated and MNTH was getting ready to graduate its third. The school partnered with Austin Community College and the University of Texas-Austin (UT Austin) in order to enhance both students' and teachers' academic experiences. It also received support from the New Tech Network model to design and implement its project-based learning (PBL) approach to classroom instruction (Lynch et al., 2013).

MNTH served a diverse student population that was 19% African American and 44% Hispanic; more than 50% low socioeconomic status; and 50% of the students would be in the first generation in their families to go to college. According to the principal, when MNTH first opened, "it was just to get our kids to go to college. I mean we [Manor ISD] had a 40% high school completion rate, and maybe 15% of students go[ing] to college" (Lynch et al., 2013, p. 12). At the time of the OSPrI visit, attendance rates at MNTH were over 96%; 97% of graduates for the previous three years had been accepted into two or four year colleges; and post-secondary enrollment rates were 74% and 81% for the two previous graduating classes. These rates were higher for MNTH than comparison schools, district, and state. Students at MNTH also performed as well or better than comparison schools across almost all measures of Texas standardized testing (Lynch et al, 2013).

In the MNTH classrooms, three-week projects were typical, and small group learning was observed far more often than full-class teacher-led lessons. Project-based learning was such an important strategy at MNTH that teacher professional development focused on it, and teachers took time to teach students the steps and routines that would increase the likelihood of effective and efficient student learning through projects.

Teachers were hired for their experience with project-based learning, and MNTH demonstrated their commitment to this instructional approach by providing teachers with additional learning experiences in project-based learning through professional development offered during the summers and throughout the school year. Teachers became comfortable implementing project-based learning in their classrooms; and also working collaboratively to design and refine their lessons, and create projects that supported student learning in line with the Texas state standards. Teachers guided students in learning how to learn through project-based experiences. Ninth grade teachers structured the students' first projects to teach them strategies for achieving positive outcomes through project-based learning, including addressing some of the social and emotional challenges of group learning. Students learned how to use project entry documents and assessment rubrics to develop their "knows" and "need to knows" [these terms relate to the processes involved with the New Tech Network project-based learning]. They learned to delegate and assume responsibility for different aspects of their projects, and how to cooperate and collaborate with each other to ensure that each student could meet the targeted learning goals. They learned to become responsible not only for their own learning, but also that of their team and their classmates (Lynch et al., 2013).

GJJ-HTH

The Gary and Jerri-Ann Jacobs High Tech High School (GJJ-HTH), a public charter high school in San Diego, California, opened in 2000 as the first of the now eleven High Tech High Network schools in the San Diego area. As a result of concerns about a lack of qualified workers for local high tech jobs, particularly of women and underrepresented minorities, GJJ-HTH was conceived and developed into reality through collaboration among local business leaders and educators. It was grounded in the principles of "personalization, adult world connection, common intellectual mission, and teacher as designer" (Behrend, et al., 2014, p. 10). The school website identified innovative features of the GJJ-HTH environment as "performance based assessment, daily shared planning time for staff, state-of-the-art technical facilities for project-based learning, internships for all students, and close links to the high tech workplace" (High Tech High Chula Vista, 2012, p. 4).

With a student selection system based on a lottery weighted by zip code (to counter the effect of school segregation caused by housing segregation) and active recruitment of students underrepresented in STEM, the student body of GJJ-HTH was diverse and generally representative of the student demographics in the greater San Diego area. GJJ-HTH served a student population that was over 41% Hispanic, 11% African American, and 44% low socioeconomic status. More than 96% of students attending GJJ-

HTH graduated from high school within four years. One-hundred percent of the class of 2013 intended to attend college, with 73% heading to four-year institutions. Thirty-six percent of the class of 2013 would be the first generation in their families to attend college. GJJ-HTH focused more heavily on college readiness tests such as the SAT and ACT than on California state standardized tests. As such, student performances on the SAT and ACT were on the order of 10 percentage points higher than the district and state, but state standardized test results were more variable relative to comparison schools—higher in some subjects such as Biology, Algebra I, and English Language Arts, and lower in others such as Chemistry, Physics, and Algebra II (Behrend et al., 2014).

Students who attended GJJ-HTH progressed through rigorous, non-tracked core classes where the majority of their learning was accomplished through interdisciplinary projects. There were few elective classes and most courses, except for mathematics, were integrated across two disciplines and co-taught by two different disciplinary teachers. Students were heterogeneously grouped in classes and student learning differences were addressed through academic tutors who assisted in the classrooms. Honors contracts provided opportunities for enriched student learning and differentiation. Teachers collaboratively designed their course curricula across disciplinary boundaries, creating projects that were connected to their own passions, while being attentive to the standardized tests students would need to take for college admissions (Behrend et al., 2014).

DSST: Stapleton

The Denver School of Science and Technology (DSST) opened its first public charter high school in the Stapleton area of Denver, Colorado in 2004. By 2012, the year of the OSPrI site visit, the DSST Network had grown to include a middle school onsite with DSST: Stapleton, another high school, and four additional middle schools. With a vision statement supporting the creation of "an innovative school where students acquire a rigorous academic foundation that they can apply to the community and world around them in meaningful ways," DSST: Stapleton focused on graduating all students from high school well-prepared for the rigors of a four-year college education. DSST: Stapleton provided a mastery-type, fairly traditionally taught curriculum that broadened to include increased connections to the real world and applications of course content through projects and internships in a process DSST: Stapleton referred to as "gradual release" as students moved from 9th through 12th grades (Spillane et al., 2013).

With a college acceptance rate nearing 100% and about 45% of the students intending to enroll as STEM majors, DSST: Stapleton appeared to be fulfilling its mission. Its student population of about 500 students was diverse and more representative of the Denver population than a nearby comprehensive high school. Thirty-five percent of the student body identified as Hispanic or Latino; 26% as African American; and 45% came from low-income families as defined by the Free and Reduced Lunch programs. DSST: Stapleton also had lower dropout rates, higher attendance rates, higher on-time and extended high school graduation rates, and generally better student performance on standardized tests across subject areas, demographic groups, and grades than a nearby comprehensive high school and Denver County high schools (Spillane et al., 2013).

DSST: Stapleton's goal was not just to get students into college, but to ensure they had the academic preparation and grit to graduate from college. To that end, 9^{th} and 10^{th} grade classes focused on learning and mastering STEM disciplinary course content. Courses were designed backwards from the *ACT Standards for College Readiness,* also using Colorado and Common Core standards as guidelines. Teachers used structured instructional practices, particularly for 9^{th} and 10^{th} grades, that included short learning segments and a spiral technique of revisiting concepts that included a "do now," "instruction," and a "mastery check" (Spillane et al., 2014, p. 22) leading to content mastery before application. Applications of knowledge were more present in the 11^{th} and 12^{th} grades when students participated in internships with local businesses—the majority of which were STEM focused according to one administrator—and research projects during the senior year (Spillane et al., 2014).

USA

The Urban Science Academy (USA), a science-themed traditional public high school, was a school of choice within the Boston Public School (BPS) system. It was in the third tier of selectivity, meaning that it required no specific test scores, GPAs, or requirements beyond an application to be placed into the system-wide lottery. The school was governed by the Boston Public Schools; its teachers belonged to the Boston Teachers Union; and it used approved curricula and assessments determined by BPS. USA opened with support from a grant through the Bill and Melinda Gates Foundation to create several small themed schools from large comprehensive schools in response to poor student performance and failing schools. (Peters-Burton, et al., 2014).

In 2005, USA opened with a student body of approximately 300 students, but in the fall of 2011, as a result of its success and its neighbor's struggles, USA absorbed a more poorly performing school, Parkway Academy of Technology and Health (PATH), within the same building to become a school of nearly 600 students. USA served a diverse student population with 51% identifying as African American, 39% as Hispanic, and 75% as low-income according to the state of Massachusetts. USA advertised itself as a college preparatory school with a focus on "environmental science, technology and the arts" (Peters-Burton et al., 2014a, p. 14). Students at USA completed additional coursework in science relative to the minimum requirements for the state of Massachusetts, and aimed to complete mathematics at least through pre-calculus by senior year. A co-teaching model (general and special education) in 9th and 10th grades provided support for the inclusion of all students in mainstream classes (Peters-Burton et al., 2014a).

Beyond the curricular requirements of the BPS system, decisions involving curricular and classroom practices at USA were rooted in education research, and, if different from other BPS schools, required a majority vote for acceptance by the teachers in the school according to union rules. Co-teaching fell under this umbrella as did changes in the implementation of homework policies. Teacher professional development experiences were research based, and according to one administrator, served to unify the school's vision of reform based instruction. Most STEM classes followed an inquiry-based model of "guided inquiry with significant scaffolding" (Peters-Burton et al., 2014a, p. 30).

According to one administrator, USA went from being one of the lowest performing schools in the school district when it was first opened with the majority of its students from West Roxbury High School, to a "School on the Move" finalist in 2011, being recognized among schools in BPS with the most sustained improvement over a 5-year period. However, with the assimilation of the PATH school, student performance dropped. Between 2010 and 2012 the graduation rate dropped from about 75% to 64%; attendance rates had dropped from about 85% to 82%. Retention rates had risen from about 9% to 14%; and dropout rates had risen from about 5% to 8%. USA was one of only two remaining of sixteen BPS schools originally opened under the small schools initiative in 2004 and 2005.

Research Questions: Findings

In the following section, after a brief summary of the findings across the four ISHSs in response to each research question, data that support these findings are described and summarized.

Research Question 1

1. How might the backgrounds [educational, experiential, motivational] of the STEM teachers hired to work at successful ISHSs be characterized?

Brief summary of findings. The teachers hired to work in these ISHSs were academically well prepared in the disciplinary content of the subject areas they would be teaching; philosophically well aligned with the schools' missions and visions; and demonstrated a willingness to collaborate with colleagues to achieve school goals. Additionally, teachers may have been hired for particular professional experiences or pedagogical skills that better prepared them for a unique school focus. [Note: The OSPrI data collected that related to teachers' motivations to teach, or more specifically to teach in these ISHSs, were in the form of a few comments on the teacher survey relating to the pathways teachers followed in coming to teach in their schools. These data were determined to be inadequate to characterize the motivational characteristics of STEM teachers in ISHSs; therefore the motivation of teachers in the quintain are not described nor further discussed in this study.]

Teacher characteristics. To arrive at a description of the characteristics of the STEM teachers working in the four ISHSs, data from the Teacher Survey administered before each site visit, along with data from onsite teacher, administrator, and business partner interviews; teacher, student, and parent focus groups; and classroom observations were reviewed. It should be noted that responding to the Teacher Survey was voluntary. While approximately half of the STEM teachers in each of the schools participated, it is not possible to know whether the sample was truly representative of the full STEM faculty within or across schools. The Teacher Survey responses were collected and reviewed before each of the school site visits and were used to prepare follow-up questions asked in teacher focus groups and during teacher interviews. In this chapter, in many of the tables summarizing Teacher Survey data, means were calculated from the collected responses across the four schools. These values were used for guidance only, and corroboration was sought through additional data sources including the voices of teachers, administrators, and students, and through classroom observations. This section describes how administrators and school websites characterized the teachers they sought to hire, and how teachers described their academic, professional, and experiential preparation for teaching.

Teacher hiring. Across the four case studies, administrators described having some latitude to determine their criteria for hiring teachers. Some schools had more autonomy than others, but all administrators cited this independence as an important factor in developing a cohesive faculty. An administrator from GJJ-HTH explained, "Hiring is the most important thing that directors do." At DSST: Stapleton, administrators described looking for "a total fit" in the teachers they selected, those demonstrating "solid content knowledge, mission-driven efforts, and a collaborative work ethic" (Spillane et al., 2013, p. 38). At MNTH, an administrator described being able "to hire people who are really open minded," those who "aren't afraid of saying 'I don't know' and are willing to get help." Administrators at USA described the importance of having a group of "solid, committed teachers… at the core of the high school." A teacher added that USA administrators were "really looking to get the best teachers on the ground and getting all of the teachers to buy into the mission." At GJJ-HTH, an administrator explained that finding good teachers could be challenging, "given the way we do things here." And that in order to "hire the best teachers we can hire," administrators needed to be able to focus on hiring teachers who had the skills and inclination to engage in project-based learning, teacher curriculum design, and collaborative practice.

Willingness to collaborate. Across the four ISHSs, all administrators identified a teacher's willingness to collaborate and be part of a team working toward common school goals as an important criterion for hiring. An administrator at MNTH explained, "[The teachers] have to know the content, but also be able to collaborate with colleagues." At USA an administrator explained that part of the interview protocol for hiring new teachers centered on cooperation and collaboration, and described seeking teachers interested and willing to “work together in authentic ways” to “share ideas…successes, or failure.” He added that these efforts in teacher hiring led to the development of a “collaborative spirit” among a community of “professionals who are trying to do their best as a group.” At GJJ-HTH, an administrator explained that because all community members “really rely on each other,” an important part of the interview process included observing prospective teachers for “how they collaborate and interact” when engaged in group work and problem solving.

*Academic background***.** In addition to interest in collaboration, all schools appeared to seek teachers who had earned bachelor’s degrees in the disciplines they were teaching or a very closely allied field. A school administrator from MNTH explained, “You can’t teach what you don't know,” and an administrator at DSST identified that their initial screening of applicants looked for teachers who were “high performers, high achievers” and those who were “really at the top of their college classes at elite universities.”

From the responses of the teachers who completed the Teacher Survey (approximately half of all STEM teachers in these ISHSs) and averaging across all four schools it is evident that 93% of teachers held bachelor’s degrees and 86% held teaching certificates in the subject areas they were teaching or a closely related field. Fifty-nine percent of the teachers had earned higher degrees, either master’s or PhDs, about 85% of which were in a field of education. Forty-six percent of the teachers had engaged in some kind of research experience, and slightly over 30% indicated professional work experiences prior to teaching (Table 7).

Table 7

Teacher Academic Background and Professional Experience (N=46)

School (N)	% BA/BS[a]	% active teaching certification[a]	% master's or PhD	%Rsrch Exp	%Prof Exp
MNTH (10)	100	100	27	40	30
GJJ-HTH (14)	100	100	79	70	43
DSST (11)	91	54	55	55	18
USA (11)	82	91	73	18	36
MEAN	**93**	**86**	**59**	**46**	**32**

[a] Earned bachelor's degrees or certifications in subject taught or very closely allied field.

Alignment with school mission. Another common characteristic of teacher hiring across all four schools was the search for teachers who fit with the primary mission of the school, or as one administrator at USA described, teachers who "fit a certain mold." MNTH looked for teachers with project-based learning expertise and often hired teachers from the UTeach program at UT Austin. Of the 14 teachers hired for the opening academic year (2007-2008), seven were from the UTeach program. According to the principal, "All my math and science teachers had no teaching experience whatsoever the first year; they were all UTeach graduates." He went on to explain, "They're from the school of natural sciences where they take mathematicians and scientists and talk them into becoming teachers." Thus when they began their teaching at MNTH, these incoming teachers had the academic content background of an undergraduate science or mathematics major along with the UTeach pedagogy coursework in project-based learning.

GJJ-HTH prioritized teachers' professional field experiences that could be translated into real world applications through students' projects, and sought to hire teachers who had professional STEM experiences and research experiences. Having strong content knowledge often took precedence in teacher hiring at GJJ-HTH over having appropriate state teacher certification. An administrator explained that in a recent hiring, out of fifty HTH teachers (throughout the High Tech High network of schools), twenty-five didn't have teaching credentials upon hiring, instead perhaps having "been in industry for a number of years" or having a PhD in a subject area, or maybe having "a calling," or being someone "we would really like to work here." On the Teacher Survey, several GJJ-HTH teachers described having been formerly employed as professionals in their fields in such positions as environmental consulting, cell biologist, maintenance and manufacturing engineering, and additional positions as Peace Corps volunteer and EMT lifeguard. One teacher described working in "a few different biology related jobs: biotech, consulting and zoo-archaeology." Another teacher described an important connection between a prior job and the needs of GJJ-HTH saying, "A good number of us come from industry; I wasn't trained as a teacher, but the way the industry works is project-based. My professional background was projects, and we do projects here."

According to the school website, DSST: Stapleton sought teachers who could work with some autonomy in their classrooms, but were willing to work collaboratively in shaping a learning culture of high expectations and high achievement. The school sought: "[teachers] with a track record of raising student achievement to join a team of educators dedicated to providing a rigorous college preparatory program to a diverse population." These teachers were often high achievers from diverse, challenging environments and experiences who had demonstrated perseverance in their own learning. An administrator explained they had hired "a lot of Teach for America (TFA) alumni," who were "able to push through" difficult circumstances.

Administrators at USA had less latitude in teacher hiring because of the school's place in the Boston Public School system, and instead focused energies on shaping the faculty after they were hired. An administrator explained,

> When this school first started it probably took about two years to turn over the staff and probably by year three everybody that was [still] part of the staff wanted to be here … and knew the vision and knew the mission that they were buying into; and we [now] have a strong foundation. A lot of that staff are still with us today.

Administrators across all four ISHSs described the importance of hiring teachers whose philosophies, academic or professional backgrounds, and pedagogical skills or proclivities were aligned with the schools' missions, visions, and goals. This alignment extended beyond teachers and hiring, and is further described later in this chapter in a section examining connections from hiring, through teacher professional development, to teachers' use of targeted classroom practices, and the shaping of the school-wide learning culture (see *Alignment: teacher characteristics through classroom practice*).

Cosmopolitanism. A teacher characteristic, related to teachers' academic preparation but a feature of an entire teaching staff rather than of an individual teacher, is *teacher cosmopolitanism*, described by Bryk et al. (2010) as a function of faculty academic and geographical diversity. The rationale for considering *cosmopolitanism* in this study was that teachers might learn diverse pedagogical approaches and content by studying in schools with different focuses or emphases, or by having these academic experiences in different regions of the United States, or in different countries (when applicable). These more varied experiences could provide a richer resource pool for a faculty to share as they engaged in collective learning. In an attempt to quantify the concept of cosmopolitanism, I designed an equation to calculate a *cosmopolitan factor* that assessed the number of different institutions of higher learning attended by teachers in a particular ISHS for both undergraduate and graduate study, along with the number of states represented by these institutions.

*The cosmopolitanism factor***.** An equation for a cosmopolitanism factor was created to account for academic and regional diversity. For each ISHS, the total of all different universities attended by the teaching staff for undergraduate degrees (# UGR), all different universities attended for graduate degrees (# GR), and the total number of different states represented by the universities (# STATES) were summed together. This total was then divided by the total number of teachers responding to the survey (# TEACHERS; see Table 8).

$$\frac{((\# UGR + \# GR) + (\# STATES))}{\# TEACHERS} = \textit{cosmopolitanism factor}$$

Undergraduate and graduate institutions were considered separately because the majority of graduate degrees were in education and the majority of the undergraduate degrees were in STEM majors. It seemed that these would likely represent different schools with different schools of thought, even if they were at the same university. Each different state (or country) was only counted once for all universities (undergraduate and graduate) attended by the collective faculty.

The larger the cosmopolitanism factor, the larger the number of institutions and states represented within the teaching staff. A cosmopolitanism factor equal to 1.0 might indicate that each teacher attended a different university for one degree. A number below 1.0 might indicate that multiple teachers attended the same university, and a number greater than 1.0 might indicate that teachers earned multiple degrees from different universities, or the universities attended were in different states. With an average cosmopolitanism factor of 1.9 across the four schools, it appears likely that teachers attended multiple schools across multiple states, with teachers attending different schools from each other, and often different schools for graduate and undergraduate study. This calculation is designed as a rough guide for an interesting concept. Some obvious limitations of this cosmopolitanism factor calculation include not accounting for state size, density of colleges and universities in a geographical area, or assessing any particular characteristics of the college or university.

DSST: Stapleton appeared to have a staff with the greatest cosmopolitanism and USA, the least. Beyond this, it is difficult to make any strong conclusions about what these values might mean, and the following are not meant to be anything beyond conjectures. DSST: Stapleton may have had the highest cosmopolitanism because of the school's focus on hiring "from all across the country" as described on their website. GJJ-HTH's second highest cosmopolitanism factor may have been a function of their search for teachers who had worked in their professions before coming to teach, and as a result may have traveled further from their undergraduate or graduate educational institutions. And USA's lowest cosmopolitanism may have been a function of hiring practices of the Boston Public School system, which may have had connections with the Boston teacher preparation programs; or simply of the greater density of colleges and universities situated near USA. (These data were not collected at MNTH.)

Table 8

Cosmopolitanism Factor Calculation (N=46)

School	# UGR Univ.	# GR Univ.	States/Countries Represented (UGR and GR)	# States or Countries other than US	Cosmopol-itanism Factor[b]
MNTH[a] (N=10)	-	-	-	-	-
GJJ-HTH (N=14)	14	8	CA, MA, IN, NJ, NY, TX, VA, Canada	8	2.1
DSST (N=11)	10	6	CO, DC, MD, IL, IN, MA, MD, PA, VT, WI, UK	11	2.5
USA (N=11)	9	3	MA, ME, RI, India, UK	5	1.5
MEAN					1.9

[a] Data on the location of the universities teachers attended were not collected for MNTH.
[b] The cosmopolitanism factor was calculated by adding the total number of different universities attended for undergraduate degrees (UGR), the total number of universities attended for graduate degrees (GR), and the total number of states represented by the universities (not duplicated for UGR and GR) and dividing this sum by the total number of teachers responding to the survey.

Teaching experience. To gain an understanding of teachers' teaching experience, retention, and turnover, data were collected from the responses of the teachers who chose to complete the Teacher Survey on teachers' average years of teaching experience, average years at the ISHS, and the average teacher age range (Table 9). For reference, the number of years each school had been in operation at the time the data were collected are also included. The research literature suggested that teaching experience (Harris & Sass, 2011) and teacher turnover (Ingersoll, 2001) could be related to student performance. High teacher turnover could also be indicative of a school environment with inadequate administrative support for teachers or limited teacher input into school decision-making

(Ingersoll, 2001). The data in Table 9 suggest that the average STEM teacher in the ISHSs had been teaching for over six years, had been at their ISHS for over four years, and was between 30 and 34 years old.

Table 9

Years of Teacher Service

School (N)	Year School Opened (years since opening at time of OSPrI visit)	Average Years of Teaching Experience	Average Years at the ISHS	Average Age range
MNTH (10)	2007 (5)	8.1	4.1	35-39
GJJ-HTH (14)	2000 (13)	6.9	6.0	30-34
DSST (11)	2004 (9)	4.4	3.3	25-29
USA (11)	2005 (8)	7.4	3.7	30-34[a]
MEAN (46)		**6.7**	**4.4**	**30-34**

[a]Two teachers with the longest teaching experience did not provide a response of their ages so this average is most likely skewed lower than it should be for this school.

Averages, however, can be deceiving, perhaps presenting an inaccurate description of the actual make-up of the teaching staff. To better show the variation across the teacher ages in the schools, frequency counts for each of the age ranges are included in Table 10. Teachers' modal age range was between 25 and 29 in two of the schools individually (DSST: Stapleton and USA), and across all four schools (Table 10).

Table 10

Teacher Age Range Frequency

School (N)	< 25	25-29	30-34	35-39	40-44	45-49	50-55	NR[a]
MNTH (10)		3	2	3			2	
GJJ-HTH (14)		4	3	4	1	1	1	
DSST (11)	1	6	1	2		1		
USA (11)		4	2	1	2			2
Total (46)		**17**	**8**	**10**	**3**	**2**	**3**	**2**

[a]NR = no response

To further explore these data to better understand teacher experience and retention, three percentages were calculated: the percentage of *experienced* teachers having five or more years of teaching experience in any school—Ingersoll (2004) suggests that more than 42% of teachers leave teaching within the first five years; the percentage of teachers who had been working at the respective ISHS for more than three years, to get a sense of teacher retention; and the percentage of teachers over age 30 (Table 11). Similar to the data in Table 9, Table 11 suggests that teachers were generally experienced and stayed in their teaching positions at their ISHSs: 73% of the STEM teachers had taught for five or more years by the time of the OSPrI study, and 56% of the teachers had been at their respective ISHS for more than three years. When the data were more closely examined, some differences among the schools were noted. The data from three of the schools: MNTH, GJJ-HTH, and USA, were more similar to each other with teachers having more teaching experience, a greater percentage having taught for more than three years at their school, and a higher percentage of teachers over age 30. DSST: Stapleton had the smallest percentage of teachers who had been teaching at least five years (5%), and the smallest percentage of teachers who had been at this particular ISHS for more than three years (27%), even though the school had been in operation for eight years. USA had the highest percentage of teachers with at least five years of experience (100%). GJJ-HTH had the highest combination of experienced teachers and longevity teaching at GJJ-HTH with 71% of the teachers having taught five or more years, and 71% having taught at GJJ-HTH for more than three years. At MNTH, even though only 64% of its teachers had been teaching longer than five years, they had the highest percentage of teachers having taught longer than three years at the school (80%), and the greatest percentage of teachers over age 30 (73%).

Table 11

Teaching Experience (N=46)

School (N)	% with ≥ 5 years teaching experience	% having taught > 3 years at THIS school	% > age 30
MNTH (10)	64	80	73
GJJ-HTH (14)	71	71	72
DSST (11)	55	27	36
USA (11)	100	45[a]	64
MEAN	**73**	**56**	**61**

[a]USA absorbed another school within the same building two years prior to this study and at least 27% of the USA teachers responding to this survey joined USA during the merger, which would bring this percentage to 72% which is more in line with MNTH and GJJ-HTH.

Summary: Teacher characteristics. The research literature described several teacher characteristics as having the potential to affect student learning. These included academic disciplinary content preparation (Monk, 1994), teacher preparation (Boyd, Grossman, Lankford, Loeb, & Wykoff, 2005; Goldhaber & Brewer, 2000), and years of teaching experience (Harris & Sass, 2011). A vast majority of the teachers at the four ISHSs had earned bachelor's degrees in their content areas and held teaching certification in the disciplines they were teaching (Table 7). In addition, more than half of the teachers had earned higher degrees, the majority of which were in some field of education. Collectively these data across the schools suggest that these teaching staffs could be described as having had STEM education experiences supporting the development of STEM content knowledge and pedagogical content knowledge. Comparing these averages with national studies (Banilower, Smith, Weiss, Malzahn, Campbell & Weis, 2013; Goldring, Gray, Bitterman, & Broughman, 2013, NSB, 2012), the typical ISHS

STEM teacher responding to the Teacher Survey for this study was more likely to have earned a bachelor's degree (93% at ISHSs versus a range of 45% – 60% nationally), and was similarly likely to be certified (86% at ISHSs versus about 87% nationally). The average ISHS STEM teacher was younger (a range of 30 – 34 years in these ISHSs versus a range of 31 – 40 years for science teachers, and 41 – 50 years for math teachers nationally), and had been teaching for a shorter period of time (6.7 years of teaching experience in ISHSs versus 11 – 20 years nationally). It should be noted that the four schools had been open for a range of 5 – 13 years.

The literature also suggested that teacher research experiences could positively affect student academic performance (Silverstein et al., 2009). Forty-six percent of the teachers in these ISHSs reported having engaged in some kind of scientific or education research. Also, 32% of the teachers reported having had prior professional experiences in the STEM fields [national averages were not available for research or professional experiences]. The teachers in these ISHSs, in comparison with national samples, were, on average, younger, with fewer years of teaching experience, but about the same levels of teaching certification; were academically better prepared based on undergraduate degrees in their STEM teaching subject areas; and many came with prior research and professional experiences.

Across these measures of teacher background preparation for teaching, the strengths and weaknesses of each school's teaching staff differed. Schools were most similar in their percentages of teachers having earned bachelor's degrees in the subject areas they were teaching, but other measures differed more notably. GJJ-HTH's STEM teachers had stronger STEM academic backgrounds with a greater percentage of the teachers having earned advanced degrees, having engaged in research experiences, and having previous professional experiences. Teachers from MNTH were slightly older on average, with a smaller percentage under age 30. These teachers also all held bachelor's degrees and active teaching certifications, but fewer had earned advanced degrees. Of the four schools, MNTH had the largest percentage of teachers having taught at the school for more than three years, perhaps suggesting less teacher turnover. DSST: Stapleton had the greatest percentage of young, inexperienced teachers, and the lowest percentage of teachers holding active teaching certifications. However, most DSST: Stapleton teachers had earned bachelor's degrees in their subject areas, and collectively the teaching staff had the highest cosmopolitanism factor of the four schools, with teachers coming to DSST: Stapleton from the greatest diversity of undergraduate and graduate institutions and from the greatest number of states. They also reported the largest percentage of teachers having taught at DSST: Stapleton for fewer than four years, which might suggest a higher teacher turnover rate. USA, a school subject to the hiring requirements of the local public school system, had the lowest percentage of teachers holding subject area bachelor's degree. And although their percentage of certified teachers was fairly high, it still was not 100%. Perhaps in parallel with a smaller percentage of teachers having earned subject area STEM bachelor's degrees, USA's teachers also had the lowest percentage of research experience. However, USA teachers had the most experienced teaching staff of the four ISHSs with 100% of STEM teachers reporting having taught for five or more years.

Administrators in these ISHSs described the importance of having the autonomy to hire teachers with strong STEM content knowledge, a philosophical alignment with the schools' missions and visions, and a demonstrated willingness to work collaboratively to achieve the schools' goals. The data appear to demonstrate that, in general, administrators were successful in their hiring practices. Teachers were hired with the described academic, pedagogical, and experiential backgrounds to help them carry out their jobs. However, in these ISHSs, teacher learning did not end with their hiring. Teachers were not expected to simply go into their individual classrooms and work some magic. Continuing professional development was intentionally planned, scheduled, and implemented in each school, as described in the next section.

Research Questions 2 and 3

2. How is professional development conceptualized at each of these ISHSs?
3. How do STEM teacher characteristics relate to the conceptualization and implementation of teacher professional development at these ISHSs?

Brief summary of findings. Teacher professional development in these ISHSs was aligned with Desimone's (2009) framework of effective professional development. It was an ongoing process that tended to begin before teachers entered their classrooms in the fall and continue throughout the school year. Intentionally conceived, formal and informal professional development experiences involved collaborative, active teacher engagement aligned with school mission and vision, and addressed teacher or student needs. Professional development was flexible and nimble enough to change as school, teacher, or student needs changed. [The data responding to research questions 2 and 3 overlapped enough to warrant their collective discussion. In Chapter 5, individual responses to these two questions are provided.]

Teacher professional development. The data used to shape an understanding of the teacher professional development experiences in these ISHSs came from sources as varied as administrators' interviews and school websites that described the intent of professional development; the Teacher Survey, and information from teacher focus groups and interviews that presented teachers' perspectives; and classroom observations that provided insight to the translation of professional development experiences into classroom practices.

Teachers' professional development opportunities in these ISHSs took a variety of forms, involved different combinations of participants, came from a number of sources, and served a diversity of needs and purposes. Across the four schools, there were similar patterns of professional development experiences, and individual variation within these patterns; yet all schools highlighted the importance of the development of a community of adult learners. A board member at DSST: Stapleton described, "An incredible learning community" where "the teachers help each other [and] … are part of a learning community that is so strong." A teacher at USA described their professional learning communities saying, "We do a lot of collaboration; doing some data research, creating a couple of small groups…We're also coming up with some fairs or exhibition of our own best practices." An administrator at GJJ-HTH explained, "We knew that when we started HTH it needed to be a rich learning place for the adults who worked here if we were going to succeed; we knew we needed to figure out how to engage the adults." At MNTH, an administrator explained, "[We] need teachers willing to learn, willing to try." Teacher professional development contributed to shaping these learning communities.

Professional development across the four schools exhibited many of the characteristics described in Desimone's (2010; see Figure 1) framework of effective professional development: experiences were of adequate *duration,* being intense and sustained; had a *content focus* that was *coherent* with schools' targeted reforms and the needs of teachers and students; and involved *active learning* and *collective practice.*

In this section, teacher professional development across the four schools is described according to the following logic. First, the structure of *who* was involved in professional development in the ISHSs is presented. Professional development was offered in four different groupings: (a) whole faculty experiences; (b) smaller target groups such as individual department or grade level planning groups, groups engaged in instructional rounds or groups determining the direction of school reforms; (c) teacher pairs, as in co-teachers, teacher mentors, and collegial peer partners; and (d) individuals involved in observation and feedback, often with an administrator. This discussion of *who* is followed by a discussion of *when*, relating to the timing of professional development—its intensity and duration—a feature described in Desimone's (2010) framework of professional development.

This is followed by a discussion of *what,* that considers the content of teacher professional development experiences, and *why* that explores choices made about professional development experiences, addressing the coherence of the content with targeted school reforms (aligned with the schools' missions and visions), and with teachers' or students' needs. Finally, the *how* is explored, examining the collaborative practices that underlay the majority of the professional development experiences described in these ISHSs, and the collaborative school culture that supported knowledge flow and idea exchange.

Who: Four levels of professional development. There was evidence across all four ISHSs that teachers participated in professional development experiences as a whole faculty, as part of smaller targeted groups, as classroom level teaching pairs, and as an individual teacher; although each school placed different emphasis on these groupings based on the targeted reforms, and teacher and student needs. This section begins with a brief description of the four levels of professional development in each of the ISHS. Because the majority of these experiences were collaborative, they are further described and discussed in a later section on how professional development was carried out. However individualized professional development played an important role in some of the ISHSs and is described separately at the end of this section.

MNTH appeared to have a fairly even distribution across the four groupings. Weekly, ongoing all staff Critical Friends meetings brought teachers together to address concerns related to the project-based learning. Summer experiences were used to jump-start new teachers or invigorate subject area teachers with new or extended content or process learning; and teachers met regularly as departments to align projects with the Texas state learning standards. Many courses were co-taught, encouraging collaboration at the classroom level. An Instructional Coach kept a close watch on classroom teaching and learning and supported and guided individual teachers as they honed their skills.

GJJ-HTH had summer orientation for all new teachers, and teachers had an hour every day before school for various all staff and smaller group meetings. Almost all courses were co-taught and all teachers had either a peer mentor or were in collegial coaching partnerships with another teacher. GJJ-HTH appeared to have a lesser focus on individual observation and coaching, which may have been a function of the open classroom, open school environment, and the public presentation of products of learning, which meant that a teacher's work was always on display requiring less in-classroom monitoring or intervention.

DSST: Stapleton provided summer orientations for new teachers and planning time for all teachers. There was time during the school year for department meetings and at the end of each trimester, subject area teachers met to analyze student data and to formulate plans to address gaps in individual student's learning. Individual teacher observation and feedback seemed to be the strongest form of professional development at DSST: Stapleton, and individual classroom monitoring was fairly intensive, especially for newer teachers.

At USA, teachers described weekly opportunities to meet with colleagues, but department meetings were optional and compensated. Teachers were required to participate in eighteen hours of professional development each year, which could include full staff meetings, instructional rounds, teacher led mini-courses, and teacher poster sessions for sharing practices. A strong in-classroom component of administrator observation and feedback provided teachers with one-on-one mentoring to examine and shape teaching practices.

Individual observations and feedback. Teachers were supported on an individual level. In some schools, designated administrators actively engaged with teachers in their classrooms to help them develop their teaching skills and to grow as educators, and in some cases these observations had an evaluative component. In others, a less formal system of individual support came through colleagues, mentors, or coaches.

In MNTH, an instructional coach explained that her focus was on instruction in the classroom. She helped teachers plan projects and figure out co-teaching, observed classes and students, provided feedback, engaged in model teaching, looked at data, and helped teachers improve. She spent time in teachers' classrooms "talking with them about the projects, asking how the scaffolding [for student learning] is done." She also provided collaborative expertise for teachers who had no "peer" in the school, explaining that sometimes when there's only one teacher per grade level per content area, they don't have an exact peer/partner to collaborate on goals about the content, and the coach could provide a sounding board "if they need to run an idea past someone." The instructional coach was, in part, hired for her background and broad expertise saying "[the principal] saw the attractiveness in hiring me because of that kind of experience; I could help in [many] different areas." She had an academic background in K-16 curriculum and instruction, and a working knowledge in multiple disciplines. She also described understanding how the school district worked and where to go to access needed supports, saying, "It comes in handy because the teachers have so many different needs. I've used all of my different skills."

At DSST: Stapleton, regular classroom observations came in a two forms and served slightly different purposes. The focus of observations by the School Director and the Director of Curriculum and Instruction was to support teacher growth and development. Academic deans also observed classrooms but were more focused on students' experiences. Yet even though one focused on the teacher and the other on the student experience, both facilitated conversations about teaching techniques and helping to improve student learning. One of the downsides of this fairly intensive observation culture was a relatively constant system of evaluation. Teachers at DSST: Stapleton were on year-to-year contracts with continuation dependent on performance, of which 50% depended on student value added growth data and performance scores. An academic dean described evaluations as playing an important role in teacher development of classroom culture:

> With the teachers…[I work] on their classroom culture to make sure [it is] a place where students can learn and have fun. I do midyear evaluations and reviews of teachers… We talk about areas they can grow and where they are doing a great job.

One teacher, however, commented on the evaluation system suggesting that these extensive evaluations led to a system of ranking that could affect teachers' morale. He said, "We are ranked all the time, observations rank us, 360s rank us. We get lots of numbers." Instead, he suggested:

> Give me comments where I need to improve, but not numbers. I don't want to worry about numbers—I want to be able to be genuine with my peers and bosses, and I don't want to suck up to get better grades. When I get my feedback, I don't want to be arrogant that everyone's rating me high, or depressed or angry at people. I want to know where to improve and what I'm doing well, but I don't need numbers to know that. Numbers cause the problems. Give everyone 3 areas to improve and 3 areas of strength.

He went on to suggest “numbers and rankings can be degrading and depressing for teachers who genuinely want to do well.”

At USA, because of a relatively intense need to shape instruction, the administration was highly proactive in evaluating new teachers, believing that was the only way to “get things moving.” Describing it as “the most frustrating part of the job,” an administrator spoke of the challenge of having teachers who did not “want to buy into your culture.” In addition, an administrator explained that having to spend extra administrative time “supporting someone who is not competent in a classroom” takes away from the school’s priority of students and academic learning, adding “It also doesn’t leave a lot of time for those teachers that are good and great and helping them improve, because they are clamouring for us to come into the classroom and provide support.” An administrator explained that some teachers felt “bothered by the [classroom] visits…bothered by the feedback…bothered by the monitoring,” adding, that some teachers had just been “left alone for so long that they are like ‘What are you talking to me for?’” However, administrators felt, that “feedback is kind, both positive feedback and probably even more importantly constructive feedback.” An administrator told researchers that “a lot of folks haven’t gotten that,” explaining that many long term teachers had never been observed, or coached, or provided feedback to encourage them to become better teachers. This intensified supervision and evaluation was described as the only effective way to “get them to work for you,” or “ultimately get them dismissed or moved.”

Teachers experienced their professional development in a variety of groups serving multiple purposes. Whole faculty experiences often served to orient and shape the learning community. Smaller group experiences addressed the needs of departments, grade level teams, or specialized learning groups. Pairs of teachers supported each other, collaborated on designing shared curricula as co-teachers, and worked as mentoring partners. Individual teachers were supported through classroom observations and targeted feedback.

When: The timing, intensity, and duration of professional development. The research literature identified both the intensity of professional development and its duration as important features supporting teacher learning (Cohen & Hill, 2000; Supovitz & Turner, 2000). This section describes how the four schools shaped intensive opportunities that often took place during the summer, and sustained ongoing learning that was provided for during the school day, week, and yearly schedule.

Summer intensive professional development. Teachers' learning opportunities in these ISHSs began during the summer and continued throughout the school year. Summer experiences at MNTH, GJJ-HTH, and DSST: Stapleton included introductory orientations for new teachers, opportunities for increased focus on individual disciplinary content, and intensive collaborative planning time in preparation for the new school year. Summer orientations were designed to help new teachers embrace each school's routines and values. At GJJ-HTH, new teachers began their active engagement in August through a summer orientation—a 10-day Odyssey program, also known as "HTH Bootcamp." Administrators explained that this time was used to help teachers learn how GJJ-HTH engaged in project-based learning, and to facilitate the development of a staff culture of adult learning. At DSST: Stapleton, the Director of Curriculum and Instruction described new teacher training taking place over three days in August that included "an instruction day, a culture day, and an application day.” In the early years of MNTH’s development, the teaching staff engaged in a week-long training called “New Schools” where, according to the principal, they learned the process of project development and had opportunities to participate in “lots of self reflection” and “buying in as a team.”

Other summer professional development included disciplinary content that targeted teachers’ needs. The engineering teachers at MNTH described participation in an extended Project Lead The Way (PLTW) training to help them prepare to teach the engineering classes. Teachers at USA spoke of attending summer inquiry-based experiences offered through the Boston Public School system, and of being supported to participate in Advanced Placement (AP) institutes. A teacher at DSST: Stapleton said the “administration encourages and pays for PD [professional development] at CU Boulder [the University of Colorado at Boulder],” and explained that engineering teachers had participated in summer programs with the CU engineering department to gain the necessary background to teach their engineering courses. Other summer experiences provided teachers with opportunities to plan for the upcoming school year. DSST teachers spoke of meeting for two weeks before the start of school, which one teacher described as “a very valuable time of year for figuring out what we’re doing, and sharing resources…it allows cross-disciplinary planning.”

Summer experiences were used to orient new teachers to the philosophies, practices, and routines of the ISHSs, and to work as a full staff to plan for the year and strengthen the learning community. Teachers also used summers to target individual needs to expand disciplinary content and pedagogical knowledge.

Ongoing professional development. Across the four ISHSs, opportunities for teacher learning continued during the school day, week, and year allowing teachers to regularly engage with each other over content, pedagogy, general classroom practices, and school-wide concerns. Some of these experiences were formally organized occurring at regularly scheduled times such as all staff meetings or department meetings, but others were facilitated through open lines of communication and schedules structured around common planning time and collaborative work. The purposes of these experiences varied and included activities such as introducing new teaching strategies, trying out new lessons and receiving feedback, addressing student learning challenges, discussing grading and homework practices, and exploring curriculum design, instruction, and assessment. Ongoing professional development provided opportunities to help teachers sustain their learning; share knowledge, ideas, challenges, and struggles; and increase the fidelity of implementation of school-wide targeted practices (cf. Garet et al., 2001).

The principal at MNTH explained, “We always have an ongoing professional development,” and there were structures in place that exhibited planning toward continuous, active, and timely teacher learning at MNTH. These experiences included classroom co-teaching, a system of mentor teachers and master teachers, routine classroom visits by the principal, regular department meetings, and weekly Monday morning whole faculty *Critical Friends* meetings. Many courses at MNTH were team-taught, providing opportunities for cooperation and communication between the two teachers during the course of the regular school day. Additionally MNTH had a “three layer structure” of master teachers, mentor teachers, and classroom teachers. Master teachers had no teaching responsibilities and spent time in classrooms observing and supporting the classroom teachers. Mentor teachers were more experienced teachers with classroom responsibilities who could provide day-to-day, direct on-level support to teachers of similar students or similar courses. The principal also explained that he was "always in the classrooms" to measure the pulse of teaching and learning through the projects.

At GJJ-HTH, an administrator described intentionally scheduled rich learning opportunities that would ensure that "all adults would be engaged in some way or another." These were natural parts of the daily flow. The majority of the faculty at GJJ-HTH participated either in teacher mentoring relationships or in weekly collegial coaching with another teacher. An administrator explained, "We structured the day by contract so the teachers arrived an hour before the students most days," to provide time for these important learning opportunities. To ensure that these experiences were productive and didn't overwhelm teachers' time and energy, administrators explained they "were careful to make sure the meetings were about teaching and learning, advisory, *not* nuts and bolts." An administrator added that programming for professional development was adjusted "on [an] as-needed basis as things come up," indicating flexibility to meet changing needs. The Director of Instructional Support provided examples of the ways they used professional development time saying,

> We … do workshops, PD; we work with directors; we participate in Thursday PD meetings that the directors run; we help plan; how to look at student work, coaching, observations; what do you look for in an observation.

Teachers also engaged regularly with their co-teachers during project development. As one teacher explained, “There is a great deal of adult learning here; every year, every project there is something new to learn.”

At DSST: Stapleton, teachers had time scheduled to engage with colleagues for planning, observations, evaluations of data, and for feedback. Science teachers explained that they “have 75 minutes a day to plan together,” and “departmental meetings are a couple of times a month.” A math teacher explained that the math department had “several meetings each year” to “discuss practices that make us better math teachers.” Another teacher added that our “colleagues are experts in their fields” and excellent resources for each other. Teachers identified having opportunities to be observed by and to learn from administrators. One teacher explained, “We have a Director of Curriculum and Instruction and she frequently observes my classroom, giving me great feedback.” Another said, “The administration frequently visits our classrooms to monitor our teaching practices and to help us grow as teachers.”

The administrators at USA described regular weekly professional development experiences that “could take the form of a department meeting, all-staff meeting, or meeting in teams.” All-staff meetings usually focused on school-wide concerns or initiatives. Within departments, teachers were individually tasked with identifying “a professional practice goal and a student learning goal,” and the department’s professional development was focused on identified department-wide student learning goals. Administrators were in classrooms often providing guidance for teachers and offering another form of professional development targeting the individual teacher. According to one administrator, because USA was a smaller school with a smaller teaching staff, they were able to better supervise and support teachers, and ineffective teachers were less able to “hide.” As previously mentioned, USA was able to select some teachers based on their alignment with the school’s mission and vision. However, as part of the BPS system, at times USA had to take in a teacher with seniority who transferred from another BPS school or, in the case of the absorption of the PATH school, a teacher who was already teaching within the larger school building that housed USA. These teachers might have no interest in the overall focus of USA and the administration assumed the responsibility of honing the staff to encourage them to function as part of the team or to persuade them to seek work elsewhere.

Across the four ISHSs, teachers were provided both intensive professional development experiences that helped them acquire new capabilities, and sustained professional development experiences that allowed them to practice, to continue learning, to interact with and learn from others, and to plan and prepare.

Teacher survey results. To get a better understanding of how the STEM teachers felt about the time available for professional development and how this availability of time affected their instruction, teachers were asked to respond to several questions on the Teacher Survey. STEM teachers who responded to the survey described the adequacy of time for planning, working with other teachers, and for professional development (Table 12), and how that time availability either inhibited or facilitated effective instruction (Table 13). Because of the way this survey question was designed, teachers could indicate whether they had 1= no access, 2 = limited access, or 3 = adequate access to these job related activities, but could not indicate whether more time would have been desirable or might have affected their classroom practices differently. Across the four schools, teachers expressed that time available for planning, professional development, and working with other teachers ranged between limited and adequate (an average rating of 2.6 out of 3), and the availability of this time at least somewhat facilitated effective instruction (an average rating of 4.0 out of 5; see Tables 11 and 12).

Table 12

Adequacy of Time for Preparation, Planning, Collaboration, and Professional Development

Rate your access to each of the following on your classroom instruction:	MNTH (N=10) (1-3) [a]	GJJ-HTH (N=14) (1-3)	DSST (N=11) (1-3)	USA (N=11) (1-3)	**MEAN (N=46) (1-3)**
1. Time available for teachers to plan and prepare lessons	2.8	2.7	2.7	2.6	**2.7**
2. Time available to teachers to work with other teachers	2.3	2.7	2.5	2.4	**2.5**
3. Time available for teacher professional development	2.3	2.4	2.5	2.6	**2.5**

[a] 1=No Access, 2=Limited Access, 3=Adequate Access.

Table 13

The Effects of Time Available for Preparation, Planning, Collaboration, and Professional Development on Classroom Instruction

Rate the effect of each of the following on your classroom instruction:	MNTH (N=10) (1-5) [a]	GJJ-HTH (N=14) (1-5)	DSST (N=11) (1-5)	USA (N=11) (1-5)	**MEAN (N=46) (1-5)**
1. Time available for teachers to plan and prepare lessons	4.6	4.3	4.3	3.9	**4.3**
2. Time available to teachers to work with other teachers	4.0	4.4	4.1	3.5	**4.0**
3. Time available for teacher professional development	3.7	4.0	4.0	3.3	**3.8**

[a] 1=Inhibits effective instruction, 2=Somewhat inhibits effective instruction, 3=Neutral or Mixed, 4=Somewhat facilitates effective instruction, 5=Encourages or enables effective instruction.

Introductory summer experiences for new teachers often provided intensive time for teachers to learn new teaching strategies or reforms in line with the schools' missions. For returning teachers, summer often provided time for focused attention on the upcoming school year or for more in-depth experiences in disciplinary content. Once the school year started, these schools had structures in place that provided continuing opportunities throughout the school day, week, and year to sustain learning and provide teachers with forums to receive ongoing support. Across the four schools, teachers indicated general satisfaction with the amount of time available in their school schedules for professional development experiences. Teachers also identified that the time provided for professional development had a positive effect on their classroom practices, suggesting the relevance of the provided professional development on teaching and learning in these ISHSs. The next section provides a more detailed description of the connections between teachers' professional development experiences and school missions, visions, and chosen reforms; and teacher or student needs.

What and why: The content and coherence of professional development. Across the four ISHSs, teachers' professional development experiences appeared to be thoughtfully designed. The content of the professional development experiences appeared to align with the schools' missions and visions, the targeted classroom strategies and reforms, and the particular needs of the teachers who were hired or the students served. In this section, Teacher Survey data from all STEM teachers who responded to the survey are presented to characterize teachers' perceptions of the relevance of their professional development experiences to their classroom instruction. This is followed by descriptions from each of the four ISHSs to better characterize the coherence of teachers' professional development experiences, school goals, and teachers' and students' needs.

Teacher Survey data. On the Teacher Survey, teachers were asked to identify how their professional development experiences affected their classroom practices—whether experiences had no effect, confirmed what they were already doing, or caused them to change their classroom practices. Table 14 summarizes the professional development experiences that teachers across the four schools collectively found to cause the greatest changes in their classroom practices. Also included in this table are the percentages of respondents across all schools identifying that the topic or content was not addressed through their professional development.

Table 14

STEM Teachers' Perceptions of Impact of Professional Development Experiences

Considering all your professional development, how would you rate the impact in each of the following areas?	MNTH (N=10) (1-3)[a]	GJJ-HTH (N=14) (1-3)	DSST (N=11) (1-3)	USA (N=11) (1-3)	**MEAN (N=46)** **(1-3)**	**%NA[b]**
1. Learning how to use inquiry/investigation-oriented teaching strategies	2.9	2.5	2.6	2.3	**2.6**	**9**
2. Understanding student thinking in S/T/E/M	2.6	2.5	2.6	2.5	**2.6**	**9**
3. Learning how to implement problem-based or project-based learning	2.9	2.5	2.3	2.6	**2.6**	**11**
4. Learning how to teach engineering or design concepts or activities	2.8	2.5	2.7	2.3	**2.6**	**37**
5. Deepening my own S/T/E/M content knowledge	2.4	2.6	2.3	2.6	**2.5**	**7**
6. Learning how to identify,	2.3	2.8	2.5	2.2	**2.5**	**20**

locate, and evaluate technology resources that I can use with my students (e.g. websites, online data sets, etc.)						
7. Learning how to integrate the different disciplines of S/T/E/M into my course	2.1	2.6	2.6	2.5	**2.5**	**24**

[a] 1=Little or no impact, 2=Confirmed what I was already doing, 3=Caused me to change my teaching practice, 4=NA.
[b] Teachers were asked to respond NA if their professional development did not cover particular topics.

Most notable among the Teacher Survey results were the teachers' higher ratings for professional development experiences that were related to the use of STEM reform practices such as inquiry and investigative strategies, problem or project-based learning, and engineering design. Teachers also identified experiences related to understanding students' thinking in STEM and deepening their own STEM content knowledge as important. They reported that professional development related to integrating content across the STEM disciplines and learning how to access and assess technological resources for STEM were also experiences likely to effect changes in classroom instruction.

In the ISHSs. In each of the four individual ISHSs, teachers' perceptions of the most effective professional development experiences appeared to be those that were best aligned with important aspects of their school's mission and vision (for more detail see individual case studies in Appendix C). For example, the pedagogy at MNTH strongly focused on project-based, inquiry-based learning, and engineering practices. In line with this, teachers at MNTH rated professional development related to these topics as having the greatest effects on their classroom practices. Similarly, at GJJ-HTH with its emphasis on co-teaching cross-disciplinary courses of the teachers' own design that encouraged student use of technological resources for researching the projects, teachers noted the importance of professional development related to enhancing their own content knowledge, learning how to integrate across disciplines, and learning how to identify, locate, and help students access and use technological resources (Table 14). Even though the ratings on the impact of their professional development experiences from teachers at DSST: Stapleton and USA were somewhat lower on the experiences that rose to the top of the four schools collectively, the fact that they were still strong across all four schools demonstrated the overall importance of teacher professional development related to reform-based classroom practices within every ISHS. Also, the individual Teachers and Teacher Professional Development Case Studies (Appendix C) show that the experiences identified as most important by the DSST: Stapleton and USA teachers were well aligned with the missions, visions, and goals of their individual ISHSs.

As Table 14 and its discussion indicate, teacher professional development across the four schools appeared to be aligned with the targeted school missions, visions, and goals. There was also evidence that these professional development experiences were designed to address the needs of the teachers and students. At MNTH, one teacher explained that the administration was "highly supportive by providing us with the proper professional development that we as a staff feel is more needed for us to be a successful New Tech school that incorporates STEM education." Some professional development experiences helped teachers learn classroom practices that a school supported. At DSST: Stapleton, teachers described their professional development as helping them become skilled in certain classroom delivery and pacing methods supported by the DSST

Network that had roots in two books: *Brain Rules* (Medina, 2010) and *Teach Like a Champion* (Lemov, 2010). Many teachers, particularly the younger and less experienced, commented on their awareness of and attention toward these classroom practices, along with opportunities to practice, be observed, and receive feedback from administrators and other teachers to help them improve. One teacher explained that their classroom observations were "very traditional," but added,

> There is that support and a decent amount of instructional coaching: they tell you how to teach; there are systems about how to run a classroom. When I was new, there was someone in the classroom three days a week. I had a lot of support, and someone was always there to support from other science teachers or [the] Director of Curriculum and Instruction.

Professional development experiences sometimes helped to fill gaps in teacher expertise. At GJJ-HTH, a teacher described particular pedagogical training that dovetailed with content level expertise saying,

> I started by training Project Lead the Way and it was great because I didn't have a formal background [in teaching]. I started in 2001 and I knew engineering well and I didn't have a lot of background in designing lesson plans. It was great for me and I could focus on how to teach it.

Other professional development experiences might be targeted to teachers' needs relative to a school-wide initiative or change. At the time of the OSPrI visit, USA had redirected its focus to address the student achievement goal that at least 80% of students who attended school at least 80% of the time should pass all of their courses. To support this goal, the Instructional Leadership Team explored research-based practices to determine what changes might be effective. Two initiatives to address this included a shift to performance-based grading, and the implementation of backwards planning where teachers used ideas supported in *Understanding by Design* (Wiggins & McTighe, 2005) when planning lessons. Professional development experiences helped teachers learn to focus less on assessments of homework completion, effort, or good conduct, and more on achievement relative to course standards. They learned how to provide opportunities for students to engage in higher order thinking. In the spring before the OSPrI visit, administrators described coming to agreement with teachers on the Six Core Values for USA, and then providing professional development experiences so teachers could reflect on these values relative to school wide decisions about student achievement and classroom practices. An administrator explained that all-staff professional development time was being used to help prepare and support teachers with making these changes.

At USA, one form of professional development that was available every other month was *instructional rounds,* similar, in theory, to medical rounds. Teams of self-selected teachers observed several classrooms and collected data focused on a particular theme. The teacher leaders had taken a BPS course to learn how to implement instructional rounds in the school, and according to these teachers, USA was the only school to incorporate it and use it school-wide. The teacher leaders described the instructional rounds process as follows. Over the course of three days, groups of 6-9 teachers took turns teaching and observing and collecting "nonjudgmental notes." Observers focused on the "instructional core—[the] triangle between content, teacher, and students." These teachers then collectively synthesized and analyzed the data to “look for patterns [and]…make connections” to “pull findings and make recommendations.” Information gathered through these instructional rounds was used to influence subsequent professional development.

The teacher leaders explained that teachers had led the school-wide changes in student grading practices. Saying “This is a big shift for us: most teachers are used to grading in a very traditional way,” teacher leaders added that changes such as these—“a heart change, an attitude change”—could be particularly difficult, and “there are a lot of teachers disgruntled.” However, teachers’ professional development efforts were focused on the identified reforms as a teacher leader explained:

> Even though everyone may not be 100% on board…we are moving in that direction. People talk about it; it’s a common topic of conversation, but underneath that is really instructional practices, teachers’ beliefs about students and what our role is; all these things come to the surface when you talk about grading. We knew that it would be hard. As far as I’m concerned, there is no argument on the table about whether the old system is better, but it only works to the extent that people believe in it and support it.

Across the four ISHSs, there was an obvious coherence between teachers’ professional development experiences and the chosen school reforms designed to respond to the schools’ missions and visions, and to address the needs of teachers and students. Teachers’ professional development experiences, aligned with the schools’ reforms, were also designed to support teachers in the implementation of the desired classroom practices.

Alignment: from teacher characteristics through classroom practice. The alignment within these ISHSs went beyond professional development that was designed around what the school hoped to do and what teachers needed to learn. Across all four ISHSs there was intentional and thoughtful alignment and coherence that considered teachers' characteristics, as well as the professional development, and desired classroom practices as contextualized within the school environment.

At MNTH, the principal looked for STEM teachers with a strong academic content background as well as an understanding of project-based learning. Most teachers held bachelor's degrees and teaching certifications in the subject area they were teaching, and the majority had come through the UTeach teacher prep program that highlighted project-based learning as a teaching strategy. Professional development did not appear to be the "one size fits all" version, and seemed to target teachers' needs, ensuring that each teacher could take advantage of the professional learning to improve. Classroom observations and comments from students and parents indicated that the targeted project-based learning classroom practices were indeed the dominant teaching strategy. Thus there was alignment among the characteristics that teachers possessed upon hiring, how they perceived their professional development experiences, and ultimately what appeared to be happening in the classrooms.

At GJJ-HTH, the school mission was focused on the specific goal of providing an integrated technical and academic education in order to graduate a diverse student group well prepared to be thoughtful engaged citizens ready for post-secondary education. However, the school director's described goals of "personalization, adult world connection, common intellectual mission, and teacher as designer," better reflected the process by which these outcomes were fulfilled in the everyday workings of the school. The “common intellectual mission” played a role in teacher hiring evidenced by the school’s determination to seek teachers with strong STEM content knowledge who were willing to engage in open, collective, collaborative practice. Summer teacher orientation focused on the project-based learning that formed the backbone of classroom practice, and the formation of a culture of continuous adult learning. Teachers noted that their professional development experiences focused on the use of technology within the project-based learning environment, and that the school supported its integration by providing adequate time and adequate technological training and support for both teachers and students. Teachers also said that their professional development helped guide them in meeting individualized student needs within a classroom of heterogeneously grouped students—again a featured goal of GJJ-HTH. Observations within the school demonstrated the ubiquitous use of project-based learning with an active technological component. There was thoughtful alignment among the teachers who brought strong content knowledge and professional experiences, the design of professional development that provided time for teachers to collaborate and share expertise, and the integrated cross-disciplinary project-based learning strategies featured by GJJ-HTH.

At DSST: Stapleton, the administration sought hard working, academically smart and accomplished teachers with a demonstrated ability to press on regardless—those who could persist in the face of challenge or struggle. The teachers hired to work at DSST: Stapleton included many Teach for America alumni who had previously been placed in situations that might have required them to teach with inadequate supervision and training, work with few resources, and teach students who came into schools with weak track records. These teachers also tended to have strong academic disciplinary content expertise, and a gritty determination to succeed. They tended to be relatively young with limited teacher preparation or teaching experience. The professional development at DSST: Stapleton was structured around teachers' skills and gaps. It was assumed that teachers had disciplinary content expertise but might need guidance, supervision, and support in classroom practices. There was a formulaic approach to teaching with routines involving "do nows," and chunked time with transitions, that gave inexperienced teachers a way to get started—a formula to follow that could support their initial effectiveness in the classroom. Administrators spent time in new teachers' classrooms observing and giving feedback, helping them hone their pedagogical structures to fit the DSST model. Professional development also supported a system of data collection and continuous monitoring and feedback to help teachers ensure no students fell through the cracks, and to help them adjust their own practices to better meet student needs. These teachers, who had demonstrated grit themselves in acquiring strong STEM content knowledge from challenging colleges and universities, were supported with professional development that shaped their classroom instruction to help them guide students in developing their own grit and determination as they worked to master STEM content.

The administrators at USA had a vision and, where possible, teachers were hired who shared this vision. USA was the only one of the four schools in this study that was directly influenced by the rules of the teachers union as part of their partner school system (Boston Public Schools). As such, while the teachers union itself didn't appear to be problematic—all teachers belonged—administrators at USA did not seem to have the same flexibility in teacher hiring afforded in the other three ISHSs. This led to having members of the teaching staff who may not have been completely aligned with the mission, vision, and goals of the school. According to the administrators, this situation required substantial additional administrative time to help all teachers become active and collaborative participants. The most clearly articulated criterion for teachers at USA was that they were interested in being part of a collective group working toward common goals. Administrators worked intentionally with all teachers and teacher groups to help them learn to become collaborative contributors within their departments with the ultimate goal of helping students successfully prepare for college. Teacher professional development, both provided by the school district and designed in-house, appeared to be aligned with the school coursework, school reforms, and teacher and student needs. Teachers described having time during the school day, week, and year to engage with others; and teachers expressed both a collective and an individual voice in shaping their professional development experiences and their classroom practices. Certain practices, such as performance-based grading, an inclusion model (special and general education), and co-teaching in 9th and 10th grades, were implemented at a school-wide level. While not all teachers may have agreed with these practices, teachers voted to implement them and all teachers were responsible for engaging in them as appropriate to the courses and grades they taught. Professional development was shaped around supporting teachers in targeting the desired reforms.

Overall, teachers' background skills and knowledge appeared to be well aligned with the needs of the ISHSs. Where gaps were noted, schools shaped professional development to help teachers implement the desired classroom practices and reforms.

Schools considered student needs in designing curriculum and classroom instruction, and shaped professional development to support teacher learning and practice. Conversations with teachers, students, and administrators, along with the observed classroom practices, demonstrated alignment with the instructional reforms targeted by each ISHS.

How: Collaboration. Across all four ISHSs, collaborative practice was found to underlie the majority of the professional development experiences, and collaborative school cultures appeared to support knowledge flow and idea exchange. Collaborative practice was identified by the research literature as being an indicator of effective professional development (Desimone, 2009), and a process through which expertise gained through professional development experiences could be further disseminated throughout a faculty (Sun et al., 2013). It was also considered a necessary prerequisite of the school-wide culture to facilitate changes in classroom practices through professional development experiences (Hamilton & Richardson, 1995).

As described in the section in this chapter on *Teacher hiring*, administrators identified a willingness to collaborate as one of their key requirements when hiring teachers. The presence and maintenance of a school-wide collaborative culture was identified in the literature reviewed in Chapter 2 as contributing to the promotion of social and emotional learning in schools; and also a pre-requisite for, and an outcome of, effective professional development. The existence of a collaborative culture in a school might suggest better support for collective learning. Furthermore, teachers working together toward common goals might contribute to the creation of an environment of trust, mutual support, and collegiality.

Across the four ISHSs, teachers were first provided guidance and training on how to work collaboratively. Subsequently, they had multiple, ongoing opportunities to engage with others to share ideas, skills, and knowledge, and to develop trusting, supportive relationships. Open lines of communication within the schools allowed for the free flow of ideas, strategies, and concerns among teachers and administrators.

At MNTH, the principal described collaboration for common good as a fundamental requirement for teachers being hired saying, "I was really looking for people that could come in and be a team, to make our family/team, to make this school the best there is." He also sought teachers willing to work with others to examine teaching practices, who "weren't afraid to have teachers and other people really critically analyze their projects to come up, to make them better." A teacher at MNTH recognized the importance of collective, collaborative work explaining, "Having the opportunity to work with a highly supportive team of co-workers has given me the chance to learn from their ideas and support about the integration of STEM in my classroom." At GJJ-HTH, collaboration was a pervasive a part of the school culture, which began with the hiring process, continued through the new teacher orientation, was formalized through peer-mentoring and co-teaching and regularly scheduled meeting times, and was ubiquitous in informal interchanges throughout the school day and year. The DSST: Stapleton website described a commitment to "making sure we can continue to learn from each other at all levels, across all campuses," and teachers in focus groups described being encouraged to collaborate within departments, across network schools, and with the University of Colorado. Teachers at USA described having two hours of common planning time each month, but the Teacher Leaders explained, "We could always use more time…if you look at schools that are most successful, they have more professional development; we want to create a culture where people want to volunteer [to participate in more professional development].” Teachers in the USA science department described their collective efforts saying, “We do a lot of collaboration.” They explained that they were working towards using a common language and common techniques saying, “We were already scaffolding [student’s] learning, but we keep using different language; everyone has their own technique, and we want to make it coherent.”

Teacher survey data. Teachers’ responses on the Teacher Survey to questions about their participation in various collaborative professional development activities during the three years prior to the OSPrI site visits are summarized in Table 15. Averaged across all four schools, more than 75% of the respondents reported observing other teachers teaching STEM courses, attending workshops on STEM teaching, and collaborating to integrate content across the STEM disciplines. Also more than 50% of the teachers reported collaborating with a group of non-STEM teachers to integrate across disciplines and meeting with or using telecommunications to collaborate with others about STEM teaching issues. Teachers in all four schools were less likely to have participated in state or national STEM teachers’ meetings as part of their professional development experiences. It is worth noting that teacher participation in professional development experiences was not evenly distributed across the four schools. At MNTH, teachers were much more likely to report participation in all types of professional development, and at DSST: Stapleton, the participation was generally below 50% for all except classroom observations and STEM workshop attendance.

Table 15

Percent of STEM Teachers Participating in Professional Development Experiences Within the Past Three Years

Percent of STEM teachers participating within past three years	MNTH (N=10)	GJJ-HTH (N=14)	DSST (N=11)	USA (N=11)	**MEAN** (N=46)
1. Observed other teachers teaching S/T/E/M courses as part of your own professional development (formal or informal)	100	93	91	82	**92**
2. Attended a workshop on S/T/E/M teaching	100	79	73	82	**84**
3. Collaborated with a group of S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	100	100	45	54	**75**
4. Collaborated with a group of non-S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	70	100	27	73	**68**
5. Met with a local group of teachers on a regular basis to study/discuss S/T/E/M teaching issues	90	36	45	45	**54**
6. Used telecommunications to collaborate on S/T/E/M teaching issues with a group of teachers at a distance	80	64	27	27	**50**
7. Attended a national or state S/T/E/M teacher association meeting	80	21	27	36	**41**

Co-teaching. In three of the four ISHSs, one of the more formal methods of teacher collaboration occurred through co-teaching. This took slightly different forms in each of the three schools, but in all three, co-teaching provided opportunities for school-day interaction where teachers occupied the same spaces, taught the same students, and collaborated on curriculum design, lesson planning, and instruction. At MNTH, a number of course pairings were taught by two different disciplinary teachers. For example, a course called *Phygebrics* was co-taught by a physics teacher and an algebra teacher. At

GJJ-HTH, at the beginning of the school year, teachers chose partners with whom they would design and co-teach classes. Some pairings had been in existence since the school began and others seemed to change from year to year, providing opportunities for teachers to explore different ways to interpret their own subject areas within the context of a new discipline. One teacher explained, “We do multidisciplinary projects all the time.”

At USA co-teaching was implemented as a research-supported change to facilitate the inclusion of all students in the regular classroom. All core 9th and 10th grade classes were co-taught with either a pair of subject area teachers who had special education training or a subject area teacher and a special education teacher. Co-teachers, who had a period each day of common planning time, worked together in the same classroom and often working interchangeably as lead and support teacher. According to an administrator, this co-teaching model allowed “more support to be brought to every kid,” and made it possible for “teachers to divvy up the roles in running a highly effective classroom.” Describing one effect of co-teaching, a teacher said, “I may present the problem one way and my co-teacher may present it a different way, and the students benefit.”

Collaboration and culture. Several teachers described how collaboration contributed to their learning and their teaching, and how it affected the cultures within the schools. At MNTH, a teacher explained that sometimes the struggles associated with beginning to teach through project-based learning and changing classroom practices could “seem formidable,” but having good training and being “surrounded by people who are doing it” helped support its effective and sustained use in the classroom. Teachers and administrators at GJJ-HTH provided many examples that supported collaboration as far more than a line in a mission statement. One teacher said, “We do work on our practice—not about dress code, [but] how can we do better in our work.” These teachers also described feeling comfortable accessing each other as resources. As one GJJ-HTH teacher explained, “Every teacher is so approachable if you need something [or] if you need feedback.” Adding that the “administration encourages collaboration within departments,” and noting the importance of institutional support for these kinds of interactions, a DSST: Stapleton teacher explained, “Our department chair does a great job of setting an environment where we can share ideas.” A new teacher added, “When I need help (which is frequently), other teachers will give their time to (a) discuss strategies with me, (b) observe me and give me feedback, and (c) let me observe them.”

Many members of the GJJ-HTH community explained that the school culture, which focused around student learning within a context of trust and support, fostered collaboration not only among teachers but also among students, administrators, parents, and the broader community. Describing GJJ-HTH as a “community” and a “family,” one alumnus said, “Everybody knew everybody. It was like one family; you could talk to anyone.” Another student commented, “Everyone’s here to help you, [they’re] not just coming here because it’s their job, but because this is what they want to do, help kids. The atmosphere, the different personalities, there’s a culture where everyone can learn.” And OSPrI researchers who observed classrooms noted a “very open climate where students could express ideas and questions freely.” Students at MNTH described a dynamic between teachers and students as almost “a friendship,” which rather than leading to a lack of respect, allowed students to “respect them more.” One student commented that the teachers “cared that I was learning,” adding “All the teachers really care; they’ll take time out of their lives to help you,” often coming in before school or on weekends. There appeared to be respect and trust among all community members—parents, students, teachers, and administrators all felt part of the school, as expressed by one MNTH teacher who said, “We all feel we built this.”

Summary: Teacher collaboration and a collaborative school culture. This culture of collaboration in each of the four schools helped to create an environment that reminded everyone that all were working toward common goals. At USA, an administrator explained that restructuring the schedule to provide teachers with common planning time helped “shift the culture.” The principal of MNTH explained, “We’re all speaking the same language here.” Opportunities for teachers and others to work together appeared to facilitate conversations that helped to develop collegial trust and support, providing space for the formation of collaborative learning cultures. These learning cultures appeared to shape the human interactions within the schools, and yet also were continuously shaped and enhanced by the teachers, administrators, and students working within them. One feature that seemed to interact with a school’s culture, along with the teacher characteristics and professional development experiences, was teacher professionalism. Teacher professionalism across the four schools will be explored in the next section.

Teacher professionalism and professionalization. Teacher professionalism and professionalization were described in the literature relating to a variety of school factors and teacher characteristics. Research studies included descriptions of characteristics of teachers who were professionalized (Evans, 2002, Hamilton & Richardson, 1995);

characteristics of professional development experiences that might help to develop teachers as professionals (Kennedy & Smith, 2013); and characteristics of schools or the school environment that might better support school-wide professional practices (Bloom & Unterman, 2013; Kennedy et al., 2011), or those resulting from a professionalized teaching staff (Bryk et al., 2010; Spillane et al., 2004). In reviewing the data from across the four ISHSs, evidence supporting teachers' professional standings and the existence of practices that might lead to the development of teachers as professionals emerged in a variety of ways.

Professional expertise, continuous learning, decision-making, and pathways for advancement. Across all four ISHSs, the teachers were hired for and respected for their content level expertise. Each school highlighted slightly different teacher characteristics that best matched their school's missions; however, none expected that teachers would arrive at the school with all the skills they needed to be the best teachers they could be. Teachers in these ISHSs were intentionally professionalized. They were provided with multiple, ongoing collaborative opportunities to continue to improve their skills and knowledge and to share their expertise with each other. They were also provided opportunities within the schools to advance into positions of greater responsibility and leadership. Some pathways were intentionally designed and others were more informal structures.

At MNTH, teachers were hired for their content knowledge and project-based learning expertise, yet were supported in their professionalization through targeted learning with more experienced others. Regular opportunities to dialogue and engage with their peers in an environment of trust were provided. Teachers became increasingly skilled and had opportunities to practice their skills in the presence of others—their co-teachers, the instructional coach, the principal—who could provide feedback, guidance, and advice. As teachers became more proficient there were increased opportunities to contribute as mentor teachers, leaders, and trainers. According to the principal, the teachers had become "so good that we're the national training site for all of the New Tech Network," where some of the teachers had become the trainers for other schools and districts seeking to replicate their project-based learning program.

Ongoing opportunities to share ideas, knowledge, and learning appeared to help teachers achieve a common understanding of the translation of the school's mission and vision into practice. Their knowledge and expertise appeared to help empower them as decision-makers not only in their own classrooms but also on school-wide concerns. The small size of MNTH's administrative staff seemed to provide opportunities for teachers to informally and fluidly assume leadership roles. To an outside observer, it appeared that no one needed to ask a teacher to take responsibility. When a gap was noted someone seemed to easily move to fill the void. This leadership model, often referred to as a flattened hierarchy or distributed leadership, appeared to provide teachers with opportunities to grow within the school and help them assume a sense of ownership and responsibility for the schools' outcomes, helping to create an environment of shared accountability and mutual trust.

At GJJ-HTH teachers were hired for their strong content knowledge and academic and professional experiences that could inform their inter-disciplinary project and curriculum designs. Some teachers came with solid pedagogical training, but a teacher-mentoring program and co-teaching partnerships, along with the facilitation of teaching certification through the on-site Graduate School of Education (GSE) supported teacher development for those who were hired without high school teaching credentials. Teachers were hired as professionals, but were expected to continue to develop skills and knowledge. Teachers assumed responsibility for designing their course curricula with guidance from standards for college entry, and with attention to preparing students to be competent in future academic endeavors, in the workplace, and in life. Teachers, however, did not create their curricula in a vacuum. Innovative, yet academically rigorous project-based learning experiences were integrated across disciplinary boundaries through the active engagement of pairs of teachers who chose to work together on the design. An open physical environment in the school also provided a platform for continuous observation, feedback, and self-evaluation where teachers reflected on their classroom experiences; where peer, co-, and mentor teachers could weigh in; where administrators paid regular visits; and where products of learning were shared throughout the community. Teaching and learning were collaborative public undertakings, and teachers had many opportunities to develop and grow their craft. They could pair with different co-teachers to connect their disciplinary content in creative ways and try out new integrations in project designs. Supported by opportunities for graduate level learning in the GSE, teachers could follow pathways into teacher or school leadership where they might assume mentoring roles, become inaugural teachers in a newly opened network school, teach in the GSE, or move into other network schools as school directors. The small administrative staff, comprised of many promoted from within the ranks of GJJ-HTH and well-versed in what an administrator described as the "HTH way of doing things" acquired through "conversation," helped maintain continuity of the school's philosophies. This relatively non-hierarchical administration appeared to provide a leadership presence serving as visionaries and facilitators. They enabled funding, built relationships with the community and school partners, and supported an environment fostering active, passionate, teaching.

At DSST: Stapleton, teachers had some autonomy in their classrooms that increased as they mastered the school's tenets in a process the school described as "gradual release." The Emerging Leaders Program (ELP) provided a pathway to leadership roles such as Directors of Curriculum and Instruction, Academic Deans, and School Directors within the school and school network. With minimal reliance on textbooks or other published resources, teachers were responsible for designing their classroom curricula to help their students meet academic standards and be prepared for college success. Several teachers commented with pride, "Most everything used in this grade is created by me," and "I use mostly self-created materials," and "We have, over the years I've been here, largely written the standards ourselves very much based on national standards and Colorado standards." A physics teacher explained, "No one tells you how to teach," adding "I made up the curriculum by teaching to the AP test." One experienced teacher commented,

> I put a course together of the best things I've ever taught...It's a conglomeration of things that I like to teach. One thing I noticed with things like AP Bio here is that you teach what you like, you do a really good job with it, the kids see your passion, it translates over to their passion…We had the best results ever in AP Bio because of that passion and what I like and do really well, and they did really great.

Inexperienced teachers who were hired into DSST: Stapleton without strong pedagogical backgrounds viewed this autonomy differently. One newer teacher, who was the only one teaching her subject in the school, stated, "Having a set curriculum would have been helpful, especially as a new teacher. At least to start with."

USA appeared to follow a more traditionally structured hierarchy with administrators and teachers holding distinct roles with no obvious pathway between them. However, teachers who had chosen to be actively engaged with the reforms targeted by the school appeared to play a strong role in making curricular and pedagogical decisions. A couple of teachers had been recruited to become Instructional Leaders, and they in turn empowered the entire teaching staff to collectively analyze their teaching and to take responsibility for making suggestions and implementing changes for improvement. Teachers proposed mini-courses to teach their colleagues and took part in instructional rounds to further develop their teaching skills and shape future professional development experiences. The teachers' union structure also required teachers vote on curricular changes and many teachers appeared interested in contributing beyond the minimum expectations of the teaching agreement.

Teacher autonomy. Within these schools, there was the expectation that teachers would embrace the mission, vision, and goals of the school, and work as a collective unit. However, it was also common for teachers to be trusted to be proactive and to make decisions to solve problems, and to get things done. In MNTH, the principal described seeking teachers who had "a passion, a desire to change education, to not keep it the same way, and…[who] weren't afraid to take care of business within the box, but still step outside of it…and be ready to create their own destiny." At GJJ-HTH, there was a "culture where everyone can learn," where it was "okay to try and fail…[and to] just get back up and try again." A GJJ-HTH administrator explained that the latitude to design their courses around their interests and passions kept teachers excited and engaged saying, "Our teachers are thinking deeply about their practice because they aren't told what to do." A teacher explained that teaching at GJJ-HTH was "very teacher driven, very democratic," another added, "The flexibility allows each teacher to adapt to their own strengths," and a third said, "We don't do the same thing every year. It makes it challenging to reinvent the curriculum every year, but it keeps our interest. We don't get stale or bored; we work really hard." At DSST: Stapleton teachers were expected to design their own curricula within the parameters of state and network expectations, and teachers described being granted increased autonomy with experience. At USA, teachers could "tweak" course content and instructional approaches, and could play an important role in making suggestions and contributions toward improving teaching and learning.

Each of the four ISHSs supported the development of teachers as professionals. They began by selecting teachers with strong content knowledge and a willingness to work collaboratively toward common goals. The schools then provided teachers with regular opportunities to continue to develop knowledge and skills that helped to empower them in their own classrooms and to encourage their active contributions in school-wide decision-making. All were encouraged to share responsibility for the school's outcomes. And although not universally applied, these four schools provided pathways or outlets for teachers to advance within the teaching profession to assume increased responsibility.

Teacher characteristics, teacher professional development, teacher professionalization, and the school's culture all ultimately overlapped and interacted to shape the student learning environment. The next section explores the connections among these factors and the classroom and school-wide practices that had the potential to affect learning by students underrepresented in STEM.

Research Question 4

4. How do these STEM-focused schools use teachers' characteristics and professional development experiences to support STEM learning, interest, and agency of students underrepresented in STEM majors in college and STEM careers?

Brief summary of findings. The data across all ISHSs in this study suggested that teachers used classroom strategies and practices demonstrated in the research literature to have positive effects on learning by students underrepresented in STEM. Some practices might have addressed students' STEM identity or the social and emotional learning environment. To support these classroom and school-wide practices, schools intentionally hired teachers with particular characteristics, such as content level expertise to ensure student competence in STEM subjects, and provided professional development that supported continued development of teachers' skills and knowledge to engage in such practices as project-based learning.

Supporting learning by students underrepresented in STEM. To understand the relationship between the above (teacher characteristics, teacher professional development, teacher professionalism, and the school culture) and the strategies and practices that might contribute to enhanced learning by students underrepresented in STEM, it was important to look carefully at what was happening in the classrooms in the four ISHSs.

The research literature. The research literature supported the use of particular classroom practices and strategies as having the potential to effect positive changes in STEM learning for students underrepresented in STEM. Classroom practices supporting cooperative learning demonstrated positive effects on students' conceptual understanding (Strobel & van Barneveld, 2009), academic achievement and attitude toward the sciences (Bowen, 2000), and sense of autonomy, competence, and self-concept relative to the sciences (Hänze and Berger, 2007). In explaining how small-group, inquiry-based, or project-based learning experiences might affect student learning, studies found increased opportunities for students to engage in peer-to-peer teaching and learning (Reddy et al, 2007; Sadler & Tai, 2007), opportunities for students to take greater responsibility for their own learning (De Vries et al., 2013; Roth & Weinstock, 2013), and opportunities for increased teacher-students interactions that might lead to stronger teacher-student relationships and increased students' sense of well-being (Murray & Pianta, 2007; Reddy et al., 2007). Classroom practices serving to develop students' STEM identity were also found to contribute positively to learning by students underrepresented in STEM (Aschbacher et al., 2009; Brotman & Moore, 2008; Carlone & Johnson, 2007; Hazari et al., 2010). These practices included those that provided opportunities for students to become interested in STEM and understand STEM connections to the real world (Maltese & Tai, 2011; Tai et al., 2006b); as well as those that ensured student competence in STEM, with opportunities to perform their competence and receive recognition for this competence, as might be the case in project-based learning (Hazari et al., 2010; see Chapter 2 for a more extensive discussion of relevant classroom practices).

For this study, it seemed that understanding whether and how practices such as those described above were prioritized in the ISHSs might provide information about how these ISHSs sought to support learning by students underrepresented in STEM. One common feature among these practices and strategies is small-group work. And while the simple act of putting students into small groups would not necessarily lead to the kinds of learning described, it is a reasonable precursor. To acquire an understanding of whether there was a climate in these ISHSs that could support practices demonstrated to support learning by students underrepresented in STEM, data from the LFCOP (Lesson Flow Classroom Observation Protocol) were used. Researchers used the LFCOP instrument to document whether the focus of classroom learning was on (a) the teacher, as in a lecture class; (b) small group learning; or (c) individual student work (see individual Teacher and Teacher Professional Development in ISHSs case studies in Appendix C for a more detailed description of this instrument and relevant school data). When the greater focus of the classroom time was on small group learning, there would be a greater potential for such activities as peer-to-peer learning, student directed learning, and student performance to take place.

Using lesson flow data from the LFCOP measure is arguably a rough proxy for the very specific types of learning described as consequential to learning by students underrepresented in STEM. However, when considered along with the narrative data collected by researchers that the LFCOP requires during classroom observations, a clearer view of the classroom structure is obtained. Combined with data from the Teacher Survey on teachers' levels of confidence in teaching using reform strategies, and teacher, student, and administrator voices as they emerged from interviews and focus groups, may paint a more detailed picture of these supportive classroom practices.

ISHS school data. This section examines classroom and school-wide practices identified as having the potential to support learning by students underrepresented in STEM that may be affected by the classroom teacher, the teacher's background preparation, or the teacher's professional development experiences. First, data from the Teacher Survey that describes teachers' ratings of their confidence in the use of particular reform strategies in their classrooms is presented. This is followed by data from the LFCOP that provides some information about classroom structuring and focus as described above. Finally, data from classroom observations and the voices of teachers, administrators, and students from each school are summarized to describe how each school sought to shape the learning environment for students underrepresented in STEM.

Teacher Survey data: Teacher confidence in using reform strategies. Teachers' ratings from the Teacher Survey of their confidence in using various reform classroom teaching strategies are compiled in Table 16. The average teacher response across all four schools indicated general confidence across all measures except involving parents in their students' STEM education. Teachers, on average, agreed that they felt confident in teaching using hands-on, project-based, and investigative strategies. They also described feeling confident in encouraging student STEM interest, engaging females and minorities in STEM, and responding to student diversity; and they expressed confidence in helping students take responsibility for their own learning. It should be noted that teachers in the two schools that supported a school-wide initiative for project-based learning (MNTH, GJJ-HTH) had more positive responses across all measures than teachers in the other two schools. The scores from teachers at DSST: Stapleton, where the teaching was intentionally more traditional, particularly in the 9th and 10th grades to focus on disciplinary content learning, were the lowest of the four schools. However, even though these reform strategies were not necessarily prioritized at DSST: Stapleton, teachers still indicated feeling at least somewhat confident on all measures except involving parents in their students' STEM education. The ratings of teachers at USA, a school that was working toward increased co-teaching and the use of projects for learning in 9th and 10th grades, fell in between the other schools, and responses were generally positive.

Table 16

Teacher Confidence in Utilizing Teaching Strategies

I am confident in my ability to:	MNTH (10) (1-5) [a]	GJJ-HTH (14) (1-5)	DSST (11) (1-5)	USA (11) (1-5)	**MEAN (N=46)** (1-5)
1. Manage a class of students engaged in hands-on/project-based work	4.8	4.7	3.8	4.2	**4.4**
2. Recognize and respond to student diversity	4.6	4.6	4.0	4.1	**4.3**
3. Encourage students' interest in S/T/E/M	4.6	4.6	3.8	4.2	**4.3**
4. Help students take responsibility for their own learning	4.4	4.3	3.9	4.0	**4.2**
5. Lead a class of students using investigative strategies	4.5	4.5	3.6	3.9	**4.1**
6. Use strategies that specifically encourage participation of females and minorities in S/T/E/M	4.3	4.5	3.5	3.6	**4.0**
7. Involve parents in the S/T/E/M education of their students	3.1	3.5	2.4	3.4	**3.1**

[a] 1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree.

Classroom practices. During the OSPrI visits, 23 STEM classrooms were observed across the four schools and, using the LFCOP, data were collected on the use of classroom time—whether it was teacher focused, small group focused, or focused on the individual student. Table 17 shows the average amount of time spent in each grouping for each school, and the means across all four schools suggest that for the majority of the class time, students were engaged in small group learning activities. On average, 54% of the classroom time was spent in small group work, with decreasing percentages of time focused on the teacher (33%), and on individual work (19%). Note that it was possible for more than one type of activity to occur contemporaneously, so these percentages could add up to more than 100%. Averaging across all observed classrooms, less than one-third of classroom time was focused *exclusively* on the teacher.

Table 17

Organizational Grouping and Percent of Class Time for Observed STEM Classes in Each School[a]

Class Type	% Student-directed Small Group Focused	% Individual Student Focused	% Teacher Focused	% EXCLUSIVELY Teacher Focused[b]
MNTH	56	9	44	37
GJJ-HTH	72	35	7	7
DSST	53	10	37	37
USA	34	21	48	43
MEAN	**54**	**19**	**33**	**29**

[a] Small group, individual, and teacher led activities could occur simultaneously; percentages may add to more than 100.
[b] This last column identifies time when all students were focused on the teacher as in a lecture class.

STEM identity development. Teachers across the four schools engaged in classroom practices that were described in the literature as having potential to differentially affect students underrepresented in STEM. These included practices that served to develop students' STEM identities such as helping students become interested in STEM fields and aware of STEM careers, ensuring that students developed competence in their STEM coursework, and providing students with opportunities to perform their competence to others and to be recognized for their knowledge and skills (cf. Carlone & Johnson, 2007; Hazari et al., 2010; Kanter & Konstantopoulos, 2010). Opportunities for students to engage with each other in peer-to-peer learning and to take responsibility for their own learning, as might be the case in inquiry-based, project-based learning, were also found to contribute to students' perceptions of competence (cf. Roth & Weinstock, 2013; Sadler & Tai, 2007). Finally, the classroom and/or school social and emotional environment as it contributed to better teacher-student relationships, students' sense of well being, and positive teacher or student perceptions of knowledge and theories of learning could contribute to improved student learning (cf. Aronson et al., 2002; Dweck, 1999; Reddy et al., 2007). This section presents brief descriptions of classroom practices in each of the four schools and then across all four schools, that had the potential to positively affect student STEM identity development (see individual case studies in Appendix C for more descriptive data).

MNTH's 100% focus on project-based learning helped to generate student interest in STEM through the projects that involved applications to the real world and connections with STEM careers. To support student competence in their STEM courses, teachers described reviewing state and national STEM standards to make sure individual projects were aligned, and also collaborating with teachers across grade levels and subjects to ensure that all standards would be collectively addressed by their courses.

Teachers scaffolded project learning to help students learn both academic and social and emotional skills related to engaging with groups and group work. They taught them how to learn from their projects, and ultimately helped students take responsibility not only for their own learning and production, but also for that of their peers and their groups. Small group learning provided increased opportunities for teachers to interact with students, to address individual learning needs and to develop stronger teacher-student relationships. Because students gave upwards of fifty presentations a year, students regularly put their expertise, knowledge, and skills into a public forum where they could be both guided and supported in their continued learning, and recognized for their competence building positive STEM identities through these frequent public performances of their individual STEM competence.

In GJJ-HTH, project-based learning was typical and, except for mathematics classes, courses were taught by two different disciplinary teachers who collaborated on project development. Projects were very consciously cross-disciplinary integrations that connected to the real world and were relevant to the students' lives and the local community. Teachers sought to help students of all academic abilities achieve subject-area competence within the regular classroom. One teacher explained the thinking behind the heterogeneous grouping in classes and how academic coaches helped facilitate the process:

> The only way to treat everyone equally is to treat everyone individually to meet their individual needs, but then we also scaffold lessons for everyone not just those with IEPs [Individual Education Plans]. Academic coaches are invaluable for times, for example, when kids who are auditory learners miss lectures—we

> come up with strategies that are normally thought of as IEP-type work, but it's for everyone.

There was an intentional focus on the development and presentation of a *product of learning*—the project product was significant and often presented in a public forum of peers, school community, or the broader community. Small group learning facilitated teacher-student interactions and, along with advisory groups, supported social and emotional learning and the development of strong, supportive teacher student relationships, which were described as like "community" or "family." Students described feeling supported personally as well as academically.

At DSST: Stapleton, the development of student STEM identity was guided by two strong forces: (a) ensuring that all students became competent in their STEM learning, and (b) a strong social and emotional component that focused on belonging to and being responsible to the school community. Teachers were responsible for maintaining the rigor of their courses, and for the constant monitoring of student progress. Teachers paid close attention to student performance, evaluating each assessment and creating individualized post-assessment reviews tailored to individual student learning gaps and needs. A school-wide program of social and emotional learning centered on the Core Values of DSST: Stapleton, and the regular advisory and whole school meetings helped students learn take responsibility for their actions, and understand that as a part of a larger learning community their actions affected more than themselves. Students experienced "gradual release," by their junior and senior years as they internalized the rules and routines of the school and were given increasing responsibility to shape their own learning. And while teachers expressed concerns that students' hands were held a long time at DSST: Stapleton before expecting student autonomy, students appeared to be meeting the school's academic expectations and finding success at the college level.

Three factors rose to the top as the ways that USA appeared to address the development of student STEM identity: (a) students were given extra support through co-teaching in all core classes in 9th and 10th grades to help students get on and stay on track for high school learning; (b) inquiry based learning was typical, at least in science classes, and project-based learning was becoming increasingly important across the 9th and 10th grade curriculum; and (c) all students were encouraged to take at least one AP course to help them experience the rigor of a college level course in ordered to be better prepared for college. The dominant focus at USA appeared to be on the idea of *going to college*. To help students get a good start toward college preparation in high school, all core classes in 9th and 10th grade were co-taught by teachers who together had content and special education expertise. One of the goals of this practice was to support students' learning differences within the regular classroom to allow all students access to regular level coursework. The curriculum, supported by the Boston Public School system, featured inquiry learning, and many of the teachers, particularly in the sciences, commented that they had engaged in BPS supported inquiry related professional development and felt comfortable using inquiry based strategies in their classrooms. In the observed classrooms, students participated in active, hands-on, small group learning activities, with teachers moving from group to group to interact one-on-one with students. Teachers spoke with students in respectful, caring ways, and students, in return, appeared respectful of the teachers. Teachers sought to provide students with rigorous experiences during high school that would help them stay the course once in college. Having the opportunity to experience the rigor of a college level course through AP coursework was one important way USA addressed this.

Meeting the needs of students underrepresented in STEM. There was evidence across the four schools that there were structures in place to help teachers shape classroom environments to facilitate learning by students underrepresented in STEM. Teachers had the disciplinary competence—demonstrated by their subject area majors and certifications—to help students become competent in their STEM subjects. Teachers' backgrounds, their ongoing professional development, and open lines of communication within the schools supported teachers' confidence in teaching using the reform-based strategies shown to positively affect student learning in STEM. Even though not every school approached STEM identity development the same way or focused on all aspects described in the literature to the same extent, there was evidence from classroom observations and teacher, administrator, and student voices that students were provided opportunities to become competent in the STEM subjects, to teach and learn from each other, to contribute to the design of their own learning, to perform their competence to an audience, and to be recognized for their competence. There was also evidence that classroom environments were structured to facilitate the development of supportive and trusting teacher-student relationships. Some schools intentionally structured school-wide social and emotional learning to help students learn how to work effectively in groups, to support both peers' and one's own learning, and to shape safe, supportive, intellectual communities of learners and learning.

This chapter reviewed and analyzed the data in response to the four research questions guiding this study to characterize the generalized findings for the cross-case analysis of the four selected ISHSs. The next chapter summarizes the findings for each of the four research questions, presents conclusions based on these findings relative to the current body of literature, and discusses the implications for practice and research.

Chapter 5: Interpretations, Conclusions, and Implications

Introduction

The assumption throughout this multiple case study and cross-case analysis of four successful Inclusive STEM-focused High Schools (ISHSs) was that these schools were doing something right. Identified and selected for the OSPrI study through the rigorous process described in Chapter 3, all four schools demonstrated substantially higher student STEM outcome data relative to their districts and states (see individual case studies in Appendix C). The schools were successfully preparing increased numbers or percentages of students from underrepresented groups for STEM majors in college and for pathways to STEM careers. As such, this study of the teachers and teaching within these schools provides valuable insights, implications, and information for other states or school districts seeking to design or revitalize their STEM education programs. This chapter presents a framework for STEM teaching staff development that describes the relationships among STEM teacher characteristics, teacher professional development experiences, and the school collaborative cultures that support teacher professionalization and classroom practices to enhance learning by students underrepresented in STEM majors and careers.

This chapter begins with a brief return to the conceptual framework used to frame this study followed by a summary of the findings from Chapter 4 in response to each research question. Three broad conclusions are then presented that arise from this study followed by recommendations for practice and research based on the findings and conclusions.

This study captured well the relationships among the concepts in the conceptual framework introduced in Chapter 1 (Figure 2). One of the concepts, however, was changed in this final chapter to better represent the data collected in this study. The concept: *Learning by Students Underrepresented in STEM* was changed to *Teaching Strategies that Support Learning by Students Underrepresented in STEM*. While the original conceptual framework suggested that it might be possible to examine the relationship between teacher backgrounds and their professional development experiences and student learning, this study did not provide opportunities to actually observe, assess, or evaluate student learning as a function of these teacher-related characteristics. Instead, observations of classroom practices and strategies along with data from focus groups and interviews provided evidence that teachers engaged in particular classroom practices that were supported in the research literature as having the potential to positively affect learning by students underrepresented in STEM. As a result, the conceptual framework for this study was adjusted to reflect this change (see Figure 4).

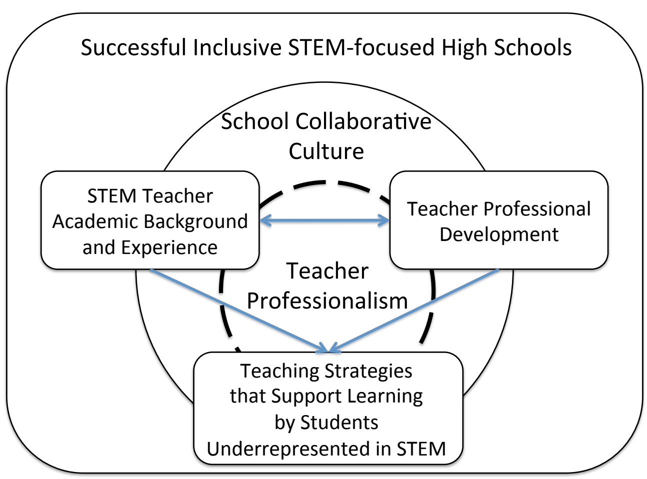


Figure 4. Research study conceptual framework.

Using an existing data set from four ISHSs that were successfully preparing students from groups underrepresented in STEM majors and careers (Lynch et al., 2011), this study sought to understand the characteristics of and relationships among STEM teachers, teacher professional development, and classroom practices related to research-identified practices shown to positively affect learning by students underrepresented in STEM. It also examined the influence of the school cultures and the social and emotional environments as they appeared to affect school-wide collaboration and teacher and student learning. This study is unique from previous studies because of its targeted attention to STEM teachers in STEM-focused schools who were finding success in preparing students underrepresented in STEM for further study and careers in science, technology, engineering, and mathematics.

The research literature suggested that learning by students underrepresented in STEM could be affected by strategies targeting STEM identity development (Carlone & Johnson, 2007; Hazari et al., 2010; Kanter & Konstantopoulos, 2010) and aspects of social and emotional learning within the classroom and school (Aronson et al., 2002; Dweck, 1999; Farrington et a., 2012; Reddy et al., 2007). Teachers' use of targeted strategies could be influenced by their academic backgrounds and expertise along with professional development experiences addressing these considerations (De Vries et al., 2013; Hamilton & Richardson, 1995; Johnson et al., 2007). A school-wide collaborative culture could support teacher learning through shared experiences, sharing of expertise, and the broad diffusion of knowledge (Goddard et al., 2007; Sun et al., 2013); and student learning through such collaborative activities as project-based learning, which supported STEM identity development and stronger teacher-student relationships (Bloom

& Unterman, 2013; Bryk et al., 2010; Kennedy & Smith, 2013). The development of teachers as professionals, supporting a school-wide distributed leadership and the development of a shared mission and mutual trust, could be supported through the symbiosis of strong teacher academic preparation and teacher professional development within a culture of collaboration (Evans, 2002; Kennedy et al. 2011; Spillane, Halverson, & Diamond, 2004). These relationships were observed in the four ISHSs and support the new conceptual framework offered in this final chapter.

Findings

These findings and conclusions represent rich data collected from four similarly structured in-depth site visits to four successful ISHSs. These descriptions coupled with in-depth analysis may provide sufficient detail to allow for transfer to contexts and situations that are similar, but not directly related to this study. These results provide a detailed understanding of STEM teachers and teacher professional development at four schools that were successfully preparing students underrepresented in STEM for STEM majors in college and for pathways to STEM careers. As such, it provides a solid platform for making inferences relative to the research literature, and making recommendations for practice and future research.

Research Questions: Summary of Findings

This section briefly summarizes the findings related to each of the research questions for this study.

1. **How might the backgrounds [educational, experiential, motivational] of the STEM teachers hired to work at successful ISHSs be characterized?**

Teachers in these ISHSs were hired for their alignment with the schools' missions and visions and their willingness to work collaboratively toward fulfilling the schools' goals. Because of their common mission to better prepare students underrepresented in STEM for STEM majors in college and pathways to STEM careers, all four schools sought teachers with strong STEM content knowledge. Individual schools also identified as important particular teacher characteristics such as having worked in STEM professions, knowing how to teach using project-based learning strategies, and knowing how to persevere through challenging experiences. [Note: Data were inadequate to establish motivational characteristics of STEM teachers in ISHSs.]

2. **How is professional development conceptualized at each of these ISHSs?**

Teacher learning in these ISHSs was an ongoing, continuous process that did not stop when teachers were hired. Teachers' professional development, as part of a school-wide culture of learning, was an intentional and thoughtfully planned part of the school day and week, usually beginning with an intensive summer orientation and continuing regularly and routinely throughout the school year. Professional development experiences matched Desimone's (2009) framework of effective professional development in that they were active, collaborative experiences aligned with school reforms and teacher or student needs, and of adequate intensity and duration. Professional development assumed a number of forms, both formal and informal, and groupings that ranged from individual observations and feedback, to co-teaching or mentoring pairs, to department or grade-level collaborations, to full faculty meetings. Teachers often took responsibility for the directions of their professional development experiences, contributing actively in collaborative decision-making, seeking solutions to student challenges, and sharing expertise and successes.

3. **How do STEM teacher characteristics relate to the conceptualization and implementation of teacher professional development at these ISHSs?**

Teacher professional development was shaped around teachers' and students' needs and the desired school reforms. In each ISHS, teachers were hired to carry out the schools' missions to meet particular goals. In selecting for particular teacher skills to meet targeted needs such as professional experiences or strong content knowledge, schools sometimes accepted that other skills might be weaker or lacking, such as particular pedagogical training. As such, these schools designed professional development to fill the gaps. The schools also selected teachers for their willingness to collaborate and then provided multiple, ongoing professional development opportunities to help teachers learn how to work with each other and to develop trusting supportive relationships that could facilitate further teacher collaboration. Open lines of communication within these schools allowed for the free flow of ideas, strategies, and concerns among teachers and administrators facilitating a school-wide community of learning.

These four ISHSs intentionally and consciously created structures and environments that supported the professionalization of teachers. Teachers were hired for their expertise and treated as professionals, and ongoing professional development experiences served to strengthen all teachers' skills, knowledge, and teaching abilities in line with schools' goals. Collaborative experiences, in addition to both formal and informal pathways to roles of increased responsibility, aided in the development of mutual trust and common understandings of the schools' missions, increased teacher autonomy in classrooms, empowered teacher contributions to school-wide decision-making, and contributed to the development of a distributed leadership in the schools.

4. **How do these STEM-focused schools use teachers' characteristics and professional development experiences to support STEM learning, interest, and agency of students underrepresented in STEM majors in college and STEM careers?**

The research literature described a number of classroom and school experiences that could be influenced by teachers and that had the potential to positively affect learning by students underrepresented in STEM. It should be noted that the identified experiences represented general practices broadly targeting all groups identified as "underrepresented in STEM" and did not necessarily target particular culturally sensitive practices or strategies addressing a single group (Lynch, 2000). All schools in this study had made strides toward better preparing students underrepresented in STEM relative to comparison schools (Behrend et al., 2013; Lynch et al., 2013; Peters-Burton et al., 2014a; Spillane et al., 2013). The assumption throughout this study was that the schools were doing something right, and this study sought to understand what teacher-related factors appeared to contribute to this success.

Evidence across the four ISHSs described structures that helped teachers shape students' experiences to support their STEM learning. Teachers were hired for their content-level expertise to contribute to the development of students' STEM competence. Teachers were supported through professional development in the use of teaching strategies that contributed to students' STEM identity development through opportunities to generate interest in the STEM fields and for students to perform and receive recognition for STEM competence. School-wide social and emotional learning, supported by teachers in the classrooms, also served to enhance teacher-student relations, develop students' learning autonomy, and shape a trusting learning environment.

Conclusions

The following conclusions are a synthesis of the cumulative findings from this study. In drawing these conclusions, the findings across each of the concepts in the conceptual framework and in response each research question were reviewed and dovetailed with the broader research base on teachers and teacher professional development, especially as they related to STEM teachers, and learning by students underrepresented in STEM. Three broad conclusions emerged. The first conclusion targets STEM as a content area. The second and third conclusions apply well to teachers and professional development in the STEM disciplines, but also relate broadly to "just plain good teaching" (Lynch, 2000, p. 190) rather than exclusively to good STEM teaching.

The conclusions from this study are:

1. To teach STEM subjects, teachers need STEM content expertise and professional development that continues in the school after teachers are hired to support their own STEM learning.
2. Teachers need to collaborate. This includes (a) having a willingness to collaborate, (b) being provided training on how to collaborate, (c) having time in the school schedule to actively engage with peers and administrators, and

(d) having open lines of communication to allow for the free flow of ideas throughout the school.

3. Professionalization of the teaching staff needs to be intentional and support teacher autonomy and decision-making, responsibility for school outcomes, and pathways to roles of increased responsibility.

These three conclusions represent features that appeared to broadly affect the fabric of the four schools in ways that made them function effectively, efficiently, and productively for all participants. What follows is a discussion of these conclusions in the order presented, revisiting the literature that supported their exploration and describing findings across the four schools that contributed to their development.

Conclusion 1

1. To teach STEM subjects, teachers need STEM content expertise and ongoing professional development to support their own STEM learning.

STEM teacher hiring and teacher characteristics. Reflected in this statement from one of the administrators, “You can’t teach what you don’t know,” one of the most frequently identified characteristics for STEM teacher hiring in these ISHSs was academic competence in the subject areas they would be teaching. In this study, the majority of the STEM teachers had earned bachelor’s degrees with majors in their subject areas (cf. Goldhaber & Brewer, 2000; Monk, 1994), held teaching certifications in the subjects they taught, and more than half had earned master’s degrees, a majority of which were in some field of education (cf. Boyd et al., 2005; Darling-Hammond, 1999). Although collectively they might not be considered a veteran teaching staff, the average teacher had almost seven years of experience, and 73% of the teachers had taught for at least five years at the time of the OSPrI study. Nearly half of the teachers had research experience (cf. Silverstein et al, 2009) and more than a third had STEM-related professional experiences prior to teaching. There were also some levels of cosmopolitanism (cf. Bryk et al., 2010) among the teaching staffs at the three schools where this factor was calculated (GJJ-HTH, DSST: Stapleton, and USA). Comparing the responses of all STEM teachers responding to the Teacher Survey with the research literature, the four ISHSs would be considered to have high quality STEM teachers. Having teachers with adequate academic and experiential backgrounds laid the groundwork for ensuring that teachers were well prepared in their disciplinary content areas for teaching the courses for which they were hired.

STEM professional development. Content level expertise was important. Across the four ISHSs, if teachers needed additional training in their subject areas, especially for the more advanced levels such as AP courses, or in areas where typical teacher certification was less common as in engineering, teachers were provided training with experts through such programs as AP institutes and Project Lead the Way (cf. Felder et al., 2011; Hoepfl, 2011). Teachers also were provided or were encouraged to forge connections with local colleges and universities, especially to access STEM content expertise. For example, USA partnered with Boston University, and MNTH with UT Austin; DSST: Stapleton's engineering teachers worked extensively with the CU engineering department; and teachers at GJJ-HTH were encouraged to actively engage with experts in the field when shaping their projects. When teachers needed to learn particular pedagogical approaches to align with school practices, the ISHSs engaged professionals or professional organizations (such as the New Tech Network at MNTH);

created an in house Graduate School of Education (at GJJ-HTH); provided targeted training in classroom strategies (DSST: Stapleton); or, as in USA, set aside professional development time for teachers to explore the research literature, examine their own practices, and utilize the staff's collective knowledge to propose and implement solutions. In all four schools, teachers played some role in the focus and directions of their professional development experiences (cf. Ostermeier et al., 2010). For example, at MNTH teachers brought lessons that needed honing to the weekly Critical Friends group so peers could help them think through challenges and propose improvements, and at USA teachers designed mini-courses and shared effective practices with each other.

In addition to meeting the characteristics of effective *STEM* professional development, general teacher professional development experiences within the four schools fit the criteria of effective professional development as described in Chapter 4. Teachers often began their professional development during the summer with intensive orientations designed to familiarize them with school-wide practices and to help create a culture of adult learners and learning. These were followed by sustained and ongoing experiences designed to maintain and support initiated reforms (cf. Supovitz & Turner, 2000). Professional development was aligned with targeted school reforms, such as project-based learning at MNTH and GJJ-HTH, inquiry-based learning at USA, using student performance data to evaluate classroom practices at DSST: Stapleton and USA, and meeting the needs of diverse learners within the regular classroom in GJJ-HTH, DSST: Stapleton, and USA (cf. Cohen & Hill, 2000; Kennedy, 1998). Teachers were actively engaged during their professional development experiences as they used student performance data to revise classroom strategies, modeled learning practices for each other, observed and provided feedback on each other's teaching, and gathered data for evaluation (cf. Garet et al., 2001). Collective practice, one characteristic in Desimone's (2009) framework, played a major role in teacher professional development and in shaping the learning environments in the four ISHSs. As such it is described separately as part of Conclusion 2 in the next section.

In order to effectively teach STEM courses, teachers needed to have STEM content expertise and the ability to continue learning to increase their content knowledge and pedagogical content knowledge. They needed opportunities for regular interaction outside the classroom to collaborate with teachers with different backgrounds and experiences to share their expertise, to explore approaches to teaching and learning, and to consult with experts in their fields. ISHSs that had teachers who were academically, pedagogically, and experientially diverse, who contributed to shaping their professional development experiences, and who had opportunities to learn with and from each other, appeared to support the foundation for the creation of a positive and supportive teaching environment. In Conclusion 2, the contributions of teacher collaboration to teaching and learning as well as the larger school environment are discussed.

Conclusion 2

2. Teachers need to collaborate, including: (a) having a willingness to collaborate, (b) being provided training on how to collaborate, (c) having time in the school schedule to actively and regularly engage with peers and administrators, and (d) having open lines of communication to allow for the free flow of ideas throughout the school.

Connections to the research literature. Throughout this study, the topic of collaboration arose among all participants and all aspects of teaching and the school day. The research literature supported collaboration as a vehicle for a variety of effects, and many of these effects were corroborated through this study's findings. Collaboration was first introduced in Chapter 2 as part of Desimone's (2009) framework for effective professional development under the heading of *collective practice*, with the suggestion that groups of teachers co-experiencing professional development led to more productive learning and implementation of reforms. As described in Chapter 4, collaborative practice was a routine part of professional development in all four ISHSs.

Further exploration of the literature revealed studies that described the effects of collaborative practice: collaboration promoted the sharing of experiences and knowledge among teachers (Goddard et al., 2007); resulted in changes in teacher beliefs and the successful implementation of reforms (Johnson et al, 2007); contributed to a shared professional culture (Garret et al., 2001); and aided the dissemination and spread of knowledge, experiences, and practice (Sun et al, 2013). Sun at al. explained that collaborative practice supported dissemination through two pathways: (a) giving teachers a common language about their classroom practices to allow them to continue their shared experience, and (b) allowing teachers to disseminate their learned expertise among those who did not participate in professional development experiences, thus expanding the sphere of influence. These multiple features of collaborative practice were evidenced in the data from the four ISHSs and described in Chapter 4.

Hiring collaborative teachers. Beginning with hiring, administrators in this study described the importance of selecting teachers willing to collaborate toward school goals. At MNTH, GJJ-HTH, and DSST: Stapleton, administrators had the latitude to hire teachers who wanted to collaborate and who were philosophically aligned with the mission, vision, and goals of the school. This meant that as the school year started, administrators were already working with groups of teachers who believed in the directions the schools were headed and were interested in collectively supporting decisions aimed at meeting these goals. Professional development could focus on building trust, developing communities of learners, and working together to shape strategies aligned with targeted outcomes. As previously described, at USA the administrators had less influence when selecting the teaching staff, having to accept displaced or teachers with more seniority from the school district "excess pool" because of union rules. In this school, administrators described having to focus their attention at the beginning of each school year toward observing, supervising, and working with individual teachers to encourage new attitudes and practices of those who were not hired with a commitment to the school's reforms and practices. Thus, administrators had less time to work toward forming a cohesive working unit among those who already supported school reforms, because they were helping some teachers buy into the mission of the school and the strategies it supported.

Learning how to work collaboratively, and time to practice collaborative learning. Leaders in these ISHSs did not assume all teachers arrived at the schools knowing how to take advantage of their peers' skills and knowledge or having the capacity to effectively approach collaborative learning toward common goals. Across the four schools, time was allotted for teachers to learn strategies for working in groups, to learn how to take advantage of each other's skills and knowledge, and to contribute effectively to the learning of others. Administrators spoke of the importance of developing teachers who felt they belonged to a community of adult learners or members of a team, and most of the schools used summer professional development time to orient teachers to the schools' missions, visions, and goals, and to begin active collaborative practice.

Teachers weren't simply given basic instruction on how to work together and then expected to fend for themselves. They were provided multiple, recurring opportunities to reinforce summer learning and to work with each other to continue to develop mutual trust and to collectively craft strategies that addressed school missions. At MNTH, while many STEM teachers came with project-based learning expertise from the UTeach program, all staff engaged weekly using Critical Friends meetings to model the ways students worked in their project-based learning groups, providing regular practice for new and veteran teachers, and a forum for questioning and support. At GJJ-HTH, administrators explained that daily professional development time was spent on pedagogical and practical issues of common concern. New teachers were paired with more experienced mentor teachers to ease their transition to teaching at GJJ-HTH, and each teacher collaborated regularly with a co-teacher. At DSST: Stapleton, collaborative meeting times were often used to examine student data to explore comparisons of classroom practices and student performance to shape future learning experiences. At USA, administrators explained that when the school first started, administrators needed to actively participate in teacher department or grade level meetings to model and shape teachers' collaborative practices. Eventually, teachers came to take full responsibility for their meetings, and actively sought and valued each other's contributions.

In order to take advantage of their facility to work cooperatively, teachers needed time provided in the school schedule as well as encouragement from the administration to practice the collaborative skills they had learned.

Open lines of communication. Open pathways for both formal and informal interaction and communication among teachers and administrators provided a conduit for the effects of professional development to be dispersed and reinforced, and for ideas, knowledge, and skills to be shared. Across the four schools, the most commonly identified professional development experience involved teachers observing others for the very purpose of their own professional development. Regular communication contributed to the development of a common understanding of the school's mission and the sharing of ideas about how each person could participate to meet desired goals.

This open communication appeared most prevalent at GJJ-HTH where the open floor plan, windowed classrooms, and public displays and presentations of project products provided regular, intentional interactions among teachers, administrators, students, and ideas. There was also ongoing communication among co-teachers, grade-level and subject-area teachers, mentor and collegial coaching teacher pairs, and with building administrators. The information flow at MNTH was facilitated by regular teacher interactions in Critical Friends meetings, department meetings, and with co-teachers, and by interactions with the Principal and Instructional Coach as they moved in-and-out of classrooms engaging and supporting teachers. At USA, teachers' commitments to school outcomes and to each other appeared to support their regular conversations about student learning and classroom practices. Co-teaching facilitated communication, and USA teachers described collectively reading the research literature and gathering data from instructional rounds to make informed decisions about student learning and classroom practices. The teachers found ways to communicate through such venues as a vertical team website, presenting posters of best practices, and sharing their expertise through mini-courses. At DSST: Stapleton, teachers described having regular opportunities to work with each other and to interact with administrators. Teachers met as departments and subject-area teachers and, more broadly, with teachers in the other network schools. Teachers could access students' records from their other teachers, which could promote communications across grade levels and subjects. At the end of each trimester, teachers met within subject areas or grade levels to focus their attention on student performance and classroom practices. The Director of Curriculum and Instruction and Academic Deans observed and supported teachers in their classrooms several times a week for new teachers with decreasing frequency for more experienced teachers. In addition, in three of the schools (MNTH, GJJ-HTH, and DSST: Stapleton) whole school meetings appeared to support information sharing throughout the entire community.

Teachers entered these ISHSs with a willingness to collaborate to support the schools' missions, visions, and goals. This common mindset helped to jump-start teacher professional development allowing administrators to focus on developing communities of learners. Summer professional development helped teachers learn how to support their colleagues and to reach out to them as resources to enhance collective knowledge and skills. Collaborative work allowed teachers to influence each other's practices, so they required less convincing to buy into new and different school models. Regular opportunities to practice and reinforce collaborative learning, coupled with open lines of communication helped strengthen practices and disseminate knowledge throughout the school. Collaborative practice contributed to more than common knowledge; it helped shape the collegial working environment and empower teachers. In Conclusion 3, the role of the school environment as it related to teacher professionalization is considered more extensively.

Conclusion 3

3. Professionalization of the teaching staff is intentional and supports teacher autonomy and decision-making capacity, teacher responsibility for school outcomes, and pathways to roles of increased responsibility.

Defining teacher professionalization. As noted in Chapter 2, teacher professionalism and professionalization did not appear in the research literature as well-defined constructs. For this study, reviews of both teacher professionalism and professionalization were examined to understand the current thinking about teachers as professionals (Agarao-Fernandez & de Guzman, 2006; Bloom & Unterman, 2013; Evans, 2002; Kennedy et al., 2011; Kennedy & Smith, 2013; NRC, 2004; NSTA, 2010; Tobias & Baffert, 2009). In this section, the term professionalism is used to refer to a quality of a teacher or teaching staff that already exists or that the teacher brings to his or her teaching position, and the term professionalization is used to refer to a quality that is supported or acquired through some process occurring in the ISHSs. In Conclusion 3, the term professionalization is used to suggest that ISHSs *intentionally* engage teachers in activities within a school environment that is designed to enhance their capacities as teaching professionals and to support their active and integral participation in a professionalizing culture.

Connections to the research literature. While teacher collective practice as introduced in Desimone's (2009) framework could have simply described teachers learning the same information at the same time, in these ISHSs, it was much more. In the research literature, collective practice was described as a vehicle through which teachers shared ideas, knowledge, and teaching strategies (Goddard et al., 2007; Sun et al., 2013), and it provided space for teachers and administrators to collaborate in the development of trusting and supportive relationships (Garet et al., 2001; Johnson & Marx, 2009). A school environment that fostered collective and collaborative teacher learning and practice could support increased teacher autonomy, self-efficacy, and teacher professionalization (Hamilton & Richardson, 1995; Kennedy & Smith, 2013; NRC 2004). Two studies described a number of collective practices in which teacher professionals might participate: learning from peers, collective learning, collective reflective practice (Kennedy & Smith, 2013); and, public classroom practice, reflective dialogue, peer collaborations, and new teacher socialization (Bryk et al., 2010). Three studies described practices that could be considered behaviors of a professionalized teaching staff: teacher autonomy in the classroom and in broader community decision-making (Evans, 2002); collective leadership and vision, collective decision-making (Kennedy & Smith, 2013); and a sense of collective responsibility for student performance and school improvements (Bryk et al., 2010). These professionalized collective behaviors, often described as characteristics of a *distributed leadership*, were seen as supporting an environment of shared mission and mutual trust (Kennedy et al., 2001; Spillane, Halverson & Diamond, 2004). All of these collective practices and outcomes were evidenced in the data collected across the four ISHSs and discussed in Chapter 4.

The ISHSs. Teachers in the four ISHSs were hired for and respected for their expertise, their philosophical alignment with the schools' missions, and their willingness to work with others. Because of their academic and professional expertise, teachers were often granted some initial autonomy in their classrooms. Reflected in a comment by an administrator at MNTH, the schools sought teachers who "weren't afraid to take care of business within the box, but still step outside of it." Teachers often assumed responsibility for designing course curricula, projects, or integrated courses, or for modifying course materials to address the needs of the students in their classrooms.

Teachers were hired into environments that actively supported collaborative practice. Ongoing collaborative professional development experiences supported teachers in the continuous expansion of knowledge and skills that helped them, as a teaching staff, develop shared understanding of the school's needs and challenges. Teachers were further empowered through formal and informal pathways to roles of increased responsibility and leadership. In GJJ-HTH and DSST: Stapleton there were formalized pathways to identified leadership roles within the ISHSs or in other network schools. These schools provided in-house programs (the Graduate School of Education and the Emerging Leaders Program, respectively) that helped teachers prepare for and ultimately assume roles in teacher or school leadership. MNTH and USA had more informal pathways that broadly supported teachers' active contributions to school-wide decision-making, proposing and implementing strategies to address concerns beyond the individual classroom, and assuming greater responsibility for school and student outcomes.

School collaborative culture and teacher professionalization. The conceptual framework used for this study (Figure 4), shows teacher professionalism as a feature within or supported by the school collaborative culture. The research studies described above, along with findings from the four ISHS case studies, were used to tease apart, extract, and separate characteristics that appeared to support the development of teachers as professionals, and those that might best describe outcomes transpiring from a professionalized teaching staff.

The collective research literature in combination with the findings from this study contributed to the development of a diagram that aims to characterize the somewhat symbiotic and self-sustaining nature of the relationship between the school collaborative culture and teacher professionalization (Figure 5). In the diagram, these inputs suggest that a recurrent, self-reinforcing cycle begins with (1) a school environment that supports collective learning and collaborative practices, that serves to (2) increase teacher autonomy and teacher self-efficacy, and support teacher professionalization. Increased teacher professionalization leads to the possibility of a (3) distributed leadership in the school where more experienced faculty take increased responsibility for school-wide decisions that may affect school outcomes. This collective and distributed leadership helps to (4) support an environment of shared mission and trust, which can further enhance collective and collaborative learning in the school, thus sustaining the cycle of teacher professionalization.

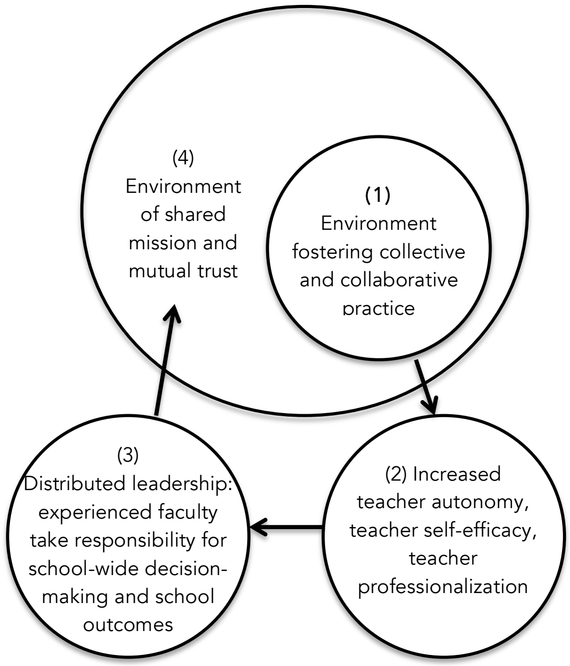


Figure 5. A cycle describing the relationship between a school's collaborative culture and the development of teachers as professionals.

Summary and Recommendations

Teachers working in supportive, collegial environments, who are valued for their professional training and provided with multiple, ongoing opportunities to engage in ways that challenge and take advantage of their expertise can better support the success of ISHSs. Providing teachers with pathways to roles of increased responsibility helps empower them to engage in school-wide decision-making and in taking responsibility for school outcomes as part of a collective unit working toward common goals. The learning environment created by these collaborative actions is continually reinforced as new teachers arrive to share new and different experiences, and as senior teachers offer institutional knowledge helping to smooth transitions for novices. As each teacher becomes increasingly professionalized, school leadership is distributed over an increasing number of professionals who embrace and take increased responsibility for school and student outcomes, further enhancing the collaborative environment in a symbiotic, self-sustaining professionalizing process.

Collective practice, working with others on activities in common, appears to play a critical and pivotal role in these ISHSs. Without it, it is impossible for the cycle described in Figure 5 to begin, let alone continue. However, collective practice is only the start of the loop; it lays the foundation for communication and idea sharing. As such, teachers need to have ideas to share and sophisticated academic and pedagogical backgrounds, in addition to some collective level of cosmopolitanism, to allow this knowledge exchange to be useful and productive. Teachers also need to learn how to share ideas and practices in ways that encourage all to participate and to actively engage. School leaders must work collaboratively with teaching faculty to shape a school environment that supports open communication in ways that create trust where teachers feel intellectually safe in exposing their weaknesses, and sharing their strengths.

STEM teachers need content knowledge, but as this study suggests, many factors contribute to a strong STEM teaching staff and no one factor alone can sustain successful practice. Overall within the ISHS teaching staff, there should be a balance between practical and professional experience and pedagogical knowledge; between teachers who have learned the latest concepts and practices and those who have had years of practice working with students in the classroom; between classroom autonomy and collective focus on a common mission; between creativity and meeting the standards; and, most importantly, teachers must have multiple, ongoing, supported opportunities to share their skills, knowledge, and expertise with each other in an open, trusting, supportive learning environment. Teachers must be aware of and buy into the school mission, vision, and goals; and must be willing to collaborate to work toward achieving them. Administrators must invest time and energy in supporting collaborative practices and teacher professionalization and establishing a school environment that actively and intentionally encourages the sharing of knowledge, ideas, and solutions.

What follows are recommendations for practice and future research based on the results of this study.

Recommendations for Practice

Recommendations for practice are directed at school systems and school leaders looking to start ISHSs or to improve the functioning of their existing STEM teaching staffs.

1. Ensure all teachers have content level expertise to teach in their subject areas.
2. Provide ongoing professional development experiences to support teacher learning, and engage teachers in determining the professional development they need to carry out their jobs effectively.
3. Provide teachers with collective training on collaborative practices such as professional learning communities or Critical Friends groups, and work to develop an environment of mutual trust and support.
4. Allocate time within the school day, week, and year for regular teacher collaboration to address issues of teaching and learning.
5. Provide teachers with pathways to increased responsibility and leadership.
6. Give schools administrators some autonomy in selecting and hiring teachers whose teaching philosophies are aligned with the school mission and vision, who are willing to work collaboratively toward achieving school goals, and who have

the background and expertise necessary to teach the courses for which they are hired.

Recommendations for Future Research

This study was designed to utilize an existing data set, and as such, the research questions were designed around the data. It was a qualitative investigation of four successful ISHSs that did not intend to result in generalizations that could be applied broadly across all schools, but instead to provide a rich description and analysis to allow for transfer to similar but unrelated contexts and situations.

It would be useful to know whether the conclusions drawn from these four schools can be validated within other successful ISHSs, or other schools of choice, small schools, or any high school with a STEM teaching staff. Also, Figure 5 suggests relationships among a collaborative school culture, the professionalization of teachers, and the formation of a distributed leadership. It would be interesting to further investigate these relationships to understand, for example: (a) the role of a collaborative culture in other schools demonstrating a distributed leadership, or (b) the existence of a collaborative culture in schools with a hierarchical leadership model. It might be possible to use a large national data set to find schools with both collaborative school cultures and distributed leadership models to statistically evaluate multiple aspects of Figure 5 to determine whether particular teacher characteristics, professional development experiences, or school environments appear to contribute to shaping the relationships between collaboration and distributed leadership.

Because ISHSs are a relatively recent yet expanding phenomenon (Lynch et al., 2011), it seems logical that research devoted to further understanding how to best develop a STEM teaching staff for these schools could be of increasing importance. Results from this study could be further validated by comparison with other successful ISHSs. Additionally it might be useful to look at ISHSs that are less successful to see whether there are apparent differences in their approaches, or the characteristics of their teachers, teacher professional development, or teachers' collaborative practices that might explain differences between levels of success.

Additional questions not answered through this study that might yield interesting results include the following:

1. To what extent does cosmopolitanism affect learning in a teaching staff? Under what circumstances does cosmopolitanism have an effect?
2. What features are most important in the development of a community of trust? Once established, what factors might ensure that this trusting community can be maintained with turnover in a teaching staff or school leadership?
3. How much collaborative practice is enough? Are there particular forms of collaborative practice that are needed or necessary to ensure the development of a community of learners, or of a trusting environment, or for teacher professionalization?
4. Does school size matter? All of these schools were relatively small in size, which might have contributed to the development of a close community of learners within them. What does collective practice look like in larger schools? Is it possible to use a similar model of professional development or must some things change besides simply making a program larger? What does a community of trust and support look like in a larger school?

Limitations of the Study

This study was limited by the existing OSPrI (Lynch et al., 2011) data set used for analysis. The nature of the original OSPrI study included the intentional selection of schools representing exemplars of ISHSs, those successfully carrying out a mission of positively affecting learning and STEM outcomes by students from groups underrepresented in the STEM fields. As such, the OSPrI study was designed to determine what similar characteristics existed that might be contributing to their success. It was not an evaluative study, but descriptive. My study of the teachers and teacher professional development sought to understand the teacher-related characteristics contributing to school effectiveness, and as a result also focused on the similarities among the schools. It also did not intend to be evaluative. In the individual case studies (Appendix C), unique characteristics of each school were described, such as how they dealt with student mastery, state teaching standards, or working with a teachers union. The cross-case analysis addressed some of the different ways that each school interpreted similar strategies, such as co-teaching models, or the use of projects for student learning. However, this study primarily sought to describe the similarities among these ISHSs to try to better understand what broad teacher-related features might be influential in the schools' success. It could certainly be the domain of future research to design studies to determine the relationships among characteristics found in this study and particular school or student outcomes, but that was not in the capacity of this study.

Final Thoughts

This study examined the experiences of teachers in four successful ISHSs to better understand who the teachers were, how their professional development experiences were shaped, and what and how factors relating to teachers or their professional development experiences appeared to contribute to the success of these ISHSs. Not all schools were equally successful in carrying out their missions, visions, and goals, but across the four schools patterns emerged that pointed to common practices that appeared to support successful outcomes. The schools were not identical in their daily routines and practices, but all focused on teacher content knowledge, collective practice, and teacher professionalization. There did not appear to be a single best way to develop the teaching staff in an ISHS. Better outcomes seemed to result in schools where there was alignment throughout all aspects of the ISHSs: school mission and vision, teacher hiring, professional development targeting school reforms and teacher and student needs, classroom practices reflecting decisions about how to best meet the needs of students underrepresented in STEM, and environments where teachers took an active, empowered role in shaping their professional development, and making decisions related to student and school outcomes.

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Appendix A – OSPrI Study 10 Critical Components

Critical Component (CC) Definitions

1. ***STEM-Focused Curriculum (CC1).*** Strong courses in all 4 STEM areas, or, engineering and technology are explicitly, intentionally integrated into STEM subjects and non-STEM subjects.
2. ***Reform Instructional Strategies and Project-Based Learning (CC2).*** STEM classes emphasize active, immersive, and authentic instructional practices/strategies informed by research. Opportunities for project-based learning and student production. Performance-based assessment practices that have an authentic fit with STEM disciplines.
3. ***Integrated, Innovative Technology Use (CC3)***. Technology connects students with information systems, models, databases, STEM research; teachers; mentors; social networking resources for STEM ideas, during and outside the school day.
4. ***Blended Formal/Informal Learning beyond the Typical School Day, Week, or Year (CC4)***. Learning opportunities are not bounded but ubiquitous. Learning spills into areas regarded as "informal STEM education." Include apprenticeships, mentoring, social networking and doing STEM in locations off of the school site, in the community, museums and STEM centers, and business and industry.
5. ***Real-World STEM Partnerships (CC5)***. Students connect to business/ industry/world of work via mentorships, internships, or projects that occur within or outside the normal school day/year.
6. ***Early College-Level Coursework (CC6)***. School schedule is flexible, and designed to provide opportunities for students to take classes at institutions of higher education or online.
7. ***Well-Prepared STEM Teaching Staff (CC7)***. Teachers are qualified and have advanced STEM content knowledge and/or practical experience in STEM careers.
8. ***Inclusive STEM Mission (CC8)***. The school's stated goals are to prepare students for STEM, with emphasis on recruiting students from underrepresented groups.
9. ***Administrative Structure (CC9)***. The administrative structure varies (school-within-a-school, charter school, magnet school, etc.). Affected by the school's age and provenance, i.e., whether the school was converted from another model or was created "from scratch" as a STEM school. Funding structure varies.
10. ***Supports for Underrepresented Students (CC10)***. Supports such as bridge programs, tutoring programs, extended school day, extended school year, or looping exist to strengthen student transitions to STEM careers. Altered, improved opportunity structures, i.e., students are positioned for STEM college majors, careers, and jobs.

Appendix B – Lesson Flow Classroom Observation Protocol (LFCOP)

Lesson Flow Classroom Observation Procotol (LFCOP)

Lesson Flow Observation Sheet Please note with an *when the lesson begins and when the lesson ends								
time	on/off topic		Center of Attention: Teacher/Individual/ Student Group			If Student Group Centered: Lab Activity or Proxy/Non-Lab Related Activity		
time	**On**	**Off**	**T**	**I**	**SG**	**LA**	**NLA**	Notes
0-2								
2-4								
4-6								
6-8								
8-10								
10-12								
12-14								
14-16								
16-18								
18-20								
20-22								
22-24								
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66-68								
68-70								
70-72								
72-74								
74-76								
76-78								
78-80								

Protocol for Lesson Flow
OSPrI

I. Introduction:

- **Definition:**

The flow of a lesson or the amount of time in a lesson (can be over several class periods) that is taken up by different types of activities, either teacher centered or learner centered. Teacher centered activities are the activities that take place in the lesson during which the teacher commands the attention of the class or directs the students' attention to a student who becomes a proxy for the teacher. These can include explanations, discussions, lectures, and demonstrations. Student centered activities are activities that take place during which the focus is on student work that is happening in groups or individually. The teacher is not the center of attention and is not leading any discourse or talk.

The unit's lessons form scripts that contain scenes that differ from the scripts and scenes that may ordinarily occur in classrooms. This organization of time and activities could lead students to different activity systems for the highly rated units, activity systems that lead the students to do more of the kinds of thinking that results in a better understanding of the target concepts. For instance, if a unit asks students to conduct a lab exercise, gather data and reason from evidence, this can result in sense making arguments among students that would not have occurred in a curriculum structure that was organized differently and resulted in activity systems of a different nature. The trick then is to be able to capture the organization of scenes and their nature.

- **Rationale:**

By studying the lesson flow, or the amount of time spent in different activities, we can assess the amount of time during lessons that is spent doing activities related to the target ideas that we are studying (on-topic) or doing activities that are unrelated to the target ideas that we are studying (off-topic) We can also see whether the on-topic activities are student (individual or group) or teacher centered activities, as well as the kinds of student centered activities (labs) that occur. More in depth, we will look at whether the comparison and treatment classrooms differ in the amount of and/or percentage of time spent doing these types of activities. We think that by looking at the lesson flow for lessons in the treatment and comparison classrooms we will be able to see the different kinds of classroom experiences the students are having in each experimental condition and be able to begin to understand the programmatic differentiation between the two.

2. Methodology:

- **Sources of Information: Classroom Observations:** An observation protocol for lesson flow will serve as a source of information. Observer should complete top part of cover sheet prior to observation and include teacher name and other accessible data. Researcher will blacken out teacher name upon receipt and record generated teacher code in gray box.

- **Data Collection Methods –** Observers must be experienced in educational classroom observations, have a working knowledge of the target idea being observed and be able to understand the definitions of the different types of activity systems that can occur in a classroom. Observers will be trained on the protocol using both video and actual classrooms as a means of piloting the scale. Inter-rater reliability will be calculated during the video training and reconciliation, in which observers discuss the rating for each variable, will occur after training. Observers will check off descriptions of the activities that are taking place in the classroom in 2-minute intervals. The observations will take place in person through site visit; each visit will last 45 to 90 minutes, depending upon period structure, until the lesson has been completed.

- ☑ How do we clarify between activities the teacher just wants students to "get done" whether it's individually or in a group?
  - *Answer*: If students are working individually but consulting with other students sporadically, still code as "on topic, individual." Be sure to note in anecdotal notes that collaboration with peers was acceptable but not specified.
- ☑ Ambiguities will exist…be sure to note them in the margins and contact SCALE-uP staff.
- ☑ Distributing papers that are related to the lesson/target idea is considered "on-topic"; distributing papers that are non-lesson/target idea is off-topic.
- ☑ If teachers' intent is individual centered (e.g. teacher says, "Do not talk to one another as you answer these questions in your notebook), but students talk to one another or they are given permission to "talk to one another if needed," it is still considered individual centered.
- ☑ Continue keeping track of time if kids keep working even if the bell has rung at the end of the lesson.
- ☑ Once a LF observer completes the LF instrument, he/she can go back to it to revise their checks if they realize something is actually on or off task, etc.
- ☑ If teacher is distributing papers that are related to the target ideas/unit of study, observers are to mark this time segment as on-topic.
- ☑ Observers are to indicate how long the block or period is on cover sheet.
- ☑ In order to aid observers in coding, they may write (in advance, if it would aid in keeping time) the time in the "minute" box.
- ☑ Observers are to continue coding if teacher continues lesson (on-topic) after bell rings to indicate the end of class. Likewise, if the teacher begins before the bell, begin coding and indicate in anecdotal notes.
- ☑ LFCOP observers' primary contacts for scheduling observations are the ISCOP observers.
- ☑ Information regarding autonomy was added to "centeredness" definitions.
- ☑ Collecting worksheets is an administrative task; therefore, it is teacher-centered, even if the teacher has students individually put their papers in a box in the back of the room; the box technically acts as a "teacher proxy" and is the center of attention.
- ☑ When observing lessons for more than 1 day, please take multiple copies of the LFCOP with you. At the beginning of a new day, start with a "clean" version and on the cover page, write "Day 2" or "Day 3" to help keep everything straight. When the lesson is complete, make sure to add the TOTAL amount of minutes for the lesson and add it to the ORIGINAL cover page.
- ☑ If possible, we would like you to email an electronic version of your final coding responses to us within 24 hours of your observation (using the version I attached to the email). This will help us to ensure we receive an accurate and timely accounting of your observation. If there are 3 observations for the lesson, we should receive 3 LFCOP's filled out. BUT, you only need to fill out one cover page.

Optional Anecdotal Notes:

Describe any factors that you feel enhanced or detracted from the learning environment (e.g., teacher's communication of expectations; fire drill in the middle of class; discussion focused only on classroom logistics, such as completing science fair; students' level of collaboration or cooperation; students' willingness to ask questions or challenge ideas, etc.).

Definitions:

On-topic and Off-topic: The goal of this coding scheme is to see the proportion of class time devoted to the target unit topic vs. other matters. Off-and On-topic activities may be directed primarily by the teacher, may occur within working groups of students, or can occur during individual seatwork. When doing classroom observations, Off- and On-topic activities can primarily be coded by observing how the teacher is directing lesson flow.

I. On-topic activity: Students and teacher are engaged in talking, listening, thinking or doing activities related to the target ideas (Seasons or Motion and Forces). When doing on-topic activities, students or teacher may take brief discursive side trips away from the topic focus. For example, if students are measuring things incorrectly, or not using safety equipment correctly, the teacher may need to halt the activity in order to reinforce something else, but the goal remains getting the work related to the topic done. Note that for this definition, if a teacher using a particular curriculum unit brings in material outside the scope of the curriculum but still related to the topic, this should be coded as on-topic. On- topic activities might include review questions, warm-ups, tests, safety rule reminders, distribution of materials, preparation for lab/activities related to target ideas, etc.

II. Off-topic activity: Students and teacher are engaged in activities unrelated to the target topic of Seasons or Motion and Forces target ideas. These can include announcements about the upcoming science fair or field trips, discussions about social activities, classroom management activities such as attendance taking, listening to announcements, etc. Even in-depth science discussion can be coded as off-

Lesson Flow Observation Sheet: Version B

Minute	Off topic or On topic	For on-topic: Teacher centered, individual centered, or student group centered	For Student group centered: Lab activity (or proxy) or non-lab related activity	Notes or Description of Activity (optional)
0-2	____On Topic ____ Off topic	____ Teacher centered ____ Individual centered ____ Student group centered	____ Lab activity or proxy ____ Non-lab related activity	
2-4	____On Topic ____ Off topic	____ Teacher centered ____ Individual centered ____ Student group centered	____ Lab activity or proxy ____ Non-lab related activity	
4-6	____On Topic ____ Off topic	____ Teacher centered ____ Individual centered ____ Student group centered	____ Lab activity or proxy ____ Non-lab related activity	
6-8	____On Topic ____ Off topic	____ Teacher centered ____ Individual centered ____ Student group centered	____ Lab activity or proxy ____ Non-lab related activity	
8-10	____On Topic ____ Off topic	____ Teacher centered ____ Individual centered ____ Student group centered	____ Lab activity or proxy ____ Non-lab related activity	

Please note with an " * " when the lesson begins and when the lesson ends

Appendix C – Teachers and Teacher Professional Development in ISHSs Case Studies

Case Study 1: MNTH Teachers and Teacher Professional Development

Introduction

Manor New Tech High School (MNTH), one of three public high schools in the Manor Independent School District (MISD), first opened as a school of choice for the 2007-2008 school year with 160 ninth and tenth grade students, 14 teachers, and three administrators. During 2011-2012, the year of the OSPrI visit, the school population had increased to 332 students in grades 9-12, and 28 teachers. It had had two graduating classes and was getting ready to graduate its third class of seniors. MNTH was conceived as one of 32 original T-STEM Academies supported through funding for a state STEM initiative, the Texas High School Project, now called Educate Texas. The school partnered with Austin Community College and the University of Texas-Austin (UT Austin) in order to enhance both students' and teachers' academic experiences. It also utilized support from the New Tech Network model to design and implement its project-based learning (PBL) approach to classroom instruction (Lynch, Spillane, Peters-Burton, Behrend, Ross, House, & Han, 2013).

Project-based learning was ubiquitous in the MNTH classrooms with three-week projects typical, and small group learning observed far more often than full-class teacher-led lessons. Teachers were both hired for their experience with project-based learning and provided additional learning experiences in PBL through professional development offered both during the summers and ongoing throughout the school year. Teachers became comfortable not only with implementing project-based learning in the classroom, but also designing and refining lessons with the assistance of others, and working to create projects that supported student learning in line with the Texas state standards (Texas Assessment of Knowledge and Skills; TAKS). Students were guided in learning how to learn through project-based experiences. Projects early in the ninth grade year were designed to guide students through the PBL process with activities structured to teach steps and strategies in achieving positive outcomes through project-based learning, including addressing some of the social and emotional challenges of group learning. Students learned how to use their entry documents and assessment rubrics to develop their "knows" and "need to knows." They learned to delegate and assume responsibility for different aspects of the project, and how to cooperate and collaborate to learn with and from each other to ensure that each student would meet the targeted learning goals. They learned to become responsible not only for their own learning, but to their team and to contribute to the learning of others (Lynch et al., 2013).

Teachers

Hiring

The principal had the latitude to hire teachers whom he felt would work collectively to successfully carry out the mission of MNTH through project-based learning. He was not constrained by the hiring policies of MISD. Of the 14 teachers hired for the opening academic year (2007-2008), seven were from the UTeach program at UT Austin. According to the principal, "All my math and science teachers had no teaching experience whatsoever the first year; they were all UTeach graduates." He went on to explain "They're from the school of natural sciences where they take mathematicians and scientists and talk them into becoming teachers," and so these incoming teachers had the academic content background of an undergraduate science or mathematics major along with the UTeach pedagogy coursework when they began their teaching at MNTH.

When hiring teachers, the principal explained that while having "composite or multiple certifications or masters in their content area so they can be adjunct faculty at the community college" might get them an interview, he additionally sought those who had "a passion, a desire to change education, to not keep it the same way, and…weren't afraid to take care of business within the box, but still step outside of it…and be ready to create their own destiny." He sought those who were eager to teach using projects rather than textbooks. Another school administrator concurred saying, "You can't teach what you don't know. [The teachers] have to know the content, but also be able to collaborate with colleagues. [We] need teachers willing to learn, willing to try." Clearly, the administration at MNTH sought teachers who were capable in their content areas and the PBL pedagogy, but also those who were interested in ongoing learning and being part of a community of learners.

STEM teacher academic background and experience

Seventeen of 28 teachers responded to the OSPrI Teacher Survey for the 2011-2012 school year, 10 of whom were STEM teachers. Of the STEM teachers, the average teaching experience was 7 years, but the mode was five, with the mean being offset by two teachers who had been teaching for more than 14 years. Seven of the 10 STEM teachers had been teaching for five or fewer years. The average age of the STEM teachers was close to 40, with three teachers in their upper twenties, two in their young thirties, three in their upper thirties, and two over age 50. Thus, while the teachers did not necessarily have extensive teaching experience, many described having had other professional, and life experiences, such as serving in the military, doing computer programming, engineering, and medical technology, that may have contributed to their content level expertise. Also 40% of the STEM teachers described having engaged in either educational or scientific research. All STEM teachers had appropriate credentialing, including both undergraduate majors and state teaching certifications in the content areas they were responsible for teaching, and the majority had a solid grounding in PBL pedagogy through the UTeach pathway.

Both academic content and project-based learning pedagogy were important qualifications for the STEM teachers hired at MNTH, but the principal also looked for teachers who "brought in great ideas and didn't want to give up their tool chest that they've accumulated, but they could add to it." There were formal structures in place that provided teachers with opportunities and incentives to engage in ongoing learning that facilitated their abilities to "add to" their knowledge and skills for teaching.

Teacher Professional Development

Intense and Sustained

Professional development opportunities for teachers took a variety of forms, came from a number of sources, and served a diversity of needs and purposes. To the extent observable, these experiences were targeted and aligned with the reforms and project-based learning supported by MNTH's mission, vision, and goals. The principal at MNTH explained, "We always have an ongoing professional development," and there were structures in place that exhibited mindfulness toward continuous, active, and timely teacher learning at MNTH.

Extended summer or specialty training. Teachers began with summer programs designed to help them acquire specific skills or practice targeted teaching strategies. According to the principal, in the early years of MNTH the teachers relied more heavily on the New Tech Network for PBL training, curriculum materials, and the structure and design of the cross-disciplinary courses. The original set of MNTH teachers attended a week-long training called “New Schools” where according to the principal, they learned the process of project development as well as having opportunities to engage in “lots of self reflection” and “buying in as a team.” The New Tech Network professional development experiences were in line with the New Tech model of project-based learning, and a mentor from the New Tech Network was assigned to MNTH whom teachers appeared to feel quite comfortable contacting. The teachers had access to a “project library” of projects that the teachers described as quite useful, but which they could also tailor to “match the students’ needs and skills.” The engineering teachers participated in an extended Project Lead The Way (PLTW) training in the summer to help them prepare to teach the engineering classes.

Regular in-school ongoing professional development. Ongoing professional development built into the school day, week, and year was designed to support teachers in the successful implementation of desired classroom reforms and of generally good teaching. These included classroom co-teaching, a system of mentor teachers and master teachers, routine classroom visits by the principal, regular department meetings, and weekly Monday morning *Critical Friends* meetings.

Co-teaching and instructional coaching. Many courses were team-taught providing opportunities for cooperation and communication between the two teachers during the course of the regular school day for planning and curriculum design. Additionally there was a “three layer structure” described by the instructional coach, of master teachers, mentor teachers, and classroom teachers. Master teachers [which appear to be the same as Instructional Coaches] had no teaching responsibilities and spent time in classrooms observing and supporting the classroom teachers. Mentor teachers were more experienced teachers with classroom responsibilities who could provide day-to-day direct on-level support to teachers of similar students or similar courses. And the principal explained that he was “always in the classrooms” to measure the pulse of teaching and learning through the projects.

The instructional coach regularly spent time in teachers’ classrooms “talking with them about the projects, asking how the scaffolding [for student learning] is done,” and helping teachers recognize both their strengths and areas where they could improve. An instructional coach, who had served four years in this capacity before moving to a district position, described this role. She explained that her focus was on instruction in the classroom, helping teachers plan projects and figure out co-teaching, observing classes and students, providing feedback, engaging in model teaching, looking at data, and helping teachers hone their skills. The instructional coach also provided collaborative expertise for teachers who had no “peer” in the school, explaining that sometimes when there’s only one teacher per grade level per content area, they don’t have an exact peer/partner to collaborate on goals about the content, and the coach could provide a sounding board “if they need to run an idea past someone.” The instructional coach was in part hired for her background and expertise in a wide variety of areas saying “[the principal] saw the attractiveness in hiring me because of that kind of experience; I could help in [many] different areas." She had an academic background in K-16 curriculum and instruction as well working knowledge in multiple disciplines. In addition, she had an understanding of how the school district worked and where to go to access needed supports, saying "It comes in handy because the teachers have so many different needs. I've used all of my different skills. And I know the people in the district who may be able to help out."

Critical Friends meetings. The weekly Critical Friends sessions were a significant piece of the MNTH faculty professional development experience. The principal explained that during these sessions teachers met to discuss a project-based learning "instructional piece, the student work, and … field testing strategies" brought forward by one or two faculty members. These faculty members described a lesson and explained their approaches and challenges. The rest of the faculty responded with "likes" describing what they saw as the positive features of the lesson, "I wonders" asking questions to clarify their understanding and sometimes asking the presenting teachers to explain their thinking behind choices made, and "next steps" where the faculty gave suggestions about different approaches that might be tried. These meetings were congenial, supportive, and highly productive, demonstrating a willingness to challenge and criticize each other coupled with a high degree of trust and what might be described as *intellectual safety*. The teachers appeared willing to put their practices and their ideas on the line, seeking thoughts and guidance from their peers in order to improve. One teacher described the Critical Friends experience on the Teacher Survey when asked to identify a particularly useful professional development experience at MNTH, saying:

> One professional development experience that made a significant difference in my teaching of STEM started with a rubric. During a Monday morning meeting [Critical Friends weekly meeting], we were given a rubric and an end product, which was a PowerPoint presentation. We were to analyze the rubric and see whether the end product showed that the student actually learned what he/she was supposed to, according to the rubric. We also classified which requirements the student was not able to meet from the rubric, and whether that was because of a student or a teacher issue. If it was a teacher issue, we discussed ideas on how to make the rubric represent the content better and if it was a student misconception, then we were to figure out … new ways to make them understand the content in a better way. This was a very meaningful professional development.

Other professional development. Beyond programs designed specifically for the reforms targeted by MNTH, there was state or district supported professional development that seemed to meet a broader skill-set focusing on "administrative things" such as grade recording, the use of technology, and learning about different programs available. Additionally, the T-STEM network provided "technical assistance" and "free seats to some professional development" for MNTH teachers.

Teacher survey data. According to the Teacher Survey, teachers articulated that they felt they had time to plan their lessons, to work with other teachers and to experience professional development although this time might have been less than adequate, and these experiences somewhat facilitated effective classroom instruction (see Table A-1). [Note: this survey only allowed responses of 1) No access, 2) Limited access, and 3) Adequate access, relative to questions about the adequacy of the amount of time provided for each activity. It would have been helpful to have a fourth category of something along the lines of "Ideal access," or "I could not ask for more." The three categories did not allow enough differentiation to get a sense of whether teachers would have appreciated more.]

Table A-1

The Effects of Time and Access on Classroom Instruction

Rate both your access to and the effect of each of the following on your classroom instruction:	Access[a] (1-3)	Effect on Instruction[b] (1-5)
1. Time available for teachers to plan and prepare lessons	2.8	4.6
2. Time available to teachers to work with other teachers	2.3	4.0
3. Time available for teacher professional development	2.3	3.7

[a]1=No Access, 2=Limited Access, 3=Adequate Access.
[b]1=Inhibits effective instruction, 2=Somewhat inhibits effective instruction, 3=Neutral or Mixed, 4=Somewhat facilitates effective instruction, 5=Encourages or enables effective instruction, 5=N/A or Don't Know.

Targeting School Reforms And Teacher/Student Needs

According to STEM teachers' responses on the Teacher Survey, teachers' professional development experiences appeared to be well aligned with the reform based teaching practices supported by MNTH (see Table A-2). With one exception, the mean score of all STEM teachers ranked the professional development experiences as at least confirming what they were already doing. And more significantly, for those experiences that focused on the project-based, inquiry-based, interdisciplinary, design-based learning that represented the reform goals at MNTH, teachers were more likely to rank their professional development experiences as effectively causing changes in their classroom practices.

Table A-2

STEM Teachers' Perceptions of Impact of Professional Development Experiences (N=10)

Considering all your professional development, how would you rate the impact in each of the following areas? If your professional development experiences have not addressed the following areas, please check N/A.	Mean Score[a] (1-3)	N/A
1. Learning how to implement problem-based or project-based learning	2.9	1
2. Learning how to use inquiry/investigation-oriented teaching strategies	2.9	1
3. Learning how to teach engineering or design concepts or activities	2.8	2
4. Learning how to teach S/T/E/M across the high school curriculum	2.7	3
5. Understanding student thinking in S/T/E/M	2.6	2
6. Learning how to do performance based assessments in S/T/E/M	2.5	2
7. Deepening my own S/T/E/M content knowledge	2.4	1

8.	Learning how to assess student learning in S/T/E/M	2.4	1
9.	Learning how to help students perform S/T/E/M research	2.4	3
10.	Learning how to identify, locate, and evaluate technology resources that I can use with my students (e.g. websites, online data sets, etc.)	2.3	0
11.	Learning how to use technology for student activities and experiments in the S/T/E/M classroom	2.3	0
12.	Learning ways to use technology to communicate and collaborate with families about school programs and student learning	1.9	1
13.	Learning ways to use technology to communicate and collaborate with other educators	2.3	1
14.	Learning how to teach S/T/E/M in a class that includes students with special needs	2.2	4
15.	Learning how to integrate the different disciplines of S/T/E/M into my course	2.1	1
16.	Learning how to use technology/technologies for differentiating instruction for students with special needs	1.8	4

[a]1=Little or no impact, 2=Confirmed what I was already doing, 3=Caused me to change my teaching practice, 4=NA.

The professional development experiences at MNTH appeared to be tailored to teachers' needs. Summer intensive training focused on specific content such as engineering, or general processes such as project-based learning. Ongoing in-class mentoring served to meet teachers where they were and helped them target individual problem areas. Through Critical Friends meetings, teachers could raise concerns about problematic projects or seek help in project development. Several teachers commented that the New Tech professional development was the most effective because it "tended to focus on instructional practices that are relevant to project-based learning" and because these experiences "exposed me to many educators, many strategies and tools that relate to problem based learning." One teacher clearly articulated the significance of the collaborative learning experiences and the expertise of the teacher-educators in the New Tech professional development experiences:

> Attending education conferences with like minded educators and participating in education chats on twitter are incredibly more beneficial to my professional growth than any PD conducted by any school district I have been involved with in my 20 years in education. I would like to see more Edcamp-style PD's [a type of participatory professional development where the participants determine the direction of the experience] where resident experts in specific areas of knowledge instruct educators wishing to learn about that topic.

One teacher summed this idea up nicely saying that the administration at MNTH was "highly supportive by providing us with the proper professional development that we as a staff feel is more needed for us to be a successful New Tech school that incorporates STEM education."

Professional development experiences at MNTH were not static; they changed with the needs of the school and staff. Noting the importance of integrating STEM beyond the STEM classrooms the principal explained that several teachers were going to be attending Robotics training and "it's not your engineers; it's your English teacher, a physics teacher, a math teacher" to help them better understand robotics to integrate it into their projects. And while MNTH had been in existence for about five years and was doing well as a school, the principal was mindful that it was possible to become complacent with the way things were going, suggesting the possibility that they had perhaps "hit a plateau." At the time of the OSPrI visit, he was preparing to collaborate with all of the faculty who had been on board from the beginning to engage in professional development to "hit the restart button" to figure out their next steps in moving forward.

Professional Development Summary

The professional development experiences at MNTH met many of the criteria in Desimone's Framework of successful professional development. Teachers' experiences appeared to be aligned both with the school mission, vision, and goals, as well as being focused on what the teachers needed to learn and what they wanted students to be able to accomplish. The introductory summer experiences were extensive enough to help teachers become skilled in new strategies and school-targeted reforms of project-based learning and engineering practices. There were structures in place that provided sustained support for reforms throughout the school day, week, and year through co-teaching, master, and mentor teaching, regular visits by the principal, and critical friends and department meetings. The professional development experiences involved active engagement with problems and materials—teachers engaged in engineering activities, project-based learning experiences, Critical Friends interchanges, and work with student data. Teachers had opportunities to practice what they learned, to receive feedback on their efforts, and to both contribute to the learning of and to learn from their peers in cooperative and collaborative activities.

Collaborative practice was identified by the research literature as being an indicator of effective professional development (Desimone, 2009), a process by which expertise gained through professional development was disseminated throughout a faculty (Sun et al., 2013), and was also identified as a necessary prerequisite of the school-wide culture that facilitated changes in classroom practices as a result of professional development experiences (Hamilton & Richardson, 1995). Collaboration at MNTH is examined in the next section.

Collective Teacher Practice, Collaboration, and Teacher Professionalism

Teacher Collaboration

STEM teachers responding to the teacher survey identified a number of opportunities to engage in collaborative professional development experiences with other teachers both locally and at a distance (see Table A-3). The majority of the MNTH STEM teachers described opportunities to observe, communicate, and collaborate with teachers both in MNTH and in the broader community of educators for experiences that were both intra- and inter-disciplinary with respect to STEM. And as was shown in Table A-1, while teachers generally felt that they would appreciate even more time for these interactions, they indicated that these opportunities to work with other teachers and to engage in professional development had positive effects on their classroom teaching.

Table A-3

Number of STEM Teachers Participating by Type and Timing of Professional Development Experiences (N=10)

	Current Year	1 to 3 years ago	More than 3 years ago	Never
1. Observed other teachers teaching S/T/E/M courses as part of your own professional development (formal or informal)	9	1	-	-
2. Used telecommunications to collaborate on S/T/E/M teaching issues with a group of teachers at a distance	7	1	-	2
3. Met with a local group of teachers on a regular basis to study/discuss S/T/E/M teaching issues	8	1	1	-
4. Collaborated with a group of S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	9	1	-	-
5. Collaborated with a group of non-S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	6	1	-	3
6. Attended a workshop on S/T/E/M teaching	7	3	-	-
7. Attended a national or state S/T/E/M teacher association meeting	2	6	-	2

Collaboration for cooperative good was described by the principal as a fundamental requirement for teachers being hired to work at MNTH saying, "I was really looking for people that could come in and be a team, to make our family/team, to make this school the best there is." He also sought teachers willing to work with others to examine their practices, who "weren't afraid to have teachers and other people really critically analyze their projects to come up, to make them better."

Several teachers identified their collaborative experiences as affecting both the school environment and the effectiveness of their teaching. One teacher described some processes and outcomes of collaboration saying "Aside from having a co-teacher, I collaborate well with the other science and engineering teachers in my school, [and] collaborations with these teachers have enabled me to develop integrated projects." Another teacher described a general recognition of collective, collaborative effort where "having the opportunity to work with a highly supportive team of co-workers has given me the chance to learn from their ideas and support about the integration of STEM in my classroom." And another teacher described the support of a collaborative undertaking saying that the struggles associated with changing teaching practices to teach through project-based learning could "seem formidable," but having good training and being "surrounded by people who are doing it" facilitated its sustained use in the classroom. Collaboration among teachers was the norm at MNTH. Teachers had opportunities to communicate and cooperate with each other both formally and informally throughout the school day and year. Co-teaching provided the most obvious school-day interaction where teachers occupied the same spaces, taught the same students, and needed to cooperate on curriculum design and lesson planning. Teachers also engaged productively with each other during regular department meetings and Critical Friends sessions to improve their own teaching and to focus on student learning.

The principal described another outcome of collaborative faculty as "we're all speaking the same language here." There appeared to be evidence that this regular and routine communication afforded opportunities for everyone to have a good sense of what was going on in classrooms throughout the school and to acquire a common understanding of their collective efforts to achieve MNTH's goals. However, while the principal looked for teachers willing to buy-in to the New Tech model, he also searched for those willing to lead rather than follow. He explained, "I wasn't looking to hold somebody's hand; I wanted someone who could come in and be a leader right from the beginning, that brought in great ideas." The principal explained that while there were common expectations, "the teachers know we're very focused on the curriculum." He also supported their decision-making capacity in their own classrooms saying, "They can do anything they want, I don't care." The principal spoke highly of his teachers saying, "I have great [teachers]—obviously they're a really unique group of teachers."

Teacher Professionalism

Teachers at MNTH were hired and respected for their strong content knowledge and teacher preparation. They were provided with opportunities to continue to improve their skills and knowledge, and it was expected that they would take on training and leadership roles for the next generation of teachers. One administrator explained that one of the roles of MNTH, as part of the T-STEM grant, was to serve as "R&D for the district in instruction and design." Additionally, they sought to sustain and maintain teachers by growing and supporting professional development from within the district. An administrator explained, "If I do my job correctly it will cease to exist in a couple years because there will not be a *21st Century Learning PD Specialist*; all PD specialists will have 21st century learning experience." In the beginning, the MNTH teachers were the recipients of New Tech Network training in project-based learning, but MNTH aimed to build coaching capacity in-house so they could move away from needing New Tech coaches to support the teachers. According to the principal, the teachers had become "so good that we're the national training site for all of the New Tech Network," and some of the teachers were becoming the trainers for others schools and districts seeking to replicate the program. In MNTH's professional development model, sustainability was built in such that teachers continually grew in their knowledge and were ultimately tasked with teaching others. Teacher leaders were brought up through the ranks of MNTH as part of the normal course of professional development experience.

Beyond training roles for professional development at MNTH, teachers were observed assuming administrative roles with flawless fluidity (Lynch et al., 2013). The principal explained "If I leave tomorrow, this [the school operating] should still happen" and went on to suggest that if any of the administrators, even the district superintendent were to leave that MNTH would continue to function the same way, saying, "We believe as a community that this is the best way of learning for our students."

School Collaborative Culture

It was apparent throughout MNTH that while the teachers and administrators were "speaking the same language," they were not the only ones in sync. There was alignment between the mission and goals of MNTH from the superintendent of schools, who was said to know "everything about the school," through MNTH administrators and teachers, to students and parents. Even the business community seemed to connect with MNTH's expectations for students and student learning. A school administrator explained that because the method of instruction was different at MNTH, it was necessary to change the culture of what was "normal" indicating that it was important to "look at the structures [in the school] that support the method of instruction *as well as culture* [emphasis added]." This administrator went on to suggest that this "culture" piece might be the point at which other schools might fail, saying that while these schools might be ready to move toward change, they must also be willing to change the school structures and culture to support the change. MNTH appears to have been able to support a school culture that was open and ready for change.

There was a focus on school environment that was revealed in the OSPrI MNTH Case Study through the emergent themes of "School Culture" and "MNTH as a Family: Our House." Featured aspects that appeared to facilitate MNTH's positive school culture included a flattened hierarchical structure, positive interactions between administrators and teachers, and good teacher-student relations. MNTH was also described as "a place where students will work together to do challenging work through PBL" and where academic accomplishments were celebrated. (Lynch et al., 2013, p. 55, 56). There were structures in place to help students bond as a class, and rising seniors took on the role of orienting incoming 9th grade where the activities were "about team building and trust." Teachers explained that students who "in regular settings would be nerds or wouldn't fit in" were accepted and celebrated at MNTH, and parents concurred saying "not at this school; they [other students] don't make fun of kids." Students identified a dynamic between teachers and students that they described as almost "a friendship" where rather than leading to a lack of respect, allowed students to "respect them more." One student commented that the teachers "cared that I was learning," adding "All the teachers really care; they'll take time out of their lives to help you," often coming in before school or on weekends. There appeared to be respect and trust between all community members—parents, students, teachers, and administrators all felt part of the school, as expressed by one teacher who said, "We all feel we built this."

Supporting Learning by Students Underrepresented in STEM

The review of the literature revealed several classroom practices found to differentially affect students underrepresented in STEM. These included practices that served to develop students' STEM identities such as helping students become interested in STEM fields and aware of STEM careers, ensuring that students developed competence in their STEM coursework, providing students with opportunities to present their competence to others, and also to be recognized for their knowledge and skills (Kanter & Konstantopoulos, 2010; Carlone & Johnson, 2007; Hazari et al., 2010). Opportunities for students to engage with each other in peer-to-peer learning and to take responsibility for their own learning, as might be the case in inquiry-based, project-based learning, were also found to contribute to students' perceptions of competence (Roth & Weinstock, 2013; Sadler & Tai, 2007). And the classroom social and emotional environment as it contributed to better teacher-student relationships, students' sense of well-being, and positive teacher or student perceptions of knowledge and learning could contribute to improved student learning (Aronson et al., 2002; Reddy et al., 2007).

MNTH administrators described professional development as being an important feature of teacher development, and there were structures in place to ensure that teachers had time for appropriate learning experiences, had opportunities to learn from those with greater expertise, and were provided with regular opportunities to interact and learn from and with other teachers. Teachers acknowledged that professional development was available, well utilized, and a valuable component of their learning. Teachers' responses on the Teacher Survey indicated that they felt that their classroom practices changed as a result of their professional development experiences (Table A-2), and the majority of the STEM teachers identified that they felt confident in using reform-based teaching strategies in the classroom that supported MNTH's mission, vision, and goals (Table A-4). As a follow-up to these teacher self-reports, classroom observations and other data provided a window into the activities and strategies being used in the classrooms.

Table A-4

Teacher Confidence in Utilizing Teaching Strategies (N=10)

I am confident in my ability to:	Mean Score[a] (1-5)
1. Manage a class of students engaged in hands-on/project-based work	4.8
2. Recognize and respond to student diversity	4.6
3. Encourage students' interest in S/T/E/M	4.6
4. Lead a class of students using investigative strategies	4.5
5. Help students take responsibility for their own learning	4.4
6. Use strategies that specifically encourage participation of females and minorities in S/T/E/M	4.3
7. Involve parents in the S/T/E/M education of their students	3.1

[a]1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree.

Classroom Time

To understand how classroom time was used at MNTH, several different sets of data were accessed. During the site visit, five STEM classes were observed where Lesson Flow Classroom Observation Protocol (LFCOP) data were collected monitoring the teacher's role in the classroom and whether students worked as a whole class, in small groups, or as individuals. Comments about classroom experiences obtained during teacher, student, and parent focus groups also helped characterize the classroom practices and teacher-student relations at MNTH.

LFCOP data were collected during five STEM class observations (Table 12). Three of the five classes showed a clear majority of the time was spent in student-directed small groups, with two classes demonstrating more traditional teacher led lessons for 50% or more of the class time. There were times during all classes when a mix of group, teacher, and individual work was occurring, so the total percentages might add up to more than 100% for each class. To get a sense of the class time that involved a more traditional form of teaching with all students listening to lecture, the last column in Table A-5 shows the percentage of class time that was exclusively teacher directed. It is worth noting that during the course of a project at MNTH, if there were a minimum number of students interested (in some classes the number was five), students could request a *workshop,* which was a lesson taught by the teacher for specific content knowledge. These workshops could look very much like a traditionally taught class, the difference being that they were specifically student requested. For example, in the chemistry class, during the 36% of the class time that was identified as Teacher Focused in Table A-5, the majority of the time involved the teacher working with a group of about 10 students giving a student-requested workshop on the Ideal Gas Laws with the remainder of the students working in their small groups on projects. Only 11% of class time was exclusively teacher led.

Table A-5

Organizational Grouping and Percent of Class Time[a]

Class Type[b]	% Student-directed Small Group Focused	% Individual Student Focused	% Teacher Focused	% ONLY Teacher Focused[c]
I=Eng	87	0	18	13
S-Chem	83	0	36	11
M-Geom	77	20	17	7
M-Alg II	33	20	53	50
M-PreCalc	0	7	93	93
MEAN	**56**	**9**	**44**	**37**

[a] More than one activity could occur at the same time, so percentages may add to more than 100.
[b] M=mathematics, S=Science, I=Integrated/Engineering.
[c] Small group, individual, and teacher led activities could be occurring simultaneously. This last column identifies time when all students were focused on the teacher as in a lecture class.

Developing STEM Identity

Interest

Comments from multiple members of the MNTH community identified the connections between the projects performed in classes at MNTH, real world applications, and the world of work. One teacher explained that the New Tech academic discussions were “a real world thing” where the project provided space for creative and academic learning to come together. One student suggested that the projects “give us ideas” about the applications of their learning to future careers and fields of study. Another student described a project in her engineering class as “It’s like architecture.” And a business partner, when describing how impressed he was with the project-based learning at MNTH said, “They work the way Samsung works.” Parents commenting on the strength of the culture at MNTH praised how it helped students think about college and career readiness. Giving specific examples from classes, students talked about using a “case file” in biology to determine what was wrong with a patient and making their own beverages in chemistry class. Alumni of MNTH commented, “The integration of math was really helpful” saying that when math and science were integrated in college, “it was natural for us.”

Teachers deliberately generated interest for STEM through their teaching. Several teachers spoke about how projects were used to motivate students to get them interested in the learning. One described using “reverse engineering projects” where instead of creating something they were taking it apart and “tinkering” to figure out how it worked. Others described helping students learn about “catastrophic failures,” and organized discussions about lawsuits and the business and human sides of engineering projects.

Ensuring Competence

There was a preponderance of evidence supporting student-centered teaching that focused on meeting the needs of the individual students as well as holding all students accountable for high standards of learning. As mentioned earlier in this case study, teachers worked collectively to make sure that their projects addressed the Texas state standards, and teachers of courses that were tested by the state took great responsibility for ensuring that courses were adequately rigorous to enable students to be successful on these assessments. Teachers and administrators also had access to data for each student from the previous year, which helped them determine how to structure projects to support student mastery. One administrator explained “We get a printout from the state on each student on what objectives they mastered, and what they didn’t, and we take that master and use it to develop projects.” An administrator also noted, that “high stakes objectives” in the standards would be included in every project to give students regular practice to make sure they were adequately prepared by the time they were assessed.

An administrator explained that the teachers were “really being analytical about the way they teach, how they teach, [and] how they are reaching their students,” adding that teachers “work to design projects [that consider] the needs of their specific students.” All students were expected to become competent in the material addressed through each project. An administrator explained that teachers “have to make sure that the students clearly know that they are expected to know all of this material” when presenting projects as a group. She went on to describe processes that teachers used during presentations to elicit adequate responses from all students to ensure that there were no gaps in their knowledge. Student competence, as measured by percentages of students either “meeting standard” or achieving “commended performance” on the TAKS mathematics and science tests indicated that MNTH students were achieving at greater percentages than students in the comprehensive high school or the school district. In addition, student scores within a cohort group at MNTH (mean score changes from 8th through 11th grades) improved with each additional year they were at MNTH (Lynch et al., 2013).

A teacher commented that because of the academic rigor at MNTH, the students “can go to college … and be confident.” And according to the principal, MNTH students seemed to be both getting into college—the acceptance rate for the two graduating classes prior to the OSPrI site visit was near 100%—and persisting in college—the principal said that according to the National Student Clearinghouse, 82% of the students who went were still in college. And this is with 50% or more of the student body being first in their generation to attend college.

Presentation and Recognition

The project-based learning format used at MNTH, where students often divided up the learning tasks for the projects and were thus responsible for teaching each other what they had learned and formally presented projects more than 50 times per year, provided students with multiple opportunities to demonstrate their expertise and to be recognized by others for their efforts. Presentations were usually made to classmates and teachers, but panels of outside guests, business partners, and other volunteers were sometimes brought in to hear and evaluate student work. One student described his experience with presentations:

> I used to hate speaking in public and now I am comfortable speaking in public … During the first presentation everyone would get red in the face and not want to talk and now it seems like nothing. It is easier to talk with people because of it [the regular practice]; I had several interviews and it is easier to talk to the people.

Another student describing his first presentation explained, "I had to do the presentation and learned that I should have no *ums*, *buts*, or *likes,* or read off the board for content. I memorized my whole presentation and I got an amazing grade. I didn't know I could do it." Regular practice presenting projects to others served MNTH students well. An administrator commenting on student preparation for interviews for jobs or college stated, "Our kids can talk." And providing an example where these skills had been particularly useful, one teacher told a story of two students who had participated in a science fair and even though their project did not win, one of the judges, who was from Samsung, offered internships to the students because they so impressed him with their presentation skills and confidence.

Developing Student Autonomy

It was clear that one goal of the teaching strategies used at MNTH was to increase students' autonomy in taking responsibility for their own learning. This is also sometimes referred to as *autonomy supported teaching* (Roth & Weinstock, 2013) or as aspect of social and emotional learning, which Durlak et al. (2011) described as including "self-awareness, self-management, social awareness, relationship skills, and responsible decision making" (p. 406). During freshman year, to scaffold leaning about *how* to learn using projects and how to navigate project-based learning to achieve the desired products and goals, students carried out a series of short projects targeting different aspects of the project-based learning process. To help students focus on the process, and to understand that it involved more than "trial and error," teachers asked students to document group decisions about the directions they chose for their project, and clearly articulating what data or information directed them along a particular pathway.

Teachers explained that project learning was also scaffolded in the project "briefcase," that provided students the tools and most of the information they would need to carry out their independent projects. *Bread crumbs* provided in the *entry documents* at the start of every project gave students clues to the content they would need to understand, resources they might access, and the workshops they might request from the teacher. *Rubrics* gave students information about how the project product would be assessed and also provided guidance for project management.

In addition to helping students understand the mechanics of working through a project, teachers helped students navigate group dynamics to learn how to work productively and effectively. Teachers explained that students had to learn how to address failure, and what to do to move beyond a problem or an apparent road block.

They also learned what it meant to be a good team member and what to do if a group member had to be "fired" for failure to carry their own weight in the group. Students had opportunities to regularly evaluate their own and their group members' collaborative efforts, and appeared to take this task seriously with a goal of improving their group work. One student described an experience that helped him learn to work with others:

> Last year I always prayed that I was never in a group with one certain person, one who interrupted class all the time. This year he's changed somewhat and I've learned to work with him. Also I have learned to put things in group contracts that help with that. I didn't think I'd be able to do that. It's all right. I can work with him.

Teachers served as guides throughout the learning process. One administrator described this role saying that the teachers had to be creative and to "step back and nourish the learning of students rather than be at the forefront of it." A student explained, "sometimes the teachers don't help … they don't give you the answer … they will give you guidance of where to look." One student described the process:

> [the teacher] just gave us the resources that we needed for the project; if we need help we ask and she gives workshops, and we are on our own for the project … it's hard, but it teaches you responsibility. If I have a partner who can't do the work, I explain to them.

During class observations, the OSPrI researchers noted that teachers were seen monitoring how the students worked together in their groups in addition to keeping track of student content understanding. They routinely circulated among the students asking such questions as how they were thinking about hearing everyone's ideas and making sure everyone was included in the process.

Students described learning how to work independently and how to go to peers for assistance first before going directly to the teacher. They learned how to avoid procrastinating, and to realize that sometimes a "not-so-good group experience" could help them figure out how to individually be more proactive in getting group work accomplished. One student described the challenge of having multiple projects going at the same time saying, "you have to learn to manage your time better; you have to go directly to the rubric and go step-by-step." An alumna of MNTH reflected on how her project work at MNTH helped her in college: "There are a lot of people in my classes [in college] that aren't used to working with people, communicating or distributing the load of work. So it really helps us because we are really used to working with people."

Summary—Learning by Students Underrepresented in STEM

Many data sources provided examples of classroom practices that supported the development of a student's STEM identity and contributed to their social and emotional learning, particularly as it related to projects. Projects helped students understand the real life connections of the course content, and often provided information about relevant careers. Students acquired competence in the subject matter through the conscious efforts of the teachers to align standards and project learning, by being held to high academic standards, and being held accountable for not only their own learning but also that of their project groups. Students were taught how to take responsibility for their own learning, and had multiple opportunities to practice as they managed their learning through their projects. Working in small groups gave students opportunities to regularly engage in meaningful peer-to-peer teaching and learning, and also provided opportunities for increased interactions between teacher and student, which supported the development of positive teacher-student relations.

Analysis and Discussion

In the descriptions of teachers, their professional development, and the use of classroom strategies identified as supporting learning by students underrepresented in the STEM fields, there was evidence at MNTH that the school was engaged in research-supported reforms. The characteristics of the teachers hired were in line with characteristics of "good" STEM teachers supported by the literature (cf. (Boyd, Grossman, Lankford, Loeb, & Wykoff, 2005; Goldhaber & Brewer, 2000; Monk, 1994; Silverstein, Dubner, Miller, Glied & Loike, 2009). The professional development followed Desimone's (2009) framework exhibiting the majority of the characteristics described as effective in facilitating changes in classroom teaching. And the strategies in use in MNTH's classrooms were aligned with those demonstrating support for the development of students' STEM identities and their sense of autonomy in guiding their own learning, helping students feel empowered to pursue future study in STEM fields.

One feature that appeared to cut across the characteristics of teachers, their professional development, and their classroom practices within the school environment was teacher professionalism. Teacher professionalism was identified in the literature as a factor that was interrelated with more effective implementation of learning targeted through professional development, a more collaborative school culture characterized by a sense of relational trust and mutual responsibility for goals, and distributed school leadership (Bryk et al., 2010; Evans, 2002; Kennedy et al., 2011). At MNTH there was a sense of conscious *teacher professionalization* where intentional pathways existed for the constant flow of teachers from novice to skilled practitioner, mentor, and leader. Teachers shared skills and knowledge, were continuously guided to explore and improve their abilities within an able, supportive, and trusted community, were provided multiple opportunities to demonstrate their expertise and be acknowledged for their competence and contributions, and ultimately shared responsibility for school outcomes.

"Professionalization"

Teachers. Teachers were hired for their expertise, and yet were intensely supported to improve and gain additional skills and knowledge to allow them to move along a professional continuum of assuming responsibilities within their classrooms and leading students in their development of knowledge and skills. They were expected to contribute within the broader school, helping their peers, and those who arrived later to follow in building, shaping, and strengthening the MNTH model. Teachers were supported in their professionalization through targeted training by more experienced others and regular opportunities to dialogue and engage with their peers in an environment of trust rather than judgment. Through training, teachers became increasingly expert in their knowledge and skills and had immediate opportunities to practice these skills in the presence of others—their co-teachers, the instructional coach, the principal—who could provide feedback, guidance, and advice, which the teachers used to improve. As teachers became more proficient in leading student learning through project-based activities, there were increased opportunities to assist the more inexperienced teachers in the capacity of mentor teachers, or as New Tech trainers helping disseminate the project-based learning model, in addition to ongoing collaborative faculty engagement.

These ongoing opportunities to share ideas, knowledge, and learning served to make the teaching at MNTH transparent, helping all teachers fully understand the translation of the mission, vision, and goals of the school into practice. This knowledge and expertise helped empower teachers as decision-makers not only in their own classrooms, but also on matters of school-wide concern. There was a small administrative staff at MNTH, and perhaps because of this, when an administrator had to be out of the building teachers readily rose to assume administrative responsibilities. To an outside observer, it almost appeared as if no one needed to ask a teacher to take responsibility, that as soon as a gap was noted, someone moved to fill the void and the school continued to function as if nothing were different. This leadership model, often referred to as a flattened hierarchy or distributed leadership, provided teachers with opportunities to grow within the school and gave them a sense of ownership and responsibility for the schools' outcomes creating an environment of shared accountability and mutual trust.

Teachers gained expertise through formal and informal professional development opportunities, and were respected by students, peers, administrators, parents and the community for the roles they served in the school. This conscious collaborative effort appeared to raise all teachers to high standards of teaching and there was a coherence in the staff that seemed to suggest that all were better when each member improved, and that the sum was greater than the individual parts.

Students. There is a parallel to this idea of teacher professionalization in the efforts made by teachers to help students be successful that might almost be considered a "professionalization" of the students as they gained integrity and competence in designing their learning. Students arrived at MNTH with few project-based learning skills because this learning approach was not used at any of the elementary or middle schools at the time of the OSPrI visit. Students were introduced to the process of project-based learning, and gently, but relentlessly, guided to acquire the social and emotional skills and the process knowledge they would need to shape their learning through projects. Teachers modeled the project-based learning that the students were expected to master during their time at MNTH. Co-teachers collaborated in planning classroom lessons, and departments engaged in project-based learning-type activities as they endeavored to match the state standards with project goals so all standards would be met by the time students were assessed. The Critical Friends meeting that was observed during the OSPrI site visit followed a process similar to what was observed as students engaged in projects in the classrooms. Students were guided by their teachers, and engaged in dialogue with their peers, both teaching and learning from them, as they learned what it meant to take responsibility for their own learning and for that of their group. As students progressed through the grades, both teachers and students described their becoming more and more skilled in creating the strategies and structure, and becoming increasingly independent as students who knew how to learn. Through the project-based learning, students had multiple opportunities to develop their STEM identities. They could become confident in their content knowledge, and were provided multiple opportunities to present and receive recognition for their knowledge. They had opportunities to learn about the connections between the course content and the world beyond their classrooms, and were to relate this learning to careers or pathways they might consider in the future.

At first, the students were guided by experts—their teachers—as they were introduced to the structure of project-based learning. This structure helped them learn how to learn using the project as a medium. They were then given countless opportunities to practice this new knowledge as they engaged in productive dialogue, teaching, and learning with their peers under the watchful eyes of their teachers. Teachers prodded when necessary, and helped students learn to fail and get back up to try different strategies to solve their problems. Students had opportunities to learn to direct their own learning and to contribute effectively as members of a team. Students were also provided multiple forums to engage with an audience larger than their classrooms through presentations to community members and at science fairs, and to be recognized for their expertise. Students not only had opportunities to grow personally, acquiring knowledge as they progressed from 9th through 12th grades, but to also grow as members of a team and members of a class acquiring the skills to ultimately become members of the community taking increased responsibility for the functioning of the school and its outcomes.

Alignment

Another feature that cut across the data of teachers, professional development, and classroom practices as contextualized within the school environment was that of intentional and thoughtful alignment and coherence. Most significantly, this alignment described the relationship among: (a) what the school said it did, (b) what the teachers, students, parents, and community members perceived that it did, and (c) what happened in the classrooms.

Hiring and teacher characteristics. There was alignment between what the school said it did and what happened in the school. The previous sections described the characteristics of the teachers hired to work at MNTH, the professional development they experienced, and the classroom practices. What was most noteworthy was the alignment demonstrated throughout these observations. The features identified by the principal as those of the teachers he sought were aligned with the characteristics the teachers possessed. The principal looked for STEM teachers with a strong academic content background as well as an understanding of project-based learning. Most teachers had bachelors degrees in the subject area they were teaching, were certified to teach those subjects, and the majority of the STEM teachers had come through the UTeach teacher prep program that highlighted project-based learning as a teaching strategy.

Professional development and classroom practices. These teachers were not, however, abandoned at the doorsteps of their classrooms under the assumption that they were fully prepared to enact brilliant teaching. Formal and informal professional development experiences helped to hone skills and provide opportunities for teachers to share their expertise. The principal described summer and ongoing professional development that ensured that all teachers were on the same page with the reform strategies targeted by MNTH, and weekly Critical Friends meetings helped teachers refine their project plans. Teachers were supported by peers and near peers through master and mentor teachers, and regular opportunities to engage with co-teachers and department members on issues of curriculum development and meeting student needs. In agreement with the structure described by the principal, the Teacher Surveys reflected teachers' perceptions of the benefits of the professional development and indicated their confidence in being able to teach using the reform practices learned. The professional development did not appear to be the "one size fits all" version, and seemed to target teachers' needs, ensuring that each teacher could take advantage of the professional learning to improve. Professional development, as described by the administration, appeared to match the professional development that teachers described experiencing in the school, and also appeared to meet the needs of the teachers in providing learning aligned with desired reforms and practices.

Classroom observations and comments from students and parents indicated that the targeted classroom practices were indeed the dominant teaching strategies in use. Thus there was also alignment among the characteristics that teachers possessed upon hiring, how they perceived their professional development experiences, and ultimately what appeared to be happening in the classrooms. In addition, there was apparent alignment between the reforms supported by teacher professional development and the practices observed in the classrooms with MNTH’s school mission, vision, and goals.

Case Study 2: GJJ-HTH Teachers and Teacher Professional Development

Introduction

The Gary and Jerri-Ann Jacobs High Tech High School (GJJ-HTH), a public charter high school in San Diego, CA, opened in 2000 as the first of the now eleven High Tech High Network schools—5 high schools, 4 middle schools, and two elementary schools—in the San Diego area. As a result of concerns about a lack of qualified workers for high tech jobs in the area, particularly of women and underrepresented minorities, GJJ-HTH was conceived through collaboration among local business leaders and educators, and developed into reality under the guidance of Larry Rosenstock. It was grounded in the principles of "personalization, adult world connection, common intellectual mission, and teacher as designer" (Behrend, Ford, Ross, Han, Peters-Burton, & Spillane, 2014, p. 10). The school website identified innovative features of the GJJ-HTH environment as "performance based assessment, daily shared planning time for staff, state-of-the-art technical facilities for project base learning, internships for all students, and close links to the high tech workplace" (High Tech High Chula Vista, 2012, p. 4).

With a student selection system based on an lottery weighted by zip code and active recruitment of students underrepresented in STEM, the student body of GJJ-HTH was diverse and generally representative of the student demographics in the greater San Diego area. Students who attended GJJ-HTH progressed through rigorous, non-tracked core classes, where the majority of their learning was accomplished through interdisciplinary projects. There were few elective classes and most courses, except for mathematics, were integrated across two disciplines and co-taught by two different disciplinary teachers. Student learning differences were addressed through academic tutors who assisted in the classrooms, and honors contracts provided opportunities for additional student learning within the heterogeneous classroom structure. Teachers designed their course curriculum in collaboration across disciplinary boundaries, creating projects that were allied with their own passions, while being attentive to the standardized tests students would need to take for college admissions (Behrend et al., 2014).

Teachers

Hiring

San Diego is a desirable location and therefore, GJJ-HTH routinely had a large number of applicants—more than 30 for each open teaching position during the year of the OSPrI site visit. Additionally according to the network coordinator and administrators, school directors had broad flexibility to hire teachers who were right for the school. According to one administrator, "Hiring is the most important thing that directors do," However, teacher hiring at GJJ-HTH was not a top-down process; teachers and students were deeply involved. An administrator explained that finding good teachers for GJJ-HTH could be challenging, "given the way we do things here," focusing on project-based learning and teacher curriculum design. To fill the need to find "the best teachers we can hire," a formalized process of teacher hiring was in place where prospective teachers were interviewed, led a discussion from a prompt, taught classes, and engaged with current teachers and students. And because all community members "really rely on each other," an important part of the interview process included observing prospective teachers for "how they collaborate and interact" when engaged in group work and problem solving. Having strong content knowledge often took precedence in teacher hiring over appropriate state teacher certification. An administrator explained that in a recent hiring, out of fifty HTH teachers, twenty-five didn't have teaching credentials upon hiring, instead perhaps having "been in industry for a number of years" or having a PhD in a subject area, or maybe having "a calling," or being someone "we would really like to work here." Teachers who didn't have teaching credentials when hired were enrolled in the Graduate School of Education (GSE), a program within the High Tech High Network that started as a credentialing program in 2004 and became a graduate school offering master's level coursework in 2007.

STEM Teacher Academic Background And Experience

Fourteen STEM teachers responded to the Teacher Survey administered prior to the OSPrI visit to GJJ-HTH for the 2013-2014 school year, including six who taught mathematics classes only, five who taught science classes only, and three who taught some combination of science, mathematics, and engineering. All of these STEM teachers held bachelor's degrees, and had academic degrees and active certifications in the disciplines they were teaching. Eight teachers held undergraduate degrees from eight different California schools, and an additional six teachers held undergraduate degrees from five different states and Canada. These included such schools as UC Berkeley, UT Austin, Northwestern University, Stanford, and the University of British Columbia. Nine of the STEM teachers held master's degrees; eight of which were in some aspect of education, three from the in-house High Tech High Graduate School of Education. One teacher held a master's in an engineering field, and two teachers held science PhDs. Over 70% of the teachers had performed research with seven teachers having participated in scientific research and an additional three having engaged in education research of some type. Several teachers had been employed as professionals in their fields before coming to teach at GJJ-HTH including such experiences as environmental consulting, cell biologist, maintenance and manufacturing engineering, and additional positions as Peace Corps volunteer, EMT lifeguard, academic tutor, and athletic coach. One teacher described working in "a few different biology related jobs—biotech, consulting and zoo-archaeology," and another described an important connection between a prior job and the needs of GJJ-HTH: "A good number of us come from industry; I wasn't trained as a teacher, but the way the industry works is project-based. My professional background was projects, and we do projects here."

Six of the STEM teachers came up through the ranks in GJJ-HTH, three initially as student teachers and three others as academic coaches or tutors. One student had graduated from GJJ-HTH, others were recruited or had been referred by friends, and four actively sought out positions at GJJ-HTH, one after being impressed with GJJ-HTH students who had come to visit their lab.

Of the fourteen STEM teachers responding to the survey, seven identified as male, and seven as female. Ten identified as White, one as Black or African American, one as Hispanic/Latina(o), one as Asian, and one provided no response. There was a fairly even spread of teacher age and teaching experience. The average age of the STEM teachers was close to 33 years, with four teachers under age 30, seven between 30 and 40, and three over 40 years. The average teaching experience was close to eight years, with an average length of service at GJJ-HTH of six years. Six teachers had taught for five or fewer years, four had taught between six and ten years, and three had taught for more than ten years.

Teacher Professional Development

Professional development existed in a variety of forms at GJJ-HTH including co-teaching, peer mentoring, and more formalized programs. The underlying structure organizing the majority of GJJ-HTH professional development appeared to involve the Graduate School of Education (GSE). This school had its seeds as a credentialing program in 2004, becoming the GSE 2007, to help teachers earn their teaching credentials or master's degrees. This graduate school, which was working its way toward having its master's programs accredited by the state, was started to fill gaps in new teachers' knowledge and skills. To meet the needs of the intended programming at GJJ-HTH, the school administrators felt that teachers' strong disciplinary content knowledge along with additional professional or academic research experiences were of primary importance. Many of the applicants who were deemed best qualified were weak in pedagogy and pedagogical content knowledge. One solution was to pair every new teacher with an experienced teacher mentor, but formalizing the structure and developing first the credentialing program and later the GSE provided a sustainable way to facilitate hiring the teachers right for GJJ-HTH.

Intense and Sustained

Describing the philosophy of all professional development at HTH, an administrator explained, "We knew that when we started HTH it needed to be a rich learning place for the adults who worked here if we were going to succeed; we knew we needed to figure out how to engage the adults." New teachers began this active engagement through their summer orientation—a 10-day Odyssey program, also known as "HTH Bootcamp," for two weeks in August. This time was used for two primary goals: 1) to help teachers learn how HTH engaged in project-based learning, and 2) to facilitate the development of a staff culture of adult learning.

Regular in-school, ongoing professional development. Rich learning opportunities that ensured that "all adults would be engaged in some way or another" continued after the school year began and were intentionally scheduled to be natural parts of the daily flow. The majority of the faculty at GJJ-HTH participated either in teacher mentoring relationships or weekly collegial coaching.. An administrator explained, "We structured the day by contract so the teachers arrived an hour before the students most days." To ensure that these learning experiences were productive and didn't overwhelm teachers' time and energy, administrators explained they "were careful to make sure the meetings were about teaching and learning, advisory, not nuts and bolts." The Director of Instructional Support for HTH provided examples of the ways professional development time was used:

> We … do workshops, PD; we work with directors; we participate in Thursday PD meetings that the directors run; we help plan; how to look at student work, coaching, observations; what do you look for in an observation.

Teachers also engaged regularly with their co-teachers during project development. As one teacher explained, "There is a great deal of adult learning here; every year every project there is something new to learn."

Meeting a particular need. With its inception in the struggles of newly hired teachers such as "PhDs from industry who could teach college, but were not certified to teach high school," strong in content knowledge but weaker in pedagogy, who flourished when paired with master mentor teachers, the GSE was initially designed to provide strong pedagogical training leading to high school California teacher certification, that would transfer to any California school.

Beginning in 2004, as an approved provider of teacher training, HTH only offered a credentialing program, but by 2007 it had evolved to include two graduate level programs: a Master's in Teacher Leadership, and a Master's in School Leadership. At the time of the OSPrI visit, the masters programs were still considered internship programs, where people came to work to receive training, rather than being a fully accredited graduate school. When asked whether the training was specific to HTH, or truly applicable to other schools, school administrators commented that the training involved activities that were "just good pedagogical practice" that could easily transfer to other school models such as KIPP and USD, whose teachers often participated. An administrator, one of the teachers in the GSE, commented on efforts within the GSE to emphasize "non-traditional" methods across all of the different disciplines, saying, "I have been going to all of these professional developments to learn how to do it; we are getting immersed in it."

Teacher survey data. According to responses to the Teacher Survey, teachers generally felt that they had time for professional development activities and that this time had a positive effect on their classroom instruction. The majority of the teachers identified having adequate time for both integrating technology into their projects and for technology instruction, to work with other teachers and to prepare lessons; and that the effect of this time at least somewhat facilitated effective classroom instruction. [Because of the response categories chosen for this survey, it is difficult to completely ascertain whether the teachers felt the amount of time available for professional development served their needs as well as it could have.] It is worth noting that the factors identified as having the most significant effects on classroom instruction were those in line with the co-teaching model and the integration of technology broadly supported within GJJ-HTH (see Table A-6).

Table A-6

The Effects of Time and Access on Classroom Instruction (N=14)

Rate both your access to and the effect of each of the following on your classroom instruction:	Access[a] 1-3	Effect on Instruction[b] 1-5
1. Time in school schedule for projects involving technology integration	2.8	4.7
2. Time available to teachers to work with other teachers	2.7	4.4
3. Time available for teachers to plan and prepare lessons	2.7	4.3
4. Time for teacher and student technology instruction	2.6	4.4
5. Time available for teacher professional development	2.4	4.0

[a]1=No Access, 2=Limited Access, 3=Adequate Access.
[b]1=Inhibits effective instruction, 2=Somewhat inhibits effective instruction, 3=Neutral or Mixed, 4=Somewhat facilitates effective instruction, 5=Encourages or enables effective instruction, 5=N/A or Don't Know.

Targeting School Reforms And Teacher/Student Needs

Professional development opportunities were generally in line with the reform intents of GJJ-HTH and with teacher and student needs. Teachers and administrators provided several examples. One administrator described an activity carried out during the summer teacher orientation that considered the needs of teachers in a school that sits "only about 17 miles from the border [where] several students cross this border every day," to be sensitive to the needs of these students. One of the orientation practices included a "project slice [where we] go down to Tijuana and explore the reality of the border." When asked about professional development planning for regular weekly meetings, another administrator explained, "We offer on [an] as-needed basis as things come up," indicating flexibility in planning. A teacher described particular pedagogical training that dovetailed with content level expertise saying,

> I started by training Project Lead the Way and it was great because I didn't have a formal background [in teaching]. I started in 2001 and I knew engineering well and I didn't have a lot of background in designing lesson plans. It was great for me and I could focus on how to teach it.

The teachers' responses on the Teacher Survey corroborated the voices from interviews and focus groups. Teachers indicated that, of the professional development they had experienced, the majority at least confirmed what they were already doing in the classroom, and many experiences caused them to change their classroom practices. Those experiences identified as having the greatest effects on teachers' classroom practices included the integration of technology and teaching using inquiry and project-based learning methods that aligned with GJJ-HTH mission and vision. Also, teachers identified those professional development experiences that contributed to their own skills and knowledge, deepening their content knowledge and helping to facilitate communications and collaborations with other educators via technology. In addition, with the heterogeneous grouping throughout GJJ-HTH classes, teachers identified the positive effects of professional development experiences that helped them understand student thinking and accommodate unique needs of students in their classroom (see Table A-7).

Table A-7

STEM Teachers' Perceptions of Impact of Professional Development Experiences (N=14)

Considering all your professional development, how would you rate the impact in each of the following areas? If your professional development experiences have not addressed the following areas, please check N/A.	Mean Score[a] (1-3)	N/A
1. Learning how to identify, locate, and evaluate technology resources that I can use with my students (e.g. websites, online data sets, etc.)	2.8	1
2. Learning ways to use technology to communicate and collaborate with other educators	2.8	1
3. Deepening my own S/T/E/M content knowledge	2.6	0
4. Learning how to integrate the different disciplines of S/T/E/M into	2.6	1

my course		
5. Learning how to teach S/T/E/M in a class that includes students with special needs	2.6	1
6. Learning how to implement problem-based or project-based learning	2.5	0
7. Learning how to use inquiry/investigation-oriented teaching strategies	2.5	0
8. Understanding student thinking in S/T/E/M	2.5	0
9. Learning how to teach engineering or design concepts or activities	2.5	3
10. Learning how to use technology to collect and analyze student assessment data	2.5	3
11. Learning how to use technology for student activities and experiments in the S/T/E/M classroom	2.4	1
12. Learning ways to use technology to communicate and collaborate with families about school programs and student learning	2.4	1
13. Learning how to use technology/technologies for differentiating instruction for students with special needs	2.4	2
14. Learning how to assess student learning in S/T/E/M	2.3	0
15. Learning how to do performance based assessments in S/T/E/M	2.3	0
16. Learning how to help students perform S/T/E/M research	2.3	3
17. Learning how to teach S/T/E/M across the high school curriculum	2.1	4

[a]1=Little or no impact, 2=Confirmed what I was already doing, 3=Caused me to change my teaching practice, 4=NA.

Collective Teacher Practice, Collaboration, and Teacher Professionalism

Teacher Collaboration

Collaboration, a part of the GJJ-HTH culture, began for the teachers with the hiring process and continued through the new teacher orientation mentioned previously, was formalized through peer-mentoring and co-teaching and regularly scheduled meeting times, and was ubiquitous in informal interchanges throughout the school day and year. The majority of the STEM teachers responding to the Teacher Survey indicated having engaged with other teachers both within and beyond the GJJ-HTH community during the current academic year. Teachers identified having participated in observational and collaborative experiences for professional development and for purposes of facilitating integration both within STEM fields and with non-STEM content (see Table A-8). Also, as was shown in Table A-6, while teachers generally felt that they would appreciate even more time for these interactions, they indicated that these opportunities to work with other teachers and to engage in professional development had generally positive effects on their classroom teaching. One thing worth noting was the clear support provided in-house for teachers, where, while the majority of the teachers had participated in collaborations and workshops, few indicated having recently attended national or state STEM professional development.

Table A-8

Number of STEM Teachers Participating by Type and Timing of Professional Development Experiences (N=14)

	Current Year	1 to 3 years ago	More than 3 years ago	Never
1. Observed other teachers teaching S/T/E/M courses as part of your own professional development (formal or informal)	12	1	1	-
2. Used telecommunications to collaborate on S/T/E/M teaching issues with a group of teachers at a distance	8	1	5	-
3. Collaborated with a group of S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	14	-	-	-
4. Collaborated with a group of non-S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	13	1	-	-
5. Attended a workshop on S/T/E/M teaching	7	4	1	2
6. Attended a national or state S/T/E/M teacher association meeting	2	1	1	8

Teachers and administrators provided many examples that supported collaboration as far more than a line in a mission statement; it breathed life into the school. Regular morning meetings facilitated teacher communication and collaboration on projects by co-teachers or cross-disciplinary integration by teachers of the same students but in different classes; within departments to ensure students were being prepared for subsequent grade levels; among teachers and academic coaches to ensure all students' needs were being addressed; and between mentor and mentee to deal with problem areas. One teacher explained, "We do work on our practice, not about dress code, [and] how can we do better in our work." In addition to the more regular collaboration time provided by weekday meetings, teachers seemed to feel quite comfortable accessing each other as resources as one teacher explained, "Every teacher is so approachable if you need something [or] if you need feedback."

Co-Teaching. One of the more formalized aspects of teacher collaboration occurred through co-teaching. Teachers selected partners with whom to co-teach for each academic year. Some pairings had been in existence since the school began and others seemed to change from year to year, providing opportunities for teachers to explore different ways to interpret their own subject areas within the context of a new discipline. One teacher explained, "We do multidisciplinary projects all the time." Teachers were paired through a process beginning with a meeting where teachers "pitch [their interests] at the end of the year for the next year," and administrators "make pairs based on interests." When GJJ-HTH first began, these pairings were more intentionally STEM and non-STEM—such that science paired with mathematics, and humanities paired with social studies, but after eleven years the model had evolved to allow teachers more latitude to pair creatively—"It has become less lock step and stagnant," an administrator explained, "There are usually teachers that want to work together on specific projects, and these working pairs of teachers create the teams for the following year." One teacher explained that the co-teaching process was "very teacher driven, very democratic," and another added, "The flexibility allows each teacher to adapt to their own strengths."

The accommodation of students with special needs also involved a collaborative effort between regular classroom teachers and the Special Education program at GJJ-HTH in a relationship that the coordinators described as co-teaching. The primary support mechanism in teaching a diverse group of students inside the classroom was through in-class *academic coaches, academic tutors,* or *resource specialists* (these terms appeared to be interchangeable). Grounded in the Special Education program, the academic coaches attended to identified students within the regular classroom setting while also helping other students who might need assistance, thus reducing any stereotyping that might come with an individualized education plan (IEP). One teacher described the flexibility of this support, saying "When I know a lesson will be tough, I can ask for a resource specialist for that lesson. And if I don't need them, then they can just hop into other classes as needed. It's very free-flowing."

Concentrated in the 9th grade science and mathematics classes to ensure students got off to a good start in their GJJ-HTH experience, each academic coach was assigned to one or two classes targeting "IEP students, but available to everyone." One teacher explained the thinking behind the heterogeneous grouping in classes and how academic coaches helped facilitate the process:

> The only way to treat everyone equally is to treat everyone individually to meet their individual needs, but then we also scaffold lessons for everyone not just those with IEPs. Academic coaches are invaluable for times, for example, when kids who are auditory learners miss lectures—we come up with strategies that are normally thought of as IEP-type work, but it's for everyone.

This support could continue outside of class both before and after school in the school's resource room, which was also available to all students, not just students with IEPs. OSPrI researchers' classroom observations supported administrators' and teachers' comments that there was time for one-on-one interaction and individualization of programming within regular classroom practices. One OSPrI researcher noted, "You can't tell who in here has an IEP… they all seem to be fine working on their projects."

Teacher Pathways

The teachers at GJJ-HTH were hired for their strong content knowledge and their real world professional and research experiences, but pedagogical knowledge and pedagogical content knowledge were valued to the extent that GJJ-HTH provided all hired teachers with pathways to earn teaching certifications in their disciplines onsite through the GSE. There were also pathways that began with college graduates who had yet to decide to become teachers who served as academic coaches, but who might later earn certifications and move into teaching roles, or for student teachers who might later be hired to work at GJJ-HTH. Teachers were given autonomy in the development of their classroom curricula, and further, were encouraged to creatively interpret their course content within the context of another discipline through co-teaching. Additionally, there were pathways for teachers to advance into different roles within the HTH network. Opportunities to advance in teacher leadership or school leadership were provided through on-site learning in the masters' programs in the GSE. Teachers could also serve as mentors to new teachers, could become inaugural teachers to help in new staff development as the HTH network expanded to open new schools, and become teachers in the GSE.

The GSE. The GSE provided pathways for HTH teachers to advance professionally. An administrator explained that the two master's level programs were primarily part-time options designed for working educators and therefore offered evening classes. The Master's in Teacher Leadership was designed to meet the needs of a teacher who might say, "I have been teaching for 8 years. I don't want to be the head of a school, but I want to be more than just a teacher." The Master's in School Leadership was designed for someone "interested in how the whole organization works." There was also a full-time one-year internship program for prospective school directors with coursework and job shadowing where "a student is immersed in a school, and later…will take over [a] school." An administrator commented that the majority of the teachers enrolled in the School Leadership masters program were HTH teachers, and three or four of the current HTH directors had gone through the School Leadership program. During the time of the OSPrI visit, there were 20 students enrolled in the two year Teacher Leadership program and 15 overall in the School Leadership program. The Teacher Leadership program followed a cohort model with regular weekly evening classes involving a sequence of courses that included an introduction to action research, equity and diversity, differentiation, and deeper learning through projects. Participants then conducted action research while continuing regular meetings for peer review during the summers. The School Leadership program sought to develop competent managers for leading PBL schools through dealing with management, budgeting, and legal issues, but intentionally didn't "let go of the instructional part." One teacher explained that the GSE was HTH centered focusing primarily on school reform, where the School Leadership capstone project examined data from an existing school exploring the reforms that could be implemented to make it better.

Demonstrating the importance of the GSE with respect to HTH school leadership, an administrator commented,

> We don't hire people from the outside. We have this intense way of bringing everyone up through. The way we are doing it, we don't have policy manuals. We have tradition and it is all from conversation. I like how we are doing it. If people come from the outside, they would think it is a preposterous idea. But it works when you bring people up from the inside.

He supported this approach suggesting that it was important that school leaders understand the role of the teacher in the school, that this knowledge was a significant facet of a school director's background, adding,

> What if I worked somewhere else? There is such a piece that I have a reputation of being a good teacher. At some level—the rumor is, I was a good teacher here. If I go somewhere else, I would not have any credibility as a teacher.

Teacher autonomy and choice. Teachers and administrators commented on how providing teachers with the latitude to design their courses around their interests and passions kept them excited and engaged. Teachers worked both individually and collaboratively to design curriculum, were encouraged to apply for grants to direct their own professional development, and were encouraged to access professionals in the community to both expand their own knowledge and to collaborate in project development.

An administrator cited an advantage of teachers' autonomy in curriculum design saying, "Our teachers are thinking deeply about their practice because they aren't told what to do," and added:

> We want to talk about the art of teaching kids writing, the art of teaching science theory. Right now it is really hodge-podge under this big idea of quality work. Do you want to organize the hodge-podge? I like the hodge-podge. We have a 1000 flowers bloom approach.

From the very beginning of teachers' orientation to GJJ-HTH, teachers were encouraged to be creative. One teacher who had participated in the summer "bootcamp" training said "The training is more like lack of training, [because] teachers come in to teach their passion—a lot of them from industry." Teacher autonomy also played out in GJJ-HTH's avoidance of AP programming, where an administrator suggested that AP program could be "an inch deep and a mile wide," but that the teachers at HTH who were teaching to their passions chose to investigate "a mile deep and an inch wide," going "for depth, not breadth."

One teacher commented on the latitude to try something and fail, in order to try again to make the work better.

> By nature of what we do here, we try and some things work great and some don't. We don't keep going down the same broken path and we aren't afraid to make mistakes. We may not learn X, Y and Z—it is more about going into depth.

And another teacher added,

> Sometimes you repeat what you've done; sometimes you try something new. We are very encouraged to try risks, collaborate with new experts, We don't do the same thing every year. It makes it challenging to reinvent the curriculum every year, but it keeps our interest. We don't get stale or bored, we work really hard.

And a third teacher concurred saying,

> There's no pressure to say, "Hey, this pacing guide; we're all on December 12 on this." It's very different. And it's not that there is one right way. There's one right way for me to do it based on my strengths and where I'm coming at from this, which is great because then students get different experiences throughout the years and in different classes.

An administrator stressed the importance of teacher autonomy in allowing teachers to direct the trajectory of their professional development and their teaching, saying, "We don't want to impose things top down and apply for a grant that tells the teachers 'you need to do this.'" Teachers appeared to be encouraged to apply for grants to support targeted professional development. As an example, one administrator described a teacher having received a $20,000 grant from the state of California along with three other teachers to support "professional development relating to inquiry and helping out the community."

School Collaborative Culture

The culture at GJJ-HTH was described by many members of the community as fostering collaboration, not only between teachers, but among students, teachers, administrators, parents, and the broader community, describing GJJ-HTH as a "community" and a "family." An alumnus said, "Everybody knew everybody. It was like one family; you could talk to anyone." And a student who had come from one of the HTH middle schools said of others who did not, "They didn't expect this type of community feeling." This culture was focused around student learning within a context of trust and support. A student commented, "Everyone's here to help you, [they're] not just coming here because it's their job, but because this is what they want to do, help kids. The atmosphere, the different personalities, there's a culture where everyone can learn." And OSPrI researchers who observed classrooms noted a "very open climate where students could express ideas and questions freely."

Student difference. There was an inclusiveness in GJJ-HTH that led to an appreciation of student difference which administrators attributed in part to the intentional diversity of the student body. This diversity was supported by the lottery process weighted by student zip code, heterogeneous classroom groupings, and small school size. An administrator explained,

> We are very proud of our student body and how it embodies San Diego. We value our "true" diversity and how classes are not homogenous. All of our kids are exposed to each other and we do not segregate.

Describing student interactions, a teacher added, "This is an example of social class integration. You have a middle class [student] and an impoverished student working together on projects in a safe and supportive environment." Parents also reinforced these observations indicating that this integration continued outside of school, saying "The kids come from everywhere, not just rich neighborhoods—we take them to many different neighborhoods, and they all mix." And this "mixing" did more than provide different friendships. Parents suggested that being in classes with different academic levels "with kids not as participatory or bright as them" provided opportunities to "navigate kids who are different," and to "see the world differently, from 'multiple perspectives' and diverse ways of looking at the same questions," ultimately, "learning a lot of acceptance of cultures and way[s] of living."

Choosing to not group students by ability led to changes in the classroom supports. In addition to the academic coaches described earlier in this case study, one teacher explained that students could do a "self-identified pull-out" by going to the resource room to work on computers in a quiet environment. Because this option—a "complete open door for everyone"—wasn't limited to students with special needs or who had been identified with IEPs, along with the use of academic coaches, it helped to break down the "stigma or stereotype" of accessing assistance. There was also an intentionality to ensure that students felt safe. A teacher explained, "We take bullying seriously and I think you will hear from the students that they feel safe here." And students echoed, "there's no bullying at this school." One alumnus described the GJJ-HTH environment saying,

> It was my favorite part of growing up. I loved the students; no cliques; [I] never felt at risk of being picked on or bullied, and I loved meeting so many different people around San Diego, which I wouldn't be able to do if I had gone to private school with everyone in the same socioeconomic group around me, or local school which picks people only from one area. There is not one thing I would change about HTH.

Small school. Many members of the GHH-HTH community attributed aspects of the safe and supportive school environment to the small school and relatively small class size. One of the
alumni said,

> What really helped HTH, we were a very small community here, so by your sophomore year you basically knew all teachers and staff. You probably had your favorite, but you didn't need one person to hold you up because everybody knew everybody, it was like one family.

Several teachers explained how smaller class sizes affected their ability to meet students' needs and foster relationships. One teacher commented,

> Class sizes are relatively small (roughly 25), [and] that allows you to get to know [the students], modify what you are doing to make it work for them. You can tailor groups so the kids can find something they can excel at—there are a number of ways.

Another teacher added, "With smaller class sizes, it is easy to see if they are engaged and asking questions or are they checked out. I know my students well and if they are learning and how they are engaged." And a third teacher summed up the many advantages of GJJ-HTH's small school and small class sizes:

> It's not like a big public school were students are known by their ID numbers, with one counselor to 500 kids. Our biggest class is 30, we keep the same kids all year, so we are constantly talking with [their other] teachers to find out what is going on at home; we have a resource staff with IEP/504s, instead of pull out classes; we have academic coaches that come into our classes, like the tutor that helps with a severely autistic student. Because we have smaller class sizes, we know where to go for help, we keep it intimate in that we get to know our kids very well and that's how we know what's going on in their lives. We talk to them so they tell us what's going on in their lives, it's an environment where it's safe and so they know they can come to us.

Supporting Learning by Students Underrepresented in STEM

As written in the MNTH case study: The review of the literature revealed several classroom practices found to differentially affect students underrepresented in STEM. These included practices that served to develop students' STEM identities such as helping students become interested in STEM fields and became aware of STEM careers, ensuring that students developed STEM competence, providing students with opportunities to present their competence to others, and also to be recognized for this competence (Kanter & Konstantopoulos, 2010; Carlone & Johnson, 2007; Hazari et al., 2010). Opportunities for students to engage with each other in peer-to-peer learning and to take responsibility for their own learning, as might be the case in inquiry-based, project-based learning, were also found to contribute to students' perceptions of competence (Roth & Weinstock, 2013; Sadler & Tai, 2007). And the classroom social and emotional environment as it contributed to better teacher-student relationships, students' sense of well-being, and positive teacher or student perceptions of knowledge and learning could contribute to improved student learning (Aronson et al., 2002; Reddy et al., 2007).

According to STEM teachers' responses on the Teacher Survey, most teachers identified that as a result of their professional development experiences and other preparation, they felt confident in teaching using the reform strategies that were in keeping with GJJ-HTH's project-based, inquiry-based learning approach. In addition, aligned with the philosophy of heterogeneous grouping in the classroom, GJJ-HTH teachers felt confident in recognizing and responding to student diversity and using strategies that encouraged inclusive participation in STEM (see Table A-9). In the focus groups, interviews, and on the Teacher Survey, teachers did not specifically differentiate any particular professional development experience as most significant in affecting their teaching, but rather mentioned a diversity: "being encouraged to work collaboratively," receiving "support from other teachers, the director and people from the credentialing program," "monthly disciplinary meetings," bi-weekly faculty meetings "dedicated to improving teaching practice and STEM work," and having "time in staff meetings to create and implement new project ideas," as well as opportunities to partner with scientists, non-profit organizations, and other community partners. This diversity of teacher descriptions of useful teacher professional development may speak well to the ongoing, pervasive nature of the collaborative, autonomous teacher experience at GJJ-HTH.

Table A-9

Teacher Confidence in Utilizing Teaching Strategies (N=14)

I am confident in my ability to:	Mean Score[a] (1-5)
1. Manage a class of students engaged in hands-on/project-based work	4.7
2. Recognize and respond to student diversity	4.6
3. Encourage students' interest in S/T/E/M	4.6
4. Lead a class of students using investigative strategies	4.5
5. Use strategies that specifically encourage participation of females and minorities in S/T/E/M	4.5
6. Help students take responsibility for their own learning	4.3
7. Involve parents in the S/T/E/M education of their students	3.5

[a]1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree.

Classroom Time

The focus of the majority of classroom time in GJJ-HTH was on learning through projects, with most classes integrating at least two disciplines. Mathematics, often taught more traditionally and as a single discipline, still had students engaging in some projects, although of shorter duration than typical in other classes. As students moved from 9th through 12th grades, projects were increasingly centered on students' personal interests. Projects at GTT-HTH were heavily focused on the *product*, often presented to a public audience or captured in a digital portfolio for assessment. When asked to describe learning at GJJ-HTH one student explained, "The school is about hands on learning…[it's about] producing things rather than reading a text book. Group work."

Lesson Flow Classroom Observation Protocol (LFCOP) data were collected for seven observed classes during the OSPrI site visit (see Table A-10). Of these classes, none had the teacher at the center of attention for more than half of the class time, and in fact only one class was teacher centered for more than 10% of class. The greatest percentage of class time was spent in student-focused small group activity with a mean of 72% across all seven classes, which included four mathematics classes.

Table A-10

Organizational Grouping and Percent of Class Time[a]

Class Type[b]	**% Student-directed Small Group Focused**	**% Individual Student Focused**	**% Teacher Focused**	**% ONLY Teacher Focused**[c]
I-Multimedia	100	100	0	0
I-Physics/Humanities	100	0	0	0
I-Biotechnology	100	0	0	0
I-Engineering	97	0	3	3
M-11th grade Math	94	0	6	6
M-12th grade Math	12	46	42	42
M-9th grade Math	3	100	0	0
MEAN	**72**	**35**	**7**	**7**

[a] More than one activity could occur at the same time, so percentages may add to more than 100.
[b] M=mathematics, S=Science, I=Integrated/Engineering.
[c] Small group, individual, and teacher led activities could be occurring simultaneously. This last column identifies time when all students were focused on the teacher as in a lecture class.

Developing STEM Identity

Interest. Student learning at GJJ-HTH was both intentionally cross-disciplinary and connected to the real world, and as one administrator explained, gave students opportunities to "do science." Every subject area except mathematics was taught in a co-teaching arrangement between two teachers from different disciplines who worked to integrate their subjects into projects that would require critical and creative applications of new knowledge. Mathematics was addressed in the projects, but not exclusively taught through projects. Each teacher sought to make learning relevant to the students, identifying connections and ensuring that students understood how to apply their learning beyond the classroom. Teachers' comments about learning and the importance of student interest and motivation included such phrases as "at the end of the day I am trying to inspire kids," and "I work with their interests and see where they are going," and "By and large, when the students are doing something they are interested in they get invested." One student suggested "Students here enjoy learning a little more," and another said, "We don't read out of the textbook…we learn it in different ways." One parent explained that the students were being exposed to STEM topics in ways that engaged and stimulated them, and the project-based learning allowed them to be active, rather than passive learners.

One teacher stated, "Our ultimate goal is getting students ready for the real world," and an administrator added, "The most successful school is one that doesn't have walls." GJJ-HTH made intentional efforts to limit "administrative administrivia" to facilitate students' field trips, inviting in outside professionals, partnering with laboratories and businesses, and accessing productive internships. It was apparent from students' comments that not only did the projects connect to the real world, but they addressed current or important local issues. One alumnus explained, "At HTH, you got a sense that work had purpose, you could do things that would influence people." One teacher described an engineering design project where students "went into the community and met and figured out what they wanted to do to help the non-profit," and a student described a project where they were "trying to prevent biofilm from developing on bottoms of boats; [which is] invasive to San Diego and will spread to other areas."

Students at GJJ-HTH recognized the connections between their learning and projects and future career applications. Students in a focus group cited interests in future fields of study that included computer technology, law, math, medicine, neuroscience, and "something…definitely science." A parent explained that her 10th grade son had an educational goal of studying military technology and engineering that was motivated by his work at GJJ-HTH.

Ensuring competence. ***Standards and scaffolding.*** Even though GJJ-HTH "let 1000 flowers bloom" giving teachers space to create the school curriculum, there was a concerted effort toward ensuring that students were well prepared for both future academic study and the world of work. One teacher commented that the goal wasn't to create an entire school of engineers, but to ensure students "will be able to learn, understand, and solve problems." There was attention given to standardized tests, but greater focus on the SAT and college admissions than on California state tests. A teacher commented, "we do use the standards, we look at them and look at them as a reference, but we're not married to them," adding "we have to be aware of what they [the students] are facing in the next year so they are prepared." And teachers, mindful of the heterogeneous nature of their classes and the different student needs, identified goals in line with ensuring that all students would learn. One student explained:

> Anyone can do it, some students may think they are not smart enough, but our teachers give everyone the opportunity to do well and to do what they want to do. It's their choice if they want to take on honors and take that challenge. But everyone knows that they can if they want to.

Learning how to engage in project-based learning was scaffolded for students, as one teacher explained "It is on the teacher to provide intermediate deliverables because this age group cannot see that far down the road yet," adding "It does get better in time." Another teacher concurred saying, "You also have to benchmark it, because if you give them four weeks to do a project, they'll wait until the third week before even thinking about it."

College prep. There were some challenges among standards, project-based learning, and college preparation identified by students and teachers. One teacher explained that one of the conscious goals of the school was to make sure that students were applying what they were learning, but there was also a struggle with the "balance between college and the real world" suggesting "they are different skill sets, and so we're always walking that balance." A teacher explained the importance of ensuring that students were learning the desired concepts, not just engaged in empty hands-on experiences saying,

> You can do PBL poorly…[which] would take away from the rigor…We do a good job here of making sure the core concepts we want them to learn are at the forefront of the project, and the superficial parts of the project we don't waste a lot of time cutting and gluing and doing things that takeaway from learning."

Even with this mindfulness, several alumni identified some challenges upon entering college, but these challenges appeared to be more situational than academic. Some described concerns about knowing how to use textbooks and being required learn content that appeared to be unrelated to any real world application. There were also struggles with entering a less egalitarian learning environment as described by one alumnus:

> There was definitely a learning curve because it was extremely more competitive in college than I was anticipating. People were obsessively competitive in college, unlike here where people are not competitive at GJJ-HTH at all.

In general, however, the GJJ-HTH community overall appeared to feel that their education was preparing students well for the future. Parents in a focus group identified that it was important for students to "get the core basics" that would facilitate application in the future, and suggested that the projects managed the delicate balance of both being stimulating and encouraging students' interest, but also being challenging and rigorous enough to ensure students were "competitive in college." A teacher commented, "I think that goal was that when they get to college, they could take any class and be comfortable, … and it is happening now." Another teacher explained:

> [GJJ-HTH's] strength is that we get the students to think deeper about the concepts, and apply them and connect them to other disciplines. We don't just say "Here are the steps" but rather "What does this mean?" and [we] get them to express in many ways their understanding of what the math concepts mean and how you connect them to other concepts in the real world.

A teacher who taught college level classes in addition to GJJ-HTH commented on the experience from the college teachers' perspective saying, "What I see from the students here [at GJJ-HTH] and there [in college] is the sort of critical thinking our kids get that most of the population from normal public schools that I see in college classes don't have." Students were held to high standards, but given the scaffolding, support, and guidance to ensure they could reach them.

Presentation and recognition. An important aspect of GJJ-HTH's programming involved a conscious focus on meaningful production, along with the thoughtful process of project-based learning. The product mattered and the project results were routinely featured in public forums. An administrator explained, "We want kids to do meaningful work" noting there was inherent value in doing "beautiful work," and in taking pride in the product as well as the process. However, it was also clear that process-learning was well scaffolded and important. The project-based learning process provided students multiple opportunities to engage with each other in meaningful discussion of their learning. During the OSPrI site visit, students in several classes were observed peer editing and critiquing each others' work. Students used group time to both teach and learn from each other, according to one student, "One of the main focuses of this school is learning from each other. We are all on the same level and help each other out." One teacher encouraged peer review to allow students to see more projects and to gain skills in writing critique. Another teacher explained the importance of giving students time to communicate with each other in mathematics problem solving so "instead of always having them direct questions to me, they ask each other questions, so that they can explain it in their own words, because the best way to learn something is to teach it." An administrator reinforced this saying, "When you teach, you learn" when he talked about students producing books on their projects. During classroom time, teachers moved among the groups questioning them as they prepared their materials, encouraging collaboration within and across groups, and checking in with individuals. A teacher added, "They learn from each other as they work together on projects."

Presentations of learning were a central and public aspect of the GJJ-HTH learning environment. As one administrator explained, "Working in groups, and presenting publicly" particularly to outside groups provides students with opportunities to put their knowledge and learning out into the world. Student work that reflected content knowledge from multiple disciplines— "art and engineering are working together to solve something," paper designs using geometry principles, poems with ecological themes, and posters encouraging civilian action on concerns of global significance lined the walls and ceilings of the school. However, it was important that the work was not just beautiful, but also demonstrated learning, an administrator explained: "Kids should be producing high quality work" that is not just "flashy and technically accurate," but includes "evidence based assertions" to support their perspectives. Teachers provided a couple of examples: For one project, in a collaboration between the museum and a biology class, students designed museum quality exhibitions for a *Mystery of Life Expo.* During the process, the museum coordinator met with students to provide feedback on "everything from type font, grammar, and audience… durability, understandability, [and] the signage." The expectations for the work were high because students' posters were going to be "showcased and it's going to be out there in a real world setting" of the museum. Science fair provided another opportunity for students to engage with the public in a significant way. A teacher explained that during the fair students presented their work in an environment where they got "hit hard with good questions from scientists" and had to be able to "stand there and explain it" answering technical and complex questions about their work. While these two examples might appear to be isolated or unique experiences, it was apparent from talking with teachers and other administrators, that community engagement with student products was both regular and routine. During the OSPrI visit, students were preparing products in several classes for presentation during an upcoming family night, and students spoke of a recent local gallery presentation.

Outside experts and community members appeared to be a regular feature of students' presentations of learning. Taking place at the school, in a local gallery, or at the museum, students demonstrated their project products, provided commentary and explanation, and engaged with school and community to explain their understanding and accomplishments. This interchange provided opportunities for students to teach and to learn, not only from peers but also from those outside of the school community, and to hone their content knowledge and their communication skills. Students were supported as they became competent in their work and demonstrated this competence to school and community, who could recognize them for their learning. There were also efforts to support social and emotional learning to guide students as they moved into life beyond the classroom, and to support their increasing independence as learners.

Socioemotional Supports

The administrators spoke of the importance of students' social and emotional learning along with their academics, describing student advisory groups as one source of "socioemotional support." This advisor-student relationship began as advisors—teachers assigned to groups of about 15 multi-grade students—went into incoming 9th students' homes to meet the students and their parents. This relationship continued to develop through an advisory that focused on "community, culture, and college preparation." Advisory groups met every Friday with the same advisor throughout their four years at GJJ-HTH. An alumna explained, "Advisory was big here…something that not everyone [outside of the school] knows about; it's kind of behind the curtain, in the background." Education at GJJ-HTH was much more than just ensuring that students acquired the necessary content knowledge to go to college. "It's part of what our school is all about," a teacher said, explaining that students must be helped to negotiate the "social nature of the school" and "manage themselves." Another teacher added, "I use a lot of ed. psych. tricks … it's the idea of meta-cognition, self-control."

Teacher-student relations. The advisory and teachers' focus on student growth appeared to be in part responsible for strong teacher-student relationships at GJJ-HTH. One teacher described one advantage of the project-based learning environment being the "unstructured time" that provided opportunities to talk with students, taking "time to chat with them, getting to know them while they're doing math," adding "It might not look productive, but that's important too … It's a community and family." Another teacher explained that the project-based learning environment coupled with smaller class sizes meant "eventually, it is a one-on-one with everyone … No one gets to hide in a corner." Students reflected the teachers' comments saying,

> Yeah everyone [at GJJ-HTH] is interested in me personally—how I am doing in class and what my grades are. The one thing that I noticed is that the teachers truly care…[and] since the classes are smaller … you can actually talk to your teachers; you can tell your teachers your problems.

Another student added, "At first I thought it was weird that everyone was asking me how I was feeling, but I now after going here for a long time, I feel like it's normal." One student described the learning environment at GJJ-HTH saying,

> At HTH, things are more conversations instead of lectures—I mean that in the literal sense, we are talking to teachers and are not just told things by them. And also in the metaphorical sense, everything we do is through conversations with both the teachers and outside world.

Several alumni in a focus group reflected on the strength of the teacher-student relations at GJJ-HTH. One explained "You could talk to any adult; [we had] incredible interpersonal relationships with lots of teachers. Not like college where you could go talk to them, but some didn't care. Everyone here at HTH; they cared; they were extremely supportive." Another added, "You could talk to them about topics that didn't have to do with school, and it was nice to feel you were on same plateau with them, talking about current events, life, arts, movie—you felt like equals. No separation. It was so nice to know we could talk to them and use their first names." And speaking to the fluidity of teacher student interactions, another alumnus added, "There's always one teacher a student gets attached to. That teacher is always there for you, whether it's personal or for school. There was never really a designated support."

Developing Student Autonomy

Students were supported in the development of their independence as learners. As previously mentioned, the project-based learning process was well scaffolded throughout the students' four years of school to provide them adequate structure to learn how to learn through projects and to ultimately use the projects to explore their passions. One student explained:

> [The teacher] gives us a baseline for an idea…and then we can take it wherever we want. It has to be approved by [the teacher] to make sure it's a good project to do, but we get to use our creative minds and pick something that interests us—so we are passionate about what we're doing.

One teacher described the scaffolding process saying,

> [I] use a lot of questions, rarely give kids answers [and] when they ask questions, I answer with a question so that they have to figure it out. My response to their question would be "Well what do you know? How can we get there? What tools do we have?" The critical thinking—that's my main goal. Never just responding with a direct answer…90% of the time, responding with a question as opposed to just telling them how it is.

One teacher explained scaffolding for younger students to direct student choice saying,

> I try to give them the illusion of choice, even though they don't—they're going to do math, but you're letting them choose what to work on. So it's giving them the idea of choice, even though really we're giving them direction.

And another teacher added, "We build a culture of freedom. I like to have less rules, but when something becomes a disturbance, we talk about why that is."

Students were aware of teachers' support during this developmental process; one student explained, "I feel like our teachers aren't really teachers just standing in front of the class … she's really helping us through the process, she is like a mentor, almost like a partner in the project, not someone to grade you." One student compared the experience at GJJ-HTH with a previous school saying,

> I used to go to the regular public school, and it's very different from being in the textbook, where they tell you what to do, what the procedure is; this is your conclusion—here what you conclude is what you conclude [and the] errors are your own because you made your own procedures, your own methods, your own hypothesis."

Another student described how structures helped students scaffold their own learning:

> For science fair especially, there was a calendar in the beginning of the semester, like you should have your introduction done, you should have your first experiment, and it was pretty much to get us to know what was going to happen, but we are so off the calendar; we are still doing a lot of work, but that's not how science works, so our grade is not being affected by that. It's not about the grade.

Through this intentional and thoughtful structuring, students learned to be independent learners. Several students described how they approached their projects. One student explained that during her 9th grade year "we were taught how to find good resources right off the bat, so we always had reliable information." And another student elaborated that teachers weren't always experts in the specific project content area and as a result, "there is a lot of self-teaching and using the resources that we have, like the Internet, or ask another student." A student explained, "We learn the process through projects." Another explained, that in the freshman year students' "projects themselves were much less well directed," but they "got better, especially in sophomore year; [our own sense of] direction increased." One student explained that not only did their competence improve but they also were given increased opportunities to direct their learning, saying "students tend to have more responsibility and freedom and autonomy in sophomore and especially in junior year" allowing the pursuit of "topics that we may enjoy more." And provided the example, "in freshman year we had to research torque, which some found interesting, some may not have. But this year, our biology teacher didn't choose any aspect of biology, it was a lot of freedom."

Beyond school walls. One student explained how the project-based learning experiences helped when moving into an internship role at a local university:

> I actually appreciated that our projects that didn't always work out. I did an internship at UCSD, it was this major project, and I was there towards the end, and the people I was working for realized that their project wouldn't work out. And HTH helped me realize that things fail, and it makes sense, and there's not always success with projects and it doesn't always go the way you expect. And so these internships where the same thing happened, it was a natural process for me, not an anomaly.

Another student explained how the project-based learning at HTH helped him not only in his capacity to learn but also how to help others structure their learning in the workplace:

> There was one thing I liked a lot in HTH, the projects … taught me to improvise a skill set I didn't have and had to develop on the fly… I realized that wasn't a skill everyone had when I was editor in chief of a newspaper. We got some new kid who had to do a layout and he freaked out when he couldn't use a program and [didn't know] how to figure it out. I had to walk them through the steps of working it out.

After GJJ-HTH. Several alumni confirmed that their experiences at GJJ-HTH contributed to their subsequent approaches to learning. One alumnus commented that GJJ-HTH prepared students for the real world by helping them learn how to "self-teach" when "information was not given to you on a plate," adding, we "were instructed to seek out help and to be self-sufficient in that manner…HTH gives you the most well-rounded education ever, its world class." Another added, "I think HTH really prepares you for the real world … they treat you like adults and projects don't work sometimes, and you have to think on your feet and make things work." And finally, one alumnus summed the experience saying,

> HTH helped with freedom, making my own schedule, going to class, paying attention, and using the professor resources such as office hours is super important—a lot of my smart friends in college never did go to office hours, and they missed out on connecting with the coolest minds out there.

Summary—Learning by Students Underrepresented in STEM

There were many practices at GJJ-HTH that supported learning by students underrepresented in STEM. Classrooms and classroom activities were structured to provide students opportunities to be exposed to and to develop an interest in STEM fields and careers. Projects were intentionally connected to the real world of STEM, to current issues, and to particular careers. Content learning was routinely grounded in its broader applications and students were used to seeking out these connections to understand the context of their academic endeavors. Projects were rigorously connected to the real world, but student competence was not forsaken for a flashy project product. Student learning through both process and product were critically important.

The process of learning through projects provided students opportunities to engage with each other, to both learn from and teach peers. With the passing of each academic year, projects required increasing autonomy, with students taking increased responsibility for project design, management, and topic of study, and directing the content to their own passions.

The project-based learning structure of small independently working groups gave teachers opportunities to connect more frequently with individual students and to establish stronger teacher-student relationships. There was a strong sense of trust and respect between teacher and student, as one student explained, “Teachers treat students as adults … [there’s] a lot of respect for each other.” Another student added, “Community here is different than other schools, because the teachers are more helpful and more willing to give one on one instruction. They’re very friendly. You get one-on-one connection with them.” These feelings of mutuality appeared to facilitate student empowerment. Students appeared to know they could shape their learning in a safe and supportive environment. The public presentations encouraged hard work and provided a forum for both displaying and honing knowledge and communication skills. The support and scaffolding provided a pathway for student professionalization, as one student described, “That's all part of HTH’s culture—little by little, they loosen the reins, and we’re more independent. From freshman year to senior year… it’s creating this autonomy and responsibility with the students where they feel a little bit more independent.” Students took pride in their work. One alumnus explained:

> HTH taught me to have a certain pride in my work no matter what the work was, so when I was at college and had essays assigned, I treated them like little works of art that I wanted to have a finished product that I was proud of. That really informed how I approach work at college.

And even a business partner noted students’ sense of responsibility saying, “I find it an oddly open environment and [the students] should be playing hooky, but they don't.” Students and teachers appeared to want to be at school, and appeared to truly relish their academic and non-academic engagement.

Analysis and Discussion

In the descriptions of GJJ-HTH teachers, their professional development experiences, and their classroom practices as they relate to learning by students underrepresented in STEM, there is evidence of alignment with research-supported recommendations. Teachers had strong academic content backgrounds and were collectively a cosmopolitan group. Professional development was aligned with school reforms and teacher and student needs, and had many characteristics of effective professional development identified by Desimone (2009), most notably collective, active, ongoing experiences, and those that filled gaps in teachers’ pedagogical training. Classroom practices supported the development of students’ STEM identity and their development as autonomous, independent learners. One feature of GJJ-HTH that appeared to support much of the strength of the school was the open communication that facilitated the diffusion of knowledge among all community participants. The goal of continuous learning for all set the stage for an environment that encouraged each member to create and contribute to collective and collaborative experiences that provided space for the empowerment of both faculty and students.

Knowledge Flow

The open school and classroom environment that one entered upon arrival at GJJ-HTH was a physical reflection of the school's human interactions. Every aspect of the school was open for public viewing. Classes met in glass-walled classrooms, and small project groups set up in the large central open spaces filled with tables, chairs, informal seating areas, and computers. The products of learning were on display on all of the school walls, and were presented to broader public audiences. A school administrator explained that the school curriculum was "very public, so it's lived, unlike a traditional school where it's a book and you don't see their projects." Just as these open spaces exposed the inner workings of the school, the open mental space allowed ideas and energy to freely flow. Communication was encouraged and supported. Teachers were given both designated time for meeting and idea exchange, and through the natural flow of every school day, had multiple, routine, and easy opportunities to engage informally with administrators, teachers, and students. These open pathways allowed for knowledge to easily diffuse, and supported the generation of a cohesive spirit that extended throughout the school community.

There was a thirst for learning defining the rich, active, engaged environment of GJJ-HTH that respected the knowledge that each participant possessed, but provided opportunities for involvement that raised each individual to higher and higher levels. Energy flowed among administrators, teachers, academic tutors, and students encouraging all to strive for creative, beautiful, and meaningful connections between course content and the real world through projects.

"Professionalization"

Teachers. Teachers were hired for their strong content knowledge and academic and professional experiences that would serve to inform their inter-disciplinary project and curriculum design. Some teachers came with solid pedagogical training, but a strong teacher-mentoring program and co-teaching partnerships, along with teaching certification facilitated by the on-site GSE supported teacher development supported those who arrived at GJJ-HTH without high school teaching credentials. These and other collaborative experiences provided teachers with opportunities to observe, question, receive feedback, and generally support each other and be supported throughout the school day, week, and year in developing rich opportunities for student learning.

Teachers were hired as professionals, but the expectation that everyone would continue to develop skills and knowledge was status quo. Teachers were expected to design their curricula with guidance from standards for college entry, and with a mindfulness toward preparing students to be competent in future academic endeavors, in the workplace, and in life. Teachers, however, did not create their curricula in a vacuum. Innovative, yet academically rigorous project-based learning experiences were integrated across disciplinary boundaries through the active engagement of pairs of teachers who chose to work together in the design. In addition, the open school environment provided a platform for continuous evaluation where teachers reflected on their classroom experiences, where peer, co-, and mentor teachers could weigh in, where administrators paid regular visits, and where products of learning were shared with the entire community. Teaching and learning were collaborative, public undertakings.

According to Bryk et al., these teachers would be considered a *cosmopolitan* group; they brought a broad array of prior experiences to the school having come from multiple college backgrounds, from different states, and with broad professional and research experiences. By the time of our visit, all of the teachers responding to the survey had obtained teacher certifications, some from the GSE, but five of the fourteen had received master's level pedagogical training from five different graduate schools. Teachers were well prepared with respect to their disciplinary content having earned bachelor's degrees in their subject areas. This diversity of experience, combined with the open communication pathways at GJJ-HTH would well serve the open knowledge pool from which all school members could draw.

Teachers at GJJ-HTH had many opportunities to develop and grow their craft. They could pair with different co-teachers to connect their disciplinary content in creative ways and try out new integrations in project designs. Teachers could also follow pathways into teacher leadership, where they might assume mentoring roles, become inaugural teachers in newly opening network schools, teach in the GSE, or move into school leadership.

The small administrative staff, many promoted from within the ranks of GJJ-HTH and well-versed in the "HTH way of doing things" acquired through "conversation," helped maintain continuity of the school's philosophies. This relatively non-hierarchical administration provided the leadership presence that after initial hiring and school start-up, appeared to serve the roles of visionaries and facilitators. They enabled funding, built relationships with the community and school partners, and supported an environment that fostered active, passionate, teaching.

Students. Students at GJJ-HTH might not have entered the school as "professional learners," but through careful guidance and project structuring, they could take on increased responsibilities both within and outside their classrooms over their four years. Students became increasingly empowered as they actively engaged with classmates to select topics and design and carry out their projects. Presentations, both formal and informal, provided a forum to dialogue and communicate knowledge and understanding with peers and teachers, as well as parents, experts from business and industry, and the broader community. Students learned not only how to structure their learning and to share it with others, but also to take responsibility for and pride in the products of their labor.

Teachers, supported by relatively small class sizes and a smaller school, had time to get to know their students, and worked to ensure that all students within each heterogeneously grouped class were learning. Academic coaches could move among students with and without designated needs, and any student could access the resources and refuge provided by the Resource Room. The tenet that all students could learn and would be supported in that endeavor appeared to create a non-competitive and collegial environment for learning. Opportunities for students to actively engage with each other in the egalitarian project-based learning environment also appeared to facilitate strong bonds among them and to blur or almost erase the borderlines between ethnic, racial, gender, and socioeconomic status differences.

Alignment

The GJJ-HTH mission focused on the specific goal of graduating a diverse student group well prepared through an integrated technical and academic education to be thoughtful engaged citizens prepared for post-secondary education. However, the school director's goals of "personalization, adult world connection, common intellectual mission, and teacher as designer," better reflected the process by which these outcomes would be fulfilled in the everyday workings of GJJ-HTH. It was through these goals that there was alignment that began with teacher hiring and was reflected in teacher professional development, classroom practices, and student learning.

The "common intellectual mission" played a role in teacher hiring where the school sought teachers with strong STEM content knowledge who were willing to engage in open, collective, collaborative practice. Teacher orientation focused on the project-based learning that formed the backbone of the classroom strategy and the formation of a culture of continuous adult learning. Teachers noted that their professional development experiences focused on the use of technology within the project-based learning environment, and that the school supported its integration by providing adequate time and adequate technological training and support for both teachers and students. Teachers also identified that their professional development helped guide them in meeting individualized student needs within a classroom of heterogeneously grouped students—again a featured goal of GJJ-HTH.

The free flow of information facilitated by a culture of trust and respect, within a structure that provided time for people to actively dialogue with each other in meaningful and important ways, helped to create an egalitarian learning environment where each participant felt valued and strived to produce good work. Teachers were valued, students were valued, and collectively they valued, supported, and cared for each other.

Case Study 3: DSST Teachers and Teacher Professional Development

Introduction

The Denver School of Science and Technology (DSST) opened its first public charter high school in the Stapleton area of Denver, CO in 2004. By 2012, the year of the OSPrI site visit, the DSST Network had grown to include a middle school onsite with DSST: Stapleton, another high school, and four additional middle schools. With a vision statement supporting the creation of "an innovative school where students acquire a rigorous academic foundation that they can apply to the community and world around them in meaningful ways," DSST: Stapleton focused on graduating a diversity of students from high school, well-prepared for the rigors of a four-year college education. DSST: Stapleton provided a mastery-type, fairly traditionally taught curriculum that broadened to include increased connections to the real world and applications of course content through projects and internships as students moved from 9th through 12th grades (Spillane, Kaminsky, Lynch, Ross, Means, & Han, 2013).

With a college acceptance rate nearing 100% and about 45% of the students intending to enroll as STEM majors, DSST: Stapleton appeared to be fulfilling its mission. Its student population of about 500 students was diverse and more representative of the Denver population than the local comprehensive high school. It also had lower dropout rates, higher attendance rates, higher on-time and extended high school graduation rates, and generally better student performance on standardized tests across subject areas, demographic groups, and grades than the comprehensive school and Denver County high schools (Spillane et al., 2013).

DSST: Stapleton's goal was not to just get students into college, but to ensure they had the academic and "grittiness" preparation to see them through. To that end, 9th and 10th grade classes focused on learning content and mastering the material. Courses were designed backwards from the *ACT Standards for College Readiness,* also using Colorado and Common Core standards as guidelines. Classroom practices, particularly for 9th and 10th grades, used fairly structured and standardized strategies that included short learning segments and a spiral technique of revisiting concepts that included a "do now," "instruction," and a "mastery check" leading to content mastery before application. Applications of knowledge were more present in the 11th and 12th grades where students participated in internships with local businesses—the majority of which were STEM focused according to one administrator—and research projects during the senior year (Spillane et al., 2014).

Teachers

Hiring

Because DSST: Stapleton was a charter school, it had the liberty to hire teachers with qualifications determined to be the best match for the needs of the school. According to the DSST: Stapleton website, they sought teachers willing to work with some autonomy in their classrooms, yet collaboratively in shaping a learning culture of high expectations and high achievement. They sought:

> [teachers] with a track record of raising student achievement to join a team of educators dedicated to providing a rigorous college preparatory program to a diverse population. At DSST Public Schools, teachers are leaders who are

responsible for developing and implementing DSST's curriculum. Teachers also play an integral role in ensuring student success through the support of our school culture, the development and instruction of a rigorous core curriculum, and the use of data to drive their daily practice.

To fulfill these roles, an administrator explained that the initial screening of applicants looked for teachers with about 3-5 years of experience, who were "high performers, high achievers, of course," and also those "able to push through" and who "won't take 'no' for an answer." Seeking those who would support the school's principles, second round applicants were asked to reflect in writing on the school's *Core Values* and Mission. Saying that seeing a teacher in action "tells us a lot," an administrator explained that each candidate was asked to provide a video of their teaching, or if they were local, to be observed in their current classrooms. An administrator explained they had hired "a lot of Teach for America (TFA) alumni," who were "really at the top of their college classes at elite universities," who had "done trial by fire in some mostly urban schools," and who appeared to posses many of the desired teacher characteristics.

STEM Teacher Academic Background and Experience

Of the eleven STEM teachers responding to the Teacher Survey, four were mathematics teachers and five taught only a science, one taught a science and an engineering course, and one taught engineering. This number represented about half of the STEM teachers at DSST: Stapleton. Four were female, seven male; one identified as Asian, ten as White. The average age was about 28, with one teacher under age 25, six between the ages of 25 and 29, one between 30 and 34, two between 35 and 40, and one in the 45-49 age group. While the mean number of years of teaching experience was a little over 6, this number was skewed by one teacher with more than 20 years of experience. Six teachers had five or fewer years of teaching experience with four having between six and ten years of experience. The average length of time a STEM teacher had been at DSST was a little over three years. Eight teachers were in their first three years of teaching at DSST. Three had been at DSST for five or more years. DSST: Stapleton had been open for 12 years.

The eleven STEM teachers had earned their bachelor's degrees from ten different colleges and universities including such schools as Williams College, Middlebury, Tufts, Lehigh, and one in Great Britain. Two had earned bachelor's degrees from the same university in Colorado. Six teachers had earned master's degrees, five in education fields from five different schools of education in four different states and one international institution. Six teachers had active teaching credentials in the disciplines they were teaching or a closely allied field, two had lapsed certifications, and one was working toward earning disciplinary certification. Two teachers had neither teaching certifications nor master's degrees.

Teacher Professional Development

Teachers' professional development experiences at DSST: Stapleton included summer intensive time for new teacher orientation and for yearlong planning by all teachers. There were also regular monthly or bimonthly department meetings, regular meeting time during the day for teachers of similar classes, two full days without students to "work with partners and grade level teams" at the end of each trimester to collaborate over student performance, and regular classroom visits and observations by administrators.

Before School Began

New teachers began in the summer before the start of the school year. The Director of Curriculum and Instruction described new teacher training taking place over three days in August that included "an instruction day, a culture day, and an application day." Following this, new teacher training sessions occurred monthly during the school year, with more formally organized sessions run by the home office, which might "focus on one core value," or "more informally [with] just a lot of checking in and working with me [the Director of Curriculum and Instruction]" at the school level. Returning teachers began the school year two weeks before the start of school with time that one teacher described as "a very valuable time of year for figuring out what we're doing and sharing resources…it allows cross-disciplinary planning."

Regular In-School Ongoing Professional Development

During the school year teachers had scheduled time to engage with colleagues for planning, observations, evaluations of data, and for feedback. Science teachers explained that they "have 75 minutes a day to plan together," and "departmental meetings are a couple of times a month." A math teacher explained that the math department had "several meetings each year" to "discuss practices that make us better math teachers." Another teacher added that our "colleagues are experts in their fields." Teachers identified having opportunities to be observed by and to learn from administrators. One teacher explained, "We have a Director of Curriculum and Instruction and she frequently observes my classroom, giving me great feedback." Another suggested, "The administration frequently visits our classrooms to monitor our teaching practices and to help us grow as teachers." Additionally, teachers had opportunities to go outside of the DSST system for targeted professional development. One teacher explained that connections with the University of Colorado were supported by DSST, saying that the "administration encourages and pays for PD at CU Boulder," and engineering teachers had participated in summer programs and experiences with the engineering department at CU to gain the necessary background to teach the engineering courses.

The DSST website described a Cross Campus Collaboration (CCC) that was designed to connect "staff working on common content areas across different campuses" for purposes of sharing "resources and best practices," and trying to figure out "how to make collaboration really work across seven schools." According to the website, these groups of teachers met during the summer then used "on-line tools to communicate among team members, [and to] provide feedback on collaboration and [the] effectiveness of on-line tools." While the website described these teams, teachers in focus groups and interviews did not identify these experiences by name or state that the CCC contributed uniquely to their professional development experiences. The chemistry teachers, however, spoke of coordinating with teachers from other schools to teach to the same standards and often the same end-of-trimester exams. This collaboration may have occurred as the result of the CCC.

On the teacher survey, when asked to describe particular professional development experiences that had a significant impact on their S/T/E/M teaching, no common experiences were highlighted. Teachers were as likely to identify attending a national conference (NCTM) or participating in a teaching fellowship program (Knowles

Fellowship), as they were to describe in-school DSST teaching practice professional development, or simply "observing and collaborating with other STEM teachers." Six of the eleven teachers did not respond to this question.

Teacher Survey Data

On the Teacher Survey, STEM teachers identified both their access to time to prepare, collaborate, and learn, and the effects of this time on their classroom instruction (Table A-11). As mentioned in the previous case studies, the ratings for "access" were only differentiated by 1=No Access, 2=Limited Access, and 3=Adequate Access. There was no way on the survey for teachers to indicate that additional time or support would have been preferable. Teachers generally reported that they had time for planning and preparing lessons, for professional development and to work with other teachers. They also identified time available for teachers and students to learn to use technology and for technology maintenance, but slightly less time for integrating projects involving technology into their classes. These rankings appeared to be a testament to the important role of technology in the school for communication and assessment, but somewhat less as an instructional tool. Teachers also identified that having time available and support for these activities had a somewhat positive effect on the effectiveness of classroom instruction.

Table A-11

The Effects of Time and Access on Classroom Instruction (N=11)

Rate both your access to and the effect of each of the following on your classroom instruction:	Access[a] 1-3	Effect on Instruction[b] 1-5
1. Time available for teachers to plan and prepare lessons	2.7	4.3
2. Technical support for the maintenance of technology	2.7	4.1
3. Time available to teachers to work with other teachers	2.5	4.1
4. Time available for teacher professional development	2.5	4.0
5. Time for teacher and student technology instruction	2.5	3.9
6. Time in school schedule for projects involving technology integration	2.4	3.7

[a]1=No Access, 2=Limited Access, 3=Adequate Access.
[b]1=Inhibits effective instruction, 2=Somewhat inhibits effective instruction, 3=Neutral or Mixed, 4=Somewhat facilitates effective instruction, 5=Encourages or enables effective instruction, 5=N/A or Don't Know.

Targeting School Reforms And Teacher/Student Needs

Teachers' professional development experiences appeared to be focused on aspects of the school's mission, vision, and goals, and teacher or student needs. Certain teaching strategies were encouraged, and new teachers spent time in the summer and in their ongoing professional development meetings learning and practicing these strategies. Teachers of similar subjects were able to coordinate their lessons and standards, and regular classroom observations provided targeted feedback to respond to individual teachers' strengths and challenges. Scheduled professional development time at the end of each trimester gave teachers time to analyze student assessment data to shape subsequent instruction to address gaps in student learning.

One purpose of DSST's professional development was to help teachers become skilled in certain classroom delivery and pacing methods with roots in two books: *Brain Rules* (Medina, 2010) and *Teach Like a Champion* (Lemov, 2010). Some techniques included structuring class time into short bursts of teaching with regular switching of learning activities to keep students interested and engaged. Teachers described the use of spiral learning techniques that involved revisiting and reinforcing content to help with learning and retention. Many teachers, particularly the younger and less experienced, commented on their mindfulness toward these classroom practices, along with opportunities to practice, be observed, and receive feedback from others to help them improve. One teacher explained that their classroom observations were "very traditional," adding

> There is that support and a decent amount of instructional coaching: they tell you how to teach; there are systems about how to run a classroom. When I was new, there was someone in the classroom three days a week. I had a lot of support, and someone was always there to support from other science teachers or [the] Director of Curriculum and Instruction.

Regular classroom observations came in a two varieties and served slightly different purposes. The focus of observations by the School Director and the Director of Curriculum and Instruction was to support teacher growth and development. Academic deans also observed but were more focused on students' experiences in the classroom. Yet even though one focused on the teacher and the other on the student experience, both facilitated conversations about teaching and teaching techniques, and helping to improve student learning.

The Teacher Survey characterized teachers' perceptions of their professional development experiences, describing whether professional development (a) covered particular topics, and (b) affected their classroom teaching. Table A-12 displays teachers' collective responses. It is interesting to note that the experiences that teachers identified as having the most significant effect on their classroom practices included features that played a prominent role in DSST's mission, vision, and goals. The role of technology as a tool for learning, researching, communicating, record keeping, and assessment was important, and professional development that contributed to teachers' and students' understanding and use of technology ranked highly. Teachers also identified that professional development centering on classroom practices of engineering design, inquiry learning, and integrating content across the STEM disciplines were more likely to effect changes in their classroom practices. It is worth noting, however, that for several of the identified learning effects in Table A-12, more than half of the teachers responded that their professional development experiences did not cover these topics, indicating that either teachers did not all have the same professional development experiences, or they did not perceive the learning targets of these experiences in the same ways. For example, on the survey, the professional development experience showing the greatest changes on classroom instruction involved learning how to teach engineering or design concepts or activities. However, only three of eleven teachers identified that they had participated in this kind of professional development.

Professional development experiences at DSST: Stapleton appeared to have a lesser effect on classroom teaching related to working with special needs students in the classroom, helping students learn to perform STEM research, teaching STEM across the high school curriculum, and using technology to communicate or collaborate with parents or other educators, and appeared less likely to focus on these issues.

Table A-12

STEM Teachers' Perceptions of Impact of Professional Development Experiences (N=11)

Considering all your professional development, how would you rate the impact in each of the following areas? If your professional development experiences have not addressed the following areas, please check N/A.	Mean Score[a] (1-3)	N/A[b]
1. Learning how to teach engineering or design concepts or activities	2.7	8
2. Learning how to use technology to collect and analyze student assessment data	2.6	0
3. Understanding student thinking in S/T/E/M	2.6	1
4. Learning how to use inquiry/investigation-oriented teaching strategies	2.6	1
5. Learning how to integrate the different disciplines of S/T/E/M into my course	2.6	4
6. Learning how to assess student learning in S/T/E/M	2.5	3
7. Learning how to identify, locate, and evaluate technology resources that I can use with my students (e.g. websites, online data sets, etc.)	2.5	3
8. Learning how to use technology for student activities and experiments in the S/T/E/M classroom	2.4	2
9. Learning how to do performance based assessments in S/T/E/M	2.4	3
10. Deepening my own S/T/E/M content knowledge	2.3	1
11. Learning how to implement problem-based or project-based learning	2.3	2
12. Learning how to use technology/technologies for differentiating instruction for students with special needs	2.3	3
13. Learning ways to use technology to communicate and collaborate with other educators	2.0	4
14. Learning how to teach S/T/E/M across the high school curriculum	2.0	5
15. Learning ways to use technology to communicate and collaborate with families about school programs and student learning	1.9	4
16. Learning how to help students perform S/T/E/M research	1.8	7
17. Learning how to teach S/T/E/M in a class that includes students with special needs	1.5	5

[a]1=Little or no impact, 2=Confirmed what I was already doing, 3=Caused me to change my teaching practice, 4=NA.
[b]Teachers were asked to respond N/A if the identified topic was not addressed in their professional development experiences.

Teachers' Concerns

Some teachers raised concerns about their teaching and their professional development experiences. While most teachers commented on the collaborative spirit and the feeling that all were "in this together," many teachers appeared stressed and exhausted. Several of the science teachers commented on these issues. One said, "There is a lot of turnaround here, and I am going to teach somewhere else. There is a lot of work here. Is it sustainable for ten years?" Another added, "I am not sure I can sustain this." Expressing some concern about teachers' preparation for the classroom one teacher described, "I was in TFA for two years, but first I was a civil engineer. I got here and they threw me to the wolves. They hire third year TFA teachers. TFA is big here." Another added, "But they also hired random people such as me, a geologist." One teacher explained that because DSST looked for academic content over teaching preparation, they were searching for "those who are willing to take the risk and learn the craft." A teacher commented, "I think we need to do better at celebrating teachers, we keep pushing for better and better, but we need to be careful with how we do that."

One teacher expressed concerns about other schools in the DSST network "bringing in all these young teachers." She went on to explain that there were some advantages to having "a good mix of diverse ages of teachers and administrators." She suggested that DSST: Stapleton did have a good balance, which was important to continue—appreciating the TFA alumni and young teachers for their "energy and bright futures," along with the solid teaching experience and wisdom of seasoned teaching veterans who were more likely to have the background to understand and assist students in challenging situations. Suggesting a way to better support teachers at DSST: Stapleton, one teacher commented,

> I think DSST needs to expand into a training school for teachers. I don't think there's a good model in the U.S. There's the college model [referring to traditional teacher preparation pathways], but you don't get people who are passionate about their subjects. Then you have the pure in-school training, sink or swim. Then you have TFA, which is similar. I'd like to see an in-school training that is much more supported.

One of the more telling statements was provided by a board member who said:

> The school is a hard environment for teachers. The demands on them are so high… You can never be good enough. There isn't anything such as good enough at Science and Tech [the term she used for DSST: Stapleton]. They have an incredible learning community. The teachers help each other, the teachers are part of a community that is so strong; that is magic there. But it's hard to be good enough.

Professional Development Summary

Several of the characteristics of DSST: Stapleton's teacher professional development experiences appeared to be in line with Desimone's (2009) framework of effective professional development. Teachers engaged in more intensive professional development in the summers, and were able to continue conversations with each other within subject areas and across departments throughout the school year. These intense and sustained experiences appeared to focus on the needs of the school, teachers, or students. Teachers appeared to have opportunities to be observed and provided feedback within their own classrooms to improve teaching in line with school practices. By being provided adequate time to actively engage in gathering and using student data, teachers were able to make informed decisions about their own work in response to students' needs. The majority of teachers' professional development experiences appeared to involve collaboration with other subject-related teachers or with administrators. Additional facets of the collaborative experience at DSST: Stapleton are explored in the next section.

Despite teacher professional development on the surface seeming to have most of the characteristics of effective professional development, there was evidence that teachers were stressed and perhaps burning out. Many teachers commented on being unprepared for teaching and feeling like they were not given enough guidance on curriculum and pedagogy beyond the chosen classroom strategies. On average, teachers were relatively young and inexperienced. Expectations were high for teacher autonomy, but there was evidence that some teachers might have appreciated more time to work on their craft before taking full responsibility for curriculum development.

Collective Teacher Practice, Collaboration, and Teacher Professionalism

Teacher Collaboration

The DSST website articulated an overall focus on collaboration and continuous learning saying, "As a learning organization, DSST is committed to making sure that we can continue to learn from each other at all levels, across all campuses." Teachers' professional development experiences provided opportunities for both formal and informal ongoing learning. Teachers in focus groups and interviews described having regular opportunities to work with each other and to observe classroom practices; however, only a slight majority of the teachers responding to the Teacher Survey identified having observed another teacher as part of a professional development experience during the current year, although most had had this experience within the past three years (Table A-13). Interestingly, of the types of professional development experiences identified on the survey, these classroom observations were the only type of professional development experience attended by the majority of the teachers within the current year. However, within the past few years, most teachers identified having had opportunities to attend workshops, to engage with other teachers to discuss STEM teaching issues, or to collaborate to integrate content across STEM. Teachers were less likely to have participated in experiences for integrating content beyond the STEM disciplines or to have attended a state or national teachers' conferences. Also even though the use of technology appeared to be important for communications and activities within the school as described in Table A-11, few teachers had participated in professional development experiences involving the use of technology to collaborate with other STEM teachers, even though this was identified as an important feature of the CCC described earlier.

Table A-13

Number of STEM Teachers Participating by Type and Timing of Professional Development Experiences (N=11)

	Current	1 to 3	More	Never	NR[a]

	Year	years ago	than 3 years ago		
1. Observed other teachers teaching S/T/E/M courses as part of your own professional development (formal or informal)	6	4	1	-	-
2. Met with a group of STEM teachers on a regular basis to study/discuss STEM teaching issues	4	1	1	4	1
3. Attended a workshop on S/T/E/M teaching	3	5	1	2	-
4. Collaborated with a group of S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	3	2	-	4	2
5. Used telecommunications to collaborate on S/T/E/M teaching issues with a group of teachers at a distance	3	-	1	7	-
6. Collaborated with a group of non-S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	3	-	2	4	-
7. Attended a national or state S/T/E/M teacher association meeting	2	1	1	7	-

[a]NR = no response.

DSST: Stapleton teachers identified during focus groups that they supported each other, collaborated within and across departments and across the DSST network schools for course alignment, and used CU Boulder as a resource. A new teacher explained, "When I need help (which is frequently), other teachers will give their time to (a) discuss strategies with me (b) observe me and give me feedback and (c) let me observe them." Suggesting that the "administration encourages collaboration within departments," one teacher explained, "Our department chair does a great job of setting an environment where we can share ideas." The science teachers identified engaging in conversations with each other to vertically align courses, and several teachers spoke of mindful attention to course content outside of science. One science teacher spoke of talking with a math teacher at the beginning of the year, and trying to "teach the same thing." Physics was intentionally moved to become a 9th grade course to provide students with the opportunity to apply their mathematics skills. According to the physics teacher, the course used "a lot of math to push the content skills to a higher level." An environmental science teacher spoke of collaborating with the English department:

> Reading science skills are what that they will need in the long run. I work with English teachers to align with science. During the summer, students will read *A Civil Action*. This is a book about social justice, earth science, law. It is not a hugely literary book, but helps them prepare for ACT.

The Creative Engineering teacher described integrating specific mathematics skills of *scale* and *measurement* into this course that students could then use in their physics and math classes.

Teacher Professionalism

Teacher professionalism is defined in the literature as encompassing a number of features such as teacher autonomy and empowerment, decision-making capacity and responsibility in the classroom and in the school, and opportunities or pathways to increased responsibility and leadership roles. At DSST: Stapleton teachers had some autonomy in their classrooms that increased as they gained experience, and the Emerging Leaders Program provided one pathway to leadership.

Teachers were expected to design their own curricula with a minimal reliance on textbooks and published resources, and were given a fair amount of autonomy in how they would help their students meet academic standards and be prepared for college success. This autonomy was perceived differently by inexperienced teachers without strong pedagogical backgrounds and by seasoned veteran teachers. Many teachers commented with pride, "Most everything used in this grade is created by me," and "I use mostly self-created materials," and "We have, over the years I've been here, largely written the standards ourselves very much based on national standards and Colorado standards." A physics teacher explained, "No one tells you how to teach," adding "I made up the curriculum by teaching to the AP test." One experienced teacher commented,

> I put a course together of the best things I've ever taught...It's a conglomeration of things that I like to teach. One thing I noticed with things like AP Bio here is that you teach what you like, you do a really good job with it, the kids see your passion, it translates over to their passion…We had the best results ever in AP Bio because of that passion and what I like and do really well, and they did really great.

And yet, one newer teacher, who was the only one teaching her subject, stated, "Having a set curriculum would have been helpful, especially as a new teacher. At least to start with."

Teachers within a discipline worked together to align the course curriculum, but one teacher commented, "The system helps to mold around the teachers, which is important," in explaining that classroom practices did not have to be identical from teacher to teacher. However, he added, "You have to prove yourself first, then you get the flexibility; We get more flexibility in how we want to teach our class once we've proven ourselves." In some similar classes, teachers gave the same end of trimester exams, which allowed them to compare student performance across teachers and classes. While this had the potential to lead to competition, or negative comparison, the idea was that these common assessments would lead to conversations about classroom practices that appeared to differentially affect student learning and where teachers could learn from the successful practices of others. Some departments described coordinating across DSST schools and a physics teacher explained, "Two other teachers in physics in another school and I work with [an administrator], but I don't have to; it is more efficient; we have the same common exams [and] stick together 85% of the time." As the DSST network grew to include more high schools, these DSST-wide collaborations were, in part, an effort to ensure some uniformity of programming across the network schools. However, they also led to some concerns about the potential of too much standardization of the curriculum content. One teacher stated that in chemistry, "breadth has won over depth," and the curriculum, lesson plans, and assessments had been "developed and locked in, and it's a little scary. Individuality is going away for chemistry," but added, "We're talking about it."

Engineering teachers collaborated outside of the DSST network with the CU Boulder engineering department. CU was a strong collaborator early in the school's design sending professors and graduate students into the school to teach the engineering electives. However, with engineering becoming a part of the curriculum, DSST: Stapleton teachers designed the courses through professional development experiences with and under the guidance of CU, and were currently "flying independent" according to the CU liaison, although teachers still identified accessing resources at CU.

Teacher autonomy in curriculum development appeared to be somewhat uneven in both its application and its advantage, resulting in a tension between too much standardization and not enough support. Some senior teachers, and especially teachers in the Senior Academy, felt very comfortable with their teaching and enjoyed the freedom to teach to their strengths. When there were multiple teachers of a subject, newer teachers appeared to have less autonomy after the curriculum had been established by previous teachers who were still teaching at DSST: Stapleton, and the expanding DSST network appeared to be affecting curricular choices. When there was no established curriculum, such as for a singleton course, and a new teacher was expected to create a curriculum from scratch, this could generate a fair amount of angst with no structure from which to work.

Teacher cosmopolitanism. The STEM teachers at DSST: Stapleton might be considered by Bryk et al. (2010) to be a cosmopolitan group. While cosmopolitanism on its own showed no effects in Bryk et al.'s study, when combined with a strong commitment to school reforms or a strong professional community, it could make the difference between school success and failure. The DSST website described the teaching staff as being diverse yet having a common focus saying, "[DSST teachers come] from all across the country with a deep belief in our mission and a desire to work collaboratively to reach it." As described in a previous section in this case study titled: *STEM teacher academic background and experience*, teachers came from multiple states, and an array of undergraduate colleges, and had earned their teaching credentials from a number of teacher prep programs, and alternative preparation routes, potentially bringing with them a diversity of experiences and perspectives.

Teacher evaluation. Teachers at DSST: Stapleton were on year-to-year contracts with continuation dependent on performance, of which 50% depended on student value added growth data and performance scores. Classroom observations appeared common and routine. An academic dean described evaluations as playing a significant role in teacher development of classroom culture:

> With the teachers…[I work] on their classroom culture to make sure [it is] a place where students can learn and have fun. I do midyear evaluations and reviews of teachers…We talk about areas they can grow and where they are doing a great job, but my main focus is their interactions with the students. I spend as much time as I can in the classrooms observing.

One teacher, however, commented on the rather extensive teacher evaluation system suggesting that the evaluations led to a system of ranking that could affect teachers' morale. He said, "We are ranked all the time, observations rank us, 360s rank us. We get lots of numbers." Instead, he suggested:

> Give me comments, where I need to improve, but not numbers. I don't want to worry about numbers—I want to be able to be genuine with my peers and bosses, and I don't want to suck up to get better grades. When I get my feedback, I don't want to be arrogant that everyone's rating me high, or depressed or angry at people. I want to know where to improve and what I'm doing well, but I don't need numbers to know that. Numbers cause the problems. Give everyone 3 areas to improve and 3 areas of strength.

He went on to suggest "numbers and rankings can be degrading and depressing for teachers who genuinely want to do well."

Teacher pathways. The Emerging Leaders Program (ELP) within the DSST network provided a pathway for teachers looking to move into administrative positions. Teachers could apply to the ELP, which under the direction of the DSST CEO, would help them to develop leadership skills that would allow them to move into positions as Academic Deans or Directors of Curriculum and Instruction. Once in these positions, they could continue training to become School Directors. The CEO suggested that about 10 teachers were taking part in the ELP at the time of the OSPrI site visit.

School Collaborative Culture

The OSPrI DSST: Stapleton Case Study described the school environment:

> Atypically high standards of expectation for the population of students served, coupled with the determination that *every* student would achieve mastery of college-level content in order to graduate, *and* unflinching and persistent support for the acquisition of this goal characterized the DSST: Stapleton school culture. (Spillane et al., 2014, p. 64)

These high academic standards, paired with a culture of personal responsibility to the larger school community permeated the environment at DSST: Stapleton, and pertained to all: administrators, teachers, and students. One administrator explained, "We're a values based institution" that is building a culture where:

> you guys [referring to students] are a part of something much larger than yourself; you are part of a community that you have expectations for and expectations from that you have to meet. You are a part of something that you have a responsibility to.

One school administrator commented, "So we basically said, hey, we can create great STEM schools for all kids. And we can demonstrate that all kids can access great STEM schools, and I think that's been very important." School directors were hired, in part, because of their commitment to upholding the mission and values of DSST, and their interest in creating a strong culture with the expectation that *every* student could succeed in meeting the mastery requirements of college prep coursework—where, according to an administrator, the students would be "100% prepared for college" with "a strong science and math background."

A comprehensive set of rules and procedures provided the structure for classroom practices and responses to academic and behavioral infractions. One parent commented that the school "holds kids accountable" for their work and their behavior. Students who failed to complete homework were assigned to after school "College Prep" sessions, and inappropriate behavior sent a student to an opportunity to reflect on the effects of the behavior in a “Refocus” session. While there were established consequences for particular behaviors, an administrator commented that students also monitored themselves and each other, reminding each other “how to behave.”

The common experience of hard work and “grit,” the most clearly articulated pathway to success at DSST, seemed to be a binding force in the school, as expressed by parents, students, faculty, and administration. Parents characterized DSST: Stapleton as a challenging but supportive environment with fairly predominant rules governing behavior. However, most appeared to stress that these rules provided a structure within which learning could take place without interruption. One math teacher compared a previous teaching position with DSST saying that he was teaching as many hours as in the previous position, but the relationships at DSST: Stapleton were “more supportive” and resulted in a greater teaching efficiency. Several students commented on the degree of challenge and support provided at DSST: Stapleton. One 9th grader said, “[we are] pressured to do well and bring up grades; it seems like a lot and we are really stressed out, but in the end it is going to pay off…stress is good.” And another 9th grader added, “I want to go to college and the teachers will push me to be successful; the rules will help me.” A junior said that the school “definitely got hard” in 11th grade, but she had been able to take advantage of tutoring and teacher help. One student suggested that she knew students in other schools who didn’t have to work as hard as she did at DSST: Stapleton, and another student explained that he appreciated the academic challenge. One student commented that she thought the school environment was actually less stressful because everyone had to “do the same thing,” and they were all working hard. Of her experience at DSST: Stapleton an alumna said “When you’re there, it’s hard and there’s a lot of rules, but it’s very loving and supporting.” And finally, a member of the governing board summed up the experience well saying, “It’s a hard school. But you’re in an incredible learning community where everyone is learning.”

This culture of gritty hard work which, for the most part, seemed to be the glue that held DSST: Stapleton together was also described as having “a dark side” (Spillane et al., 2014, p. 58), that being the pressure that many experienced in never being quite good enough. But, as was reiterated through a variety of voices, this pressure to perform appeared to result in students who were well prepared to face the challenges of college and life beyond DSST: Stapleton, as reflected in the CEO’s comment “I think helping kids persist through the academic challenges is really important.”

Supporting Learning by Students Underrepresented in STEM

As mentioned in previous case studies, the literature points to classroom practices and school wide characteristics that can differentially affect learning by students underrepresented in STEM. Classroom practices involving peer-to-peer learning can serve to develop students’ STEM identities (Carlone & Johnson, 2007; Hazari et al., 2010; Kanter & Konstantopoulos, 2010; Roth & Weinstock, 2013; Sadler & Tai, 2007), and the social-emotional learning can also play a role in student learning (Aronson et al., 2002; Reddy et al., 2007).

Teachers comments reinforced DSST: Stapleton’s mission that ensured that students not fall through the cracks saying, “We focus on every kid and try not to let kids slide by,” and “It is not perfect, but the systems captures most of the kids.” STEM teachers’ responses to the Teacher Survey demonstrated a general, but not resounding, confidence in their abilities to use a variety of teaching strategies (Table A-14). In line with DSST: Stapleton's goals, most teachers expressed confidence in responding to student diversity and helping students take responsibility for their own learning. And while positive, teachers did not demonstrate a strong confidence in using inquiry based, project-based, or investigative strategies in their classrooms. These results were not terribly surprising given the school's more direct focus on assuring student competence in academic content presented through fairly traditional teaching strategies, and the later focus on application to the real world through the internship and senior projects. Teachers did not identify feeling especially confident in targeting the needs of females or minorities in STEM or involving parents in their students' STEM learning.

Table A-14

Teacher Confidence in Utilizing Teaching Strategies (N=11)

I am confident in my ability to:	Mean Score[a] (1-5)
1. Recognize and respond to student diversity	4.0
2. Help students take responsibility for their own learning	3.9
3. Manage a class of students engaged in hands-on/project-based work	3.8
4. Encourage students' interest in S/T/E/M	3.8
5. Lead a class of students using investigative strategies	3.6
6. Use strategies that specifically encourage participation of females and minorities in S/T/E/M	3.5
7. Involve parents in the S/T/E/M education of their students	2.4

[a]1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree.

Classroom Time

The importance of a classroom structure characterized by short activity chunks and spiral learning appeared to take precedence over the creative use of technology or project-based experiences. One teacher commented that, it was "frowned upon to do activities that eat up the class period," and in reference to a project done the previous year, "[it] was cool but it was very time-consuming." A prep academy teacher explained, "In physics, I can't say we use very much technology at all."

The LFCOP (Lesson Flow Classroom Observation Protocol) data suggested that classroom time changed its focus throughout the classroom period, in keeping with the teaching strategy involving "short bursts of learning" previously mentioned. The four classes for which LFCOP data were collected showed time spent where the teacher was the center of attention, involved in small group work, and where students were completing individual work. In three of the four classes where LFCOP data were collected, the majority of the classroom time was spent in small group work, with one class being predominantly teacher focused. All students in the observed classes appeared to be involved in the same activity at the same time; there was very little overlap among the three different usages of time (Table A-15).

Table A-15

Organizational Grouping and Percent of Class Time[a]

Class Type[b]	% Student-directed Small Group Focused	% Individual Student Focused	% Teacher Focused	% ONLY Teacher Focused[c]
S-Biology	75	6	19	19
S-Chemistry	61	6	33	33
S-Physics	0	26	74	74
I-Creative Engineering	76	0	22	22
MEAN	**53**	**10**	**37**	**37**

[a] More than one activity could occur at the same time, so percentages may add to more than 100.
[b] M=mathematics, S=Science, I=Integrated/Engineering.
[c] Small group, individual, and teacher led activities could be occurring simultaneously. This last column identifies time when all students were focused on the teacher as in a lecture class.

Developing STEM Identity

The four factors identified in the research literature (Carlone & Johnson, 2007; Hazari et al., 2010) as contributing to the development of students' STEM identity—interest, competence, presentation, and recognition—were present in some form at DSST: Stapleton. However, the development of student competence in STEM featured most prominently. With the mission of preparing students to succeed in college, and the school's emphasis on mastery learning, DSST: Stapleton sought to ensure that students' academic preparation would sustain them as they pursued higher education. This pathway to success in college began with fairly traditional STEM coursework in 9th and 10th grade that sought to lay a foundation of content knowledge. The development of student interest in STEM was emphasized more during the junior and senior years, during which students also experienced increased opportunities to present and be recognized for their competence and achievements.

Ensuring competence. DSST: Stapleton focused on the academic rigor of all of its coursework with the goal of preparing students for subsequent opportunities to apply that knowledge. According to the CEO, DSST: Stapleton had

> a philosophy of [being] very rigorous and a little more traditional in the early years of our program—to build that foundation in, so that when we get to application at the end in our Senior Academy program, [students] are going to have the rigor and the skills to do college-level work there and not "fluff." Our program migrates from what I would call a little more traditional program to a lot more application.

Comments from students and parents reinforced the notion that the school was rigorous, and that students knew of this reputation before attending.

Data and support systems. There were many systems in place to ensure that students would be successful. Even before coming to DSST: Stapleton, state level data were used to assess student learning to determine whether students ran the risk of struggling. These students were provided with intensive summer learning, special course sections during the school year, and a system of tutoring to support learning. One teacher explained,

> We put a lot of safety nets in place for students. Students do experience failure… but they are supported by the trimester system, so they can bomb one trimester and work up the other two.

To make sure students were prepared for college level work, the mastery system required students to achieve at a minimum grade of 70% in each of their courses. Students were not passed on to the next level without meeting this threshold. A Board Member commented on this standard saying:

> Are you more harmed by being held back because you are not performing up to level as a 14-year-old who can't drop out of school or as a 11th grader who can? What happens when you find out that you are behind in 3 years of courses [needed to graduate] and that you have been socially promoted…there's zero chance of graduating in 12th grade? It is better to deal with it at age 14.

To meet this high learning expectation, many supports were in place in what teachers and administrators characterized as a system of "continuous accountability." Especially during 9th and 10th grades, teachers closely monitored student assignment completion, and advisors kept track of student performance across all of their classes. And the two academic deans—one for the Prep Academy, and one in the Senior Academy—described their responsibilities as primarily surrounding students' academic and disciplinary concerns.

Data were continuously used to assess student progress to keep them on track. One teacher explained how quizzes and tests were used to identify gaps in student learning, and the subsequent structures in place to help students fill these gaps:

> Each quiz has standards that we have to cover; each question covers a standard. When they take a quiz, they'll see which standards they get wrong. Then I wrote other questions that help them explore each standard. So if they miss a particular standard, they have a question that addresses that specific standard and helps them review it. … So what they do—I think they really like this—everyone gets different questions wrong on the quiz, but they get a very personalized review for the standards they miss. Instead of me standing in front of the class explaining a standard that half the kids have no problem with … if you miss particular standards, you get specific questions to review.

This rigorous use of student data helped to continuously monitor students leading to graduation with the competence necessary to successfully meet the challenges in college. One teacher commented, "Without a doubt there are kids who you think will not make it [to graduate], but they manage and are successful in college."

There was evidence that the goals for student competence were being met. The CEO reported that 100% of DSST students were accepted into college and about 45% intended to pursue STEM majors. DSST students also experienced very low rates of assignment to remedial classes in college, being in the top 5% of Colorado high schools on this measure. Additionally, none of the remediation was in STEM fields. One alumna who said that former DSST students she knew were all "breezing through" college, also suggested, "DSST teaches you to ask for support, and going here is why I know how to do that. In college, you have to ask for support" (Spillane et al., 2014).

Interest. In the years prior to the OSPrI site visit, developing student interest in STEM through a focus on real world applications and project-based learning had been a greater focus of 11^{th} and 12^{th} grade experiences than of earlier grades. The recently added 9^{th} grade Creative Engineering course, a course one student described as "pretty legit," was designed to introduce students to the applications of STEM content as they designed mini-catapults and classroom scale models. The class also provided a different kind of learning environment that teachers described as "so different from other courses" and "more hands-on," offering an environment the helped students "feel more autonomous" in their learning.

A CU engineering professor described an on-campus engineering day where the entire DSST: Stapleton 9^{th} grade spent the day at CU learning what it meant to be an engineer and learning about the engineering majors at CU. Teachers also described field trips and other informal learning experiences designed to "expose our students to the world outside of our walls." However, beyond the Creative Engineering course, efforts to tie STEM content learning to the real world did not appear to play a strong role in teachers' curriculum designs until the later years in the high school, and even there, it appeared to be the domain of the junior internship and senior project where these connections were strongest. The internship advisor suggested that the junior internship and senior project provided "real life experiences for the students" in the working world, exposing them to possible careers.

Presentation and recognition. Efforts were in place at DSST: Stapleton to increase the amount of project-based learning, as was evidenced by the recent introduction of the Creative Engineering class where students would have opportunities to engage in more student led, project-based learning. However, these changes in other classes were slow to happen and it wasn't completely clear whether there was a school-wide emphasis on this effort, particularly in the 9^{th} and 10^{th} grades. There did not appear to be targeted professional development or broad implementation efforts in this area. However, one math teacher in a focus group mentioned that project-based learning had been the focus of one summer teaching and learning session a few years back, but "not this year." Instead individual teachers identified having students do projects—the biology teacher mentioned assigning several group projects, and students in this class described opportunities to work creatively with others through these activities—and chemistry teachers were engaged in discussions about how to integrate projects into their current curricula and foster collaboration in labs while still maintaining expectations for individual accountability.

A biology teacher described his use of a partially "flipped" classroom, but wanted to make sure that this didn't lead to independent learning, suggesting the advantage of students working with peers in the learning process:

> I don't believe in fully flipped classrooms—the problem is pacing, some kids go so fast, and the assessments get hard. If you go fully flipped, you also lose opportunity for peer support… I prefer the version of flipping where some happens at home, but in class we work on the same things together.

The junior and senior level STEM classes appeared to focus slightly more on the application of the content, inquiry learning, and active engagement with other students. However, as mentioned about the 9^{th} and 10^{th} grades, there didn't appear to be an overall process or plan of how this could or should happen. Senior STEM teachers explained that seniors took two science classes where one was more content centered and the other more application centered. Teachers of the 11th and 12th grade STEM courses identified the importance of students learning "how to think like a scientist," saying that students in these classes were more likely to work with sophisticated professional level lab equipment and have more opportunities to engage in hands-on and laboratory experiences. The senior physics and engineering course centered around five main projects of one to two month duration. For these activities, students were provided project goals and rubrics for assessment, but it was up to them to determine a timeline for project completion. It was not clear whether these projects, or those in the Prep Academy followed processes that were in line with project-based learning strategies or whether they represented group work with a different emphasis. They did appear to support peer-to-peer interactions in these classes (Spillane et al., 2014).

Junior internship and senior project. Two activities that appeared to significantly contribute to students' opportunities to put their STEM learning into context and to demonstrate their competence in a more public forum occurred during 11th grade internships and 12th grade research projects. For one trimester of junior year, students participated in an internship (for example, a medical office, research lab, museum, radio, station) two days a week and met weekly as a class at school with other classmates who were also engaged in internships. These classes provided a forum that allowed students to share concerns and experiences regarding their internship placements. Class time was also used to help students prepare for the culminating experience of the internship—a poster session in a school-wide Internship Showcase that would be attended by mentors, community members, parents, teachers and administrators. In the internship class, before the showcase, students would have had classroom opportunities to give presentations, prepare slideshows or videos, and engage in conversations about their learning. The showcase was viewed as a celebration of students' accomplishments that provided an opportunity for students to practice their communication skills in a broader community environment. The internship thus combined career and real world experience with technology use, communication, and creativity (Spillane et al., 2014).

The year-long, community-based senior project provided one more opportunity for students to engage in an autonomous, passion directed exploration, and yet it still included some structures to facilitate student learning of project management, critical thinking and inquiry, and presentation skills. According to one teacher, during planning time for their senior projects, students took a civics class that would help them contextualize their project in the real world, and then a seminar class that provided additional guidance and support as students learned to work increasingly independently. This experience culminated with a ten to twenty page paper and a thirty minute defense-style, panel-moderated thesis presentation, where students could demonstrate their learning and expertise to a panel of mentors, teachers, administrators and community members (Spillane et al., 2014).

Socioemotional Learning

The development of student autonomy was a slow and deliberate process at DSST: Stapleton that began with a thorough indoctrination into what it meant to be a part of a community. Social and emotional learning played a central role in the school's daily life. While there was a focus on the individual student and on that student's well being, attention was never far from a concern for the common, or greater good, of the school community. The advisory—one teacher assigned to meet twice a week with a group of 10-15 (usually same-sex) students—as described by one academic dean, provided a more informal time for teachers and students to interact for "a lot of culture building," and to help students "get used to DSST: Stapleton" as well as a time for students to discuss issues and to be monitored for academic progress. This advisory also provided time for the development of teacher-student relations.

Weekly meetings in other combinations—as a whole school, or as separate academies (9th and 10th grade Prep Academy, or 11th and 12th grade Senior Academy)—provided a forum for the defining and reinforcement of community-wide social and emotional norms and expectations. The behavioral guidelines, or Core Values, were prominently displayed in the classrooms and hallways throughout the school, and major infractions were dealt in a well-orchestrated format through the public forum of the whole school gathering, that in part were led by students. While this could have the appearance of "public shaming," as one OSPrI researcher suggested, it was intended to help students understand that their behaviors had an effect on the entire community, and that each participant had a responsibility to this community. It was clear that helping students learn how to be constructive community participants was a responsibility that DSST: Stapleton did not take lightly, and there were structures in place to ensure that the student and the school community embraced the experience as a learning process. Many of the discussions that the OSPrI team observed during its site visit revolved around student responsibility and student accountability, and appeared strongly focused on being instructive and supportive, as opposed to punitive. Students were allowed to fail, to make restitution for their failures, and then to be supported as they picked themselves up and moved on (Spillane et al., 2014).

While there did appear to be a hierarchy between teachers and students, there was a pervasive sense that all were working together toward the same goal—that of ensuring student success. One teacher compared the experience at DSST: Stapleton with a previous job explaining, "[at another school, I was] teaching only upper crust…I was a coach, not a teacher. I [have] had to work hard here and this is the most gratifying work. [The students] see they can do it." Another teacher spoke of the importance of developing a sense of trust between teacher and student.

Developing Student Autonomy

There were efforts to ensure that the students could do more than be successful in a high school; DSST: Stapleton intended to prepare students for college success and life beyond the classroom. One teacher explained that there were opportunities for students "to learn that they can become leaders in our community, not just to learn how to be in school." One process that DSST: Stapleton used to develop student independence was termed "gradual release." This intentional process sought to prepare students with the content knowledge and behavioral guidelines directing their actions that they would come to internalize over their time in the school. The rules were very prescriptive beginning in 9th grade—or even earlier for students who attended the DSST middle school, and a highly structured environment was designed to ensure that students knew the rules and followed them. But the intent was that these rules, at the forefront in grades 9 and 10, would gradually become part of the fabric of the student and would move into the background in grades 11 and 12.

Much of the coursework in the 9th and 10th grades at DSST: Stapleton was teacher directed and teacher driven. Teachers were responsible for checking homework and assigning students to "College Prep," and monitoring behavior and directing students to "Refocus" sessions for infringements. The idea in the school was that students were being held accountable, but much of the student behavior (both academic and social) seemed to hinge on teacher accountability rather than student accountability especially in the 9th and 10th grades. Saying "We hold their hand a long time in this school," teachers suggested there might be a need to provide students with an earlier start in taking personal responsibility for their learning. The school director added, "If they own their learning, it will be a good step for us." The addition of the previously described Creative Engineering course was designed to provide a space for students to try and fail, to examine, figure out and articulate their struggles, to learn how to seek assistance, to learn to collaborate productively, and to learn to self-direct their projects.

Student experiences in 11th and 12th grades provided them with opportunities to become more independent thinkers and learners. Upper level courses were more inquiry based and problem based with greater application to the real world, and required more critical thinking skills. Juniors took part in internships, and seniors completed research projects that were of their own design. One teacher explained that these experiences provided students with opportunities to be "a young adult" by being responsible for providing their own transportation to internship sites and tracking their working hours. One teacher suggested questions to be answered through these more independent experiences:

> Can you think on your own? Can you synthesize information? Can you push through things? Can you do all these things so that when someone says, "You can do anything you want on your own," can they figure out what to do?

Summary—Learning by Students Underrepresented in STEM

Two features appeared to rise in prominence at DSST: Stapleton—a very strong culture of social and emotional learning in the development of a community of learners with responsibilities to the larger community, and a focus on ensuring student competence in STEM. Students' development of a STEM identity appeared to be a function of the development of solid STEM competence through fairly traditional classroom experiences and assessment measures, along with the requirement of a 70% mastery in order to pass each class. Classroom practices shown through research to support the learning of students underrepresented in STEM were not particularly predominant among the practices observed at DSST: Stapleton; however, the recent addition of the Creative Engineering class served to introduce students to project-based learning and the engineering design process earlier in their high school experiences. Also, some teachers individually used projects and group activities in their classrooms. Opportunities to develop interest in STEM careers and fields seemed to occur outside of the classroom through field trips, internships, and senior projects. Although students would be recognized for their competence in STEM throughout all four years for their classroom learning by passing their courses, opportunities for students to present their knowledge and to receive recognition for their capabilities in a more public and dialogic forum were targeted in the upper high school years.

Social and emotional learning played a significant role in both supporting the hard work that all were engaged in and supporting the fabric of the community as a whole.

Even as they struggled and sometimes failed, students came to learn to trust that the school would support them, and would give them opportunities to try again. This community sense extended beyond the students to the teachers and administrators such that all contributed to something much larger than themselves.

Discussion

Teachers, Professional Development, and Classroom Practices

There was alignment between the teachers that the administration sought—hard working, academically smart and accomplished, with demonstrated ability to press on regardless, to persist in the face of challenge or struggle—and the teachers hired to work at DSST: Stapleton. The teacher base, including many Teach for America alumni who had previously been placed in situations that required them to teach with inadequate supervision and training, work with fewer resources than necessary, and teach students who came into schools with weaker track records, tended to have strong academic disciplinary content expertise, and a gritty determination to succeed. They also tended to be relatively young with limited teacher preparation or teaching experience. The professional development was structured around teacher skills and gaps. It was assumed that teachers had disciplinary content expertise, but might need guidance, supervision, and support in classroom practices. There was a standardized approach to teaching with routines involving "do nows," and chunked time with transitions that gave inexperienced teachers a way to get started—a formula to follow that could support their initial effectiveness in the classroom. Administrators spent a fair amount of time in new teachers' classrooms observing and giving feedback, helping teachers hone their pedagogical structures to fit the DSST model.

The teachers possessed many of the characteristics that research described as contributing to a successful STEM teaching faculty. They were generally well prepared in their academic content areas and represented a cosmopolitan group of teachers bringing diverse academic experiences to the school. However, not all teachers were certified to teach and some did not have teacher training. The majority of the STEM teachers were under 30 years old and had fewer than five years of teaching experience. And despite an academic dean's suggestion that the previous year's teacher retention rate was "90% system-wide, network-wide," there appeared to be a fair amount of teacher turnover demonstrated by the predominance of teachers in their first three years of teaching at DSST: Stapleton, given that the school had been in operation for twelve years. Some of the teachers' struggles appeared to come from this lack of teaching experience and pedagogical content knowledge—being able to translate their content knowledge in ways to help others learn.

The professional development provided for teachers had characteristics of effective professional development. Teachers worked collectively, engaged in active learning experiences, and had regular opportunities to engage with each other both before the school year and during the school day and week on topics related to school reforms, or teacher or student needs. The system that provided fairly intense observation and guidance of new teachers served to support classroom management practices and general teaching skills, but was less targeted to content-specific practices that some teachers identified would be helpful. A weakness in this system may have to come back to teachers' lack of experience, or perhaps the experience of those observing and evaluating the teachers. Teachers could rely on each other, and appeared to have time to do so, but perhaps there was a lesser collective depth of knowledge to rely on with the large number of inexperienced teachers.

Teacher professionalization. While teachers were respected for the content area expertise they brought to the school, the school structure seemed less about helping to "professionalize" teachers than in helping them learn the DSST way of teaching. Teachers didn't appear to grow within this model as much as establish their competence to help students meet mastery and then become increasingly autonomous in their own classrooms. One structure in place to provide for teacher growth was the Emerging Leaders Program, helping teachers move into administrative positions within the school or into positions as school directors. Within the teaching staff, the teacher hierarchy appeared to be relatively flat. The only direction they seemed to move was away from imposed teaching structures to more choice in presenting material in their own classrooms. Teachers had high expectations placed on them with respect to the close monitoring of student behavior and performance. This relentless demand on teachers placed relentless demands on students to make sure they did their work and didn't fall behind.

Examining the student outcomes, it appeared that DSST: Stapleton was successful in carrying out its mission. Greater percentages of students underrepresented in STEM were graduating from high school and choosing STEM majors in college. The alumni with whom the OSPrI team spoke attested to being well prepared for the rigors of college work. The school director's comment, "We're mostly successful because of the high accountability, high support, and high standards culture," appeared to well capture the reasons behind DSST: Stapleton's student performance.

Student professionalization. Students' classroom experiences did not appear to include project-based learning that would provide for regular peer-to-peer interactions or opportunities to engage in productive dialogue about knowledge and learning. Classes appeared to be more traditional in nature with fairly standardized routines for maintaining student attention. Students were supported in social and emotional learning with respect to the development of responsibility toward the community, then gradually, over their four years at DSST: Stapleton, in the development of responsibility for their own learning. As students moved into junior and senior years, they had increased opportunities to learn how their knowledge applied to the real world and the world of work as they participated in supported internships and senior projects. These opportunities also provided students with some autonomy in their learning, opportunities to engage in dialogic exchange with other learners, and opportunities to present their learning in increasingly public and professional ways. These experiences were carefully scaffolded with deliberate support, and guidance, but with decreasing structure, and increased student input and autonomy. So while students didn't appear to have a large number of opportunities to engage in knowledge exchange with others and to take responsibility for the directions of their learning, they did learn how to do this, and appeared to be well prepared to approach their public displays with confidence.

Coherence

Grit and competence. Two concepts that showed coherence across the data on teachers, teacher professional development, classroom practices, and student learning at DSST: Stapleton were the ideas of grit, and the development of student competence. The “high accountability” and “high support” resulted in high student competence, and the grit, helped students meet the “high standards culture.”

Teachers were hired for their gritty determination, grit helped students persist as they strived to become competent, and even board members’ grittiness contributed to a determination to never give up as they worked to achieve more and better for the school. The environment in the school could be stressful. Expectations were high…for everyone. Students were expected to complete their homework every day or to attend tutoring or “College Prep” to finish; they had to behave in a manner that demonstrated consideration of others or attend “Refocus” sessions, and they had to pass all of their courses with a 70% mastery. Teachers were responsible for constantly monitoring student learning and providing immediate attention to any gaps or omissions. Teachers took responsibility for designing their own curricula and ensuring it was aligned with standards, and other courses. These curricula could still be differentiated to meet different students’ needs in the classroom. Teachers were expected to use specific structured pedagogical strategies, at least until they could demonstrate their expertise, and were observed regularly, and rated and ranked to ensure their growth. There was the constant message that whatever was going on, it wasn’t enough, or wasn’t quite good enough. This stressful environment, and the grit to persist in the face of difficulty, appeared to be one adhesive holding this community together, ensuring its success. Everyone worked hard. And everyone seemed to believe that this hard work was what would facilitate ultimate success. This was the “grit” for which teachers were hired, and which appeared to sustain many when the going got just plain tough.

Social and emotional learning. The school’s very intentional commitment to social and emotional learning and community responsibility played a role in the development and the maintenance of a supportive learning space. While there appeared to be stringent rules for behavior, the focus was on *learning* to be a good community member, not just being punished for not being one. Students learned to be reflective, to consider their actions and how their individual behaviors contributed to the overall functioning of the community. Students were asked to take responsibility for their actions, and to account for them. They also were asked to assume responsibility for their peers and to contribute to shaping the overall school environment. And as previously mentioned, students were not the only ones asked to contribute. Teachers, administrators, and even board members and the extended community appeared to feel a sense of responsibility for the school’s outcomes.

An external structure of rules and formalized behavior/response structures appeared to be the scaffolding that held the school community together. These rules kept students on track and ensured that teachers maintained student order. Students did learn, and a significant number of students did graduate and chose to to pursue STEM majors and careers. The imposition of the rules resulted in more pressure-filled 9th and 10th grade experiences for both teachers and students. It seemed more about hanging in there than enjoying the ride. But students did hang in, and graduated with the skills and knowledge to move freely and advance in the world of STEM. The pressure did have its backlash with more teacher turnover and greater stress within the student body. The school felt somewhat like a pressure cooker where the rules and evaluations kept students and teachers moving in the right direction until they embraced the common focus, but once embraced and accepted, provided an internal structure where students could grow and flourish, becoming increasingly independent.

Case Study 4: USA Teachers and Teacher Professional Development

Introduction

The Urban Science Academy (USA) was a science-themed traditional public high school of choice within the Boston Public School (BPS) system. It was in the third tier of selectivity, requiring no specific test scores, GPAs, or requirements beyond an application to be placed into the system-wide lottery. The school was governed by the Boston Public Schools, its teachers belonged to the Boston Teachers Union, and it used approved curricula and assessments determined by BPS. USA opened with support from a grant through the Bill and Melinda Gates Foundation to create small themed schools from large comprehensive schools in response to poor student performance and failing schools. (Peters-Burton, Ford, Ross, Behrend, Spillane, & Han, 2014).

In 2005, USA opened with a student body of approximately 300 students, but in the fall of 2011, as a result of its success and its neighbors' failure, USA absorbed a more poorly performing school, Parkway Academy of Technology and Health (PATH), within the same building to become a school of nearly 600 students. USA advertised itself as a college preparatory school with a focus on "environmental science, technology and the arts." Students at USA completed additional coursework in science relative to the minimum requirements for the state of Massachusetts, and aimed to complete mathematics at least through pre-calculus by senior year. A co-teaching model in 9th and 10th grades provided support for the inclusion of all students in mainstream classes (Peters-Burton et al., 2014a).

Beyond the BPS influence, decisions involving curricular and classroom practices at USA were rooted in education research, and, if different from other BPS schools, required a majority vote by the teachers in the school according to union rules. Co-teaching fell under this umbrella, as did changes in the implementation of homework policies. Teacher professional development experiences were research based and, according to one administrator, served to unify the school's vision of reform based instruction. Most STEM classes followed an inquiry-based model of "guided inquiry with significant scaffolding" (Peters-Burton et al., 2014a, p. 30).

According to one administrator, USA went from being one of the lowest performing schools when it was first opened with the majority of its students from West Roxbury High School, the comprehensive school previously housed in the building, to a "School in the Move" finalist in 2011, being recognized among schools with the most sustained improvement over a 5-year period. USA was one of only two remaining of sixteen BPS schools originally opened under the small schools initiative in 2004 and 2005.

Teachers

Hiring

When USA first opened, the principal had some latitude to hire teachers who were right for the changes envisioned for the new school focus on environmental education in an urban setting. The school was, however, somewhat constrained by union rules, so not every teacher was completely aligned with the school mission. An administrator described an attentiveness during the first few years after the school opened, to shaping the faculty:

> When this school first started it probably took about two years to turn over the staff and probably by year three everybody that was [still] part of the staff wanted to be here … and knew the vision and knew the mission that they were buying into, and we [now] have a strong foundation. A lot of that staff are still with us today.

One administrator explained that part of the interview protocol for hiring new teachers centered on cooperation. Teachers were hired to "fit a certain mold," teachers who were interested and willing to "work together in authentic ways" to "share ideas…successes, or failure." An administrator explained that these efforts in teacher hiring led to the development of a "collaborative spirit" among a community of "professionals who are trying to do their best as a group." Providing an example, he described how the 10th grade team "spent countless hours…planning and organizing" a pilot to create an interdisciplinary project where all content areas came together to engage the students in a real world application based project. Finding that it worked well, the teaching team decided to expand it to one project each quarter.

STEM Teacher Academic Background and Experience

Of the eleven STEM teachers responding to the Teacher Survey, seven taught mathematics and four taught science; six identified as female and five as male. Four teachers identified as Black or African American, one as Hispanic, two as Asian, three as White, and one did not answer this question. The average teaching experience of the eleven STEM teachers was a little over seven years, with no teachers having fewer than five years of experience, and two having taught more than ten years. Teachers had been at USA for an average of almost four years, but six teachers had been there for only two years—most likely the result of absorption of PATH two years earlier. Five teachers had been at USA for five or more years. Two teachers did not identify their age range, and both of these teachers had been teaching for ten years or longer. Of the remaining nine teachers, the average age was a little under thirty years old, with four teachers in the 25-29 age group, two between 30 and 34, one between 35 and 39, and two over forty years.

One teacher did not provide an academic background, and another did not identify the colleges or universities attended. Of the remaining teachers, five had attended undergraduate universities in the Boston, MA area, and four others attended institutions in three other states and India. Eight teachers indicated having earned master's degrees in some area of teaching or education, six from either UMass Boston or Boston College. Nine of the eleven teachers indicated having earned a bachelor's degree in the subject area they were teaching or a closely allied field and ten of the eleven teachers held active teaching certification in the subject areas they were teaching or a closely allied field. Five classes, or 14% of the classes identified on the Teacher Survey, were taught by teachers who were not expressly certified in the subject or did not have an undergraduate degree in the subject. One mathematics teacher had neither an undergraduate degree in mathematics nor any active teaching credentials in mathematics.

Teacher Professional Development

According to one administrator, USA's professional development program centered around "supporting teachers," along with the integration of "more rigorous instruction into … classes." To meet this need, time was provided for regular weekly experiences that "could take the form of a department meeting, all-staff meeting, or meeting in teams." All-staff meetings usually focused on school-wide concerns or initiatives. Within departments, teachers were individually tasked with identifying "a professional practice goal and a student learning goal," and the department's professional development was focused on identified department-wide student learning goals.

An administrator explained that about 75% of the USA curriculum was provided to the teachers by BPS, which they could "tweak" to fit their needs. Because of this, professional development offered through BPS was relevant to the courses USA teachers were teaching. Teachers described having taken advantage of professional development either provided by or funded by BPS and finding it useful and valuable. On the Teacher Survey one teacher described BPS professional development as good, but not enough.

At the time of the OSPrI visit, USA had redirected its focus to addressing the student achievement goal that at least 80% of students who attended school at least 80% of the time should pass all of their courses. To support this goal, the Instructional Leadership Team explored research-based practices to determine what should change. Two initiatives to address this included a shift to performance-based grading, and the implementation of backwards planning or teachers using ideas supported in *Understanding by Design* when planning lessons. Classroom practices were being altered so they focused less on assessments of homework completion, effort, or good conduct, and more on achievement relative to course standards, and providing opportunities for students to engage in higher order thinking. In the spring before the OSPrI visit, administrators described coming to agreement with teachers on the Six Core Values (high expectations, high support, collaboration, commitment, respect, and community) for USA, and then providing professional development experiences where teachers could reflect on these values relative to school wide decisions about student achievement and classroom practices. An administrator explained that all-staff professional development time was being used to help prepare and support teachers with making these changes.

Instructional leadership team. Teachers explained that when USA first opened, all of the professional development was organized or planned and structured by the administration, and administrators described having to "sit in [on department and other group meetings] and make sure they were doing this, and setting an agenda, and this and that." At the time of the OSPrI visit, teacher professional development was in the hands of the teachers— "We have teachers that lead the charge for grade level common planning time"—and orchestrated by two Instructional Teacher Leaders who were part of the Instructional Leadership Team. These teachers described their roles as facilitating department meetings, planning monthly meetings, planning all of the staff professional development and executing it, and working with the administration to create the vision for professional development. They met twice a year with administrators and then had autonomy to carry out their responsibilities throughout the year. Departments met for 75 minutes each month but meetings were voluntary and teachers who attended received stipends. Eighteen hours of all-staff professional development was required of every teacher.

One form of professional development that was available every other month was *instructional rounds,* similar in theory to medical rounds, where teams of self-selected teachers observed several classrooms and collected data focused on a particular theme. The teacher leaders had taken a BPS course to learn how to implement instructional rounds in the school, and according to the teacher leaders, USA was the only school to incorporate it and use it school-wide. Over the course of three days, groups of 6-9 teachers took turns observing and collecting “nonjudgmental notes,” and teaching while observers focused on the “instructional core—[the] triangle between content, teacher, and students.” These teachers then collectively synthesized and analyzed the data to “look for patterns [and]…make connections” to “pull findings and make recommendations.” Information gathered from these instructional rounds was used to influence subsequent professional development.

Teacher leaders explained that they had autonomy as a school to figure out how to spend the eighteen hours of mandatory professional development, and they assigned six hours to teacher-led mini-courses. One teacher explained, “We collaborate to come up with a curriculum for the professional development, [which includes] a number of 1.5 hour meetings.” The teacher leaders solicited proposals from teachers interested in presenting three-session mini-courses, often on topics inspired by the instructional rounds, but also on other content related to teacher’s interests, expertise, and concerns. Teacher leaders explained that teachers got “a menu of courses to choose from” for these mini-courses, and to date “feedback from the staff has been very, very positive.” In this way USA took advantage of the expertise that was in the building. One teacher described the professional development as “very strong” adding, “We have a lot of good teacher leaders; if you walk into our meetings, you see a lot of good teachers…everyone is working on something [where] the focus, and the goals, and the follow-up are pretty clear.” In addition to the mini-courses, teachers sometimes shared posters about their classroom practices. For example, teachers participated in a poster session sharing ways they embedded higher order thinking into their lessons, and another on how they prepared students to re-take assessments related to the performance based assessment initiatives.

Teacher observation and feedback. Another form of teacher professional development focused more on the individual teacher. The administration worked hard to be in classrooms to provide guidance for teachers. According to one administrator, because USA was a smaller school, in comparison with larger schools, they had been able to better supervise and support teachers, and ineffective teachers were less able to “hide.”

As previously mentioned, USA was able to select some teachers based on their alignment with the school’s mission and vision. However, as part of the BPS system, at times they had to take in a teacher with seniority transferring from another BPS school or, in the case of the absorption of PATH, a teacher who was already teaching on the premises. These teachers might have no interest in the overall focus of USA and the administration assumed the responsibility of honing the staff to encourage them to function as part of the team, or to persuade them to seek work elsewhere.

The administration was highly proactive in evaluating new teachers, believing that was the only way to “get things moving.” Describing it as “the most frustrating part of the job,” an administrator spoke of the challenge of having teachers who did not “want to buy into your culture.” In addition, an administrator explained that having to spend extra administrative time “supporting someone who is not competent in a classroom” takes a lot away from the school’s priority of students and academic learning, and “It also doesn’t leave a lot of time for those teachers that are good and great and helping them improve, because they are clamouring for us to come into the classroom and provide support.” An administrator explained that some teachers felt “bothered by the [classroom] visits…bothered by the feedback…bothered by the monitoring,” adding, that some teachers had just been “left alone for so long that they are like ‘What are you talking to me for?'" However, administrators felt, however, that "feedback is kind, both positive feedback and probably even more importantly constructive feedback," saying that "a lot of folks haven't gotten that," adding that many long term teachers had never been observed, or coached, or provided feedback to encourage them to become better teachers. This intensified supervision and evaluation was described as the only effective way to "get them to work for you," or "ultimately get them dismissed or moved."

USA was also in the process of what one administrator described as "the whole special needs and English language learners infusion into the inclusion model." They were trying to meet the needs of all learners within regular classrooms through differentiated instruction and co-teaching models. Finding that while "fluent in their content…most of the more seasoned teachers have no experience in and were not trained" in differentiating instruction, this was important to help the teachers get "on board…to differentiate their instruction to meet student needs." The administrator added "There is no structure in place to have them really do it…it has to be a voluntary thing, or…forced." And, if differentiation was not done voluntarily by a teacher, an administrator explained that it was more directly encouraged through

> evaluation, which is not the best way to get someone on board. But if they are not buying into…supporting those things of the school or working with their team, or developing their understanding or even getting that feedback and not really doing anything with it, it kind of leaves you with no other choice."

However, even though the absorption of the more poorly performing PATH was "quite challenging," an administrator pointed out that an advantage of growing the school after a solid, successful foundation had been laid was that they didn't have to start "from the ground up." There were already "committed teachers…at the core of the high school," who an administrator described as being largely responsible for the improvement in student outcomes over the first five years of the school's operation. Administrators also described a "a good amount of existing structure" that could be used as "a blueprint for expanding the school."

Teacher survey responses. According to those who responded to the Teacher Survey teachers generally felt that there was time available for planning lessons, for professional development, and for working with other teachers (Table A-16). As described in the previous case studies, because of the way this question was designed, it was not possible to determine whether "adequate access" indicated that there was enough time or whether more would have been preferable. Teachers also indicated that the effect of time for these activities on their classroom practices was slightly on the positive side of neutral. It may be noteworthy that student access to technology in their homes was seen as both quite limited, and as having a distinctly negative effect on classroom instruction. This perception was also reflected in comments in focus groups and interviews with teachers, administrators, and students. However, there appeared to be time allotted for teacher and student technology instruction, for the maintenance of school technology, and for integrating projects including technology, and having this time had a somewhat positive effect on classroom instruction.

Table A-16

The Effects of Time and Access on Classroom Instruction (N=11)

Rate both your access to and the effect of each of the following on your classroom instruction:	Access[a] 1-3	Effect on Instruction[b] 1-5
1. Time available for teachers to plan and prepare lessons	2.6	3.9
2. Time available for teacher professional development	2.6	3.3
3. Time for teacher and student technology instruction	2.5	4.0
4. Time in school schedule for projects involving technology integration	2.5	3.5
5. Technical support for the maintenance of technology	2.4	4.0
6. Time available to teachers to work with other teachers	2.4	3.5
7. Student access to technology in their homes	1.9	1.9

[a]1=No Access, 2=Limited Access, 3=Adequate Access.
[b]1=Inhibits effective instruction, 2=Somewhat inhibits effective instruction, 3=Neutral or Mixed, 4=Somewhat facilitates effective instruction, 5=Encourages or enables effective instruction, 5=N/A or Don't Know.

Targeting School Reforms and Teacher/Student Needs

Teachers' professional development experiences appeared to be aligned with the targeted school reforms and teacher or student needs. Teachers described experiences in line with the BPS curriculum and the inquiry based approaches to learning they used in their classrooms. All-staff professional development was aligned with changes in the teacher evaluation process as well as to school-wide reforms that changed approaches to homework and lesson design implemented in response to research-based practices supporting student learning. The classroom observations and evaluations carried out by the administrators were targeted to individual teachers' particular needs to help shape the school-wide culture of teamwork and to address student learning needs.

The science teachers explained that inquiry based teaching was a fairly standard approach within Boston Public Schools, saying "the curriculum in BPS is designed from elementary through high school to develop inquiry," and "all curricula are designed around inquiry, so if you're teaching from the curricula, you can't avoid that." Science teachers described participating in BPS summer programs on inquiry-based teaching and others on AP coursework. During the previous year they had engaged in a collaborative coaching model of inquiry as a department. A chemistry teacher commented that she had also had observed other teachers doing inquiry and had taken workshops on inquiry. During the current year, because of the previously mentioned school-wide changes to performance based grading, co-teaching, and district-wide changes in teacher evaluation, the science teachers explained that professional development around inquiry-based teaching had "taken kind of a back seat," although they still focused on inquiry in their classrooms.

The teacher leaders explained that teachers had led the school-wide changes in student grading practices. Saying "This is a big shift for us: most teachers are used to grading in a very traditional way," teacher leaders added that changes such as these—"a heart change, an attitude change"—could be particularly difficult, and "there are a lot of teachers disgruntled." However, teachers' professional development efforts were focused on the identified reforms and as a teacher leader explained:

Even though everyone may not be 100% on board…we are moving in that direction. People talk about it; it's a common topic of conversation, but underneath that is really instructional practices, teachers' beliefs about students and what our role is, all these things come to the surface when you talk about grading. We knew that it would be hard. As far as I'm concerned, there is no argument on the table about whether the old system is better, but it only works to the extent that people believe in it and support it."

Teacher survey responses. When asked to reflect on the Teacher Survey as to how their professional development experiences influenced their classroom practices (see Table A-17), teachers identified experiences most likely to cause changes in their classroom practices, related to better understanding one's own STEM content and exploring its relationship to other STEM and non-STEM disciplines, as well as implementing inquiry, problem, or project-based learning. With teachers focusing on ensuring rigor in their courses and the development of cross-disciplinary projects, it makes sense that teachers noted the positive effects of these professional development experiences on their classroom teaching. Experiences that had a slightly lesser impact on changing classroom practices, but still confirmed the practices they were already using in class included those related to the school's targeted reforms of performance based assessments and meeting the needs of diverse learners in the classroom.

Table A-17

STEM Teachers' Perceptions of Impact of Professional Development Experiences (N=11)

Considering all your professional development, how would you rate the impact in each of the following areas? If your professional development experiences have not addressed the following areas, please check N/A.	Mean Score[a] (1-3)	N/A
1. Deepening my own S/T/E/M content knowledge	2.6	1
2. Learning how to teach S/T/E/M across the high school curriculum	2.6	2
3. Learning how to implement problem-based or project-based learning	2.6	2
4. Understanding student thinking in S/T/E/M	2.5	1
5. Learning how to integrate the different disciplines of S/T/E.M into my course	2.5	5
6. Learning how to use inquiry/investigation-oriented teaching strategies	2.4	1
7. Learning how to do performance based assessments in S/T/E/M	2.4	2
8. Learning how to teach S/T/E/M in a class that includes students with special needs	2.3	2
9. Learning how to assess student learning in S/T/E/M	2.3	2
10. Learning how to teach S/T/E/M in a class that includes students with special needs	2.3	2
11. Learning ways to use technology to communicate and collaborate with other educators	2.3	3
12. Learning how to teach engineering or design concepts or activities	2.3	5

13. Learning how to identify, locate, and evaluate technology resources that I can use with my students (e.g. websites, online data sets, etc.)	2.2	5
14. Learning how to help students perform S/T/E/M research	2.2	5
15. Learning ways to use technology to communicate and collaborate with families about school programs and student learning	2.2	6
16. Learning how to use technology to collect and analyze student assessment data	2.0	6
17. Learning how to use technology for student activities and experiments in the S/T/E/M classroom	1.8	5

[a]1=Little or no impact, 2=Confirmed what I was already doing, 3=Caused me to change my teaching practice, 4=NA.

Summary—Teacher Professional Development

Teachers at USA were supported through a solid program of professional development. Because they taught the same curricula as BPS, professional development provided by the local school system was relevant to their needs, and because of Massachusetts' investment in teachers, professional development opportunities were funded and often came with a stipend. In addition to system-wide opportunities, USA targeted professional development experiences to the school's mission and goals and research-based reforms that teachers and administrators determined would help achieve them. During the year of the OSPrI site visit, professional development was aligned with three general initiatives: a revised teacher evaluation system implemented at the BPS system level, performance-based grading that affected homework policies and lesson planning practices at USA, and classroom inclusion and co-teaching models to support diverse learners in the classroom. There were also ongoing efforts to help teachers provide opportunities for rigorous and high-level critical thinking through their lessons. Teacher professional development was group oriented as whole-staff, department level, grade level, and as pairs of co-teachers, and also individually focused as needed. Classroom observation and feedback was provided to all teachers new to USA and served as a way to help new teachers learn about and adapt to school-wide processes and culture.

In line with Desimone's (2009) framework for effective professional development, teachers' experiences at USA appeared to be both intensive and sustained throughout the school year. Neither teachers nor administrators mentioned organizing or participating in targeted USA based professional development before the school year started, but teachers described taking advantage of BPS-wide or funded content-based summer experiences. Professional development was sustained throughout the school year through regular daily, weekly, and monthly meetings, and by routine classroom observations by administrators. The content of professional development appeared to be well aligned with the intended reforms of the school and teacher and student needs, and teachers appeared to have some choice in the professional development in which they participated. The majority of the experiences appeared to involve active engagement by collaborative groups of teachers.

Collective Teacher Practice, Collaboration, and Teacher Professionalism

Teacher Collaboration

Teachers at USA collaborated in a variety of ways. There were formal co-teaching arrangements particularly in the 9th and 10th grades, and special education teachers co-taught through a "push in" model with teachers in the regular classrooms. Teachers worked together through their Instructional Teacher Leaders to determine their needs. They designed and taught mini-courses and participated in poster sessions to share classroom practices with each other. Teachers also worked together as departments to align coursework along a disciplinary continuum, and as grade-level teams to horizontally align courses and work on using common language across different subject areas.

Co-teaching. Co-teaching was implemented as a research-supported change to facilitate the inclusion of all students in the regular classroom, but also had a side effect of providing a platform for teacher collaboration around student needs. All core 9th and 10th grade classes were co-taught with either a pair of subject area teachers who had special education training, or a subject area teacher and a special education teacher. This change was implemented within the first couple of years that USA was open, and all teachers in 9th and 10th grades were co-teaching by choice. Those who chose not to co-teach were given the option of being reassigned to another grade or another school. Co-teachers, who had a period each day of common planning time, worked together in the same classroom and often interchangeably as lead and support teacher. According to an administrator, this co-teaching model allowed "more support to be brought to every kid" and made it possible for "teachers to divvy up the roles in running a highly effective classroom." Describing one effect of co-teaching, a teacher said, "I may present the problem one way and my co-teacher may present it a different way, and the students benefit." An administrator explained that the co-teaching model also helped "shift the culture" by restructuring the schedule to provide teachers with common planning time. This shift had the effect of encouraging some teachers—those misaligned with the school's focus—to relocate to other schools wanting "nothing to do with sharing their practice with another colleague" (Peters-Burton et al., 2014a).

Less formal, but still considered co-teaching was the model of inclusion for all students. For students who had been "identified under IDEA," one of the special education teachers explained, "I push into classes, so I teach one block of study skills and I follow them [identified students] into the regular education classes so I am familiar with how they are doing in their classes. A math teacher concurred saying that special education teachers "sit in the classes" and also have "one period a day [with students] to revisit what they learn…and for organization."

Collective practice. In addition to co-teacher planning time, teachers had two hours of common planning time each month. However, the Teacher Leaders explained, "We could always use more time…if you look at schools that are most successful, they have more professional development; we want to create a culture where people want to volunteer [to participate in more professional development.]" One teacher explained, "We do a lot of collaboration; doing some data research, creating a couple of small groups, a program of recognition for teachers…We're also coming up with some fairs or exhibition of our own best practices." Teachers explained that they were:

> doing a vertical teaming with all of the science teachers…having a common website where we'll have testable questions…use the common language; using common techniques; teaching students those basic skills of writing lab reports,

writing testable questions, writing hypotheses, identifying variables, designing experiments, doing conversions, so by the time they make it to senior year, [we] don't have to explain it anymore."

They added, "We were already scaffolding their learning, but we keep using different language [in different subjects]; everyone has their own technique and we want to make it coherent, such that by the time [the students] become seniors, this will all be second nature."

Sometimes teachers had to respond to BPS directives such as the recent district-wide system of teacher evaluation being implemented. One teacher explained, "We just do what Massachusetts tells us to do," adding "There is a new system …—all online—we spent a lot of the PD efforts this year in supporting teachers in how to use it." Teachers and administrators appeared to take such requirements in stride, making time in the professional development schedule for the changes, but not letting them overwhelm the school's focus on students and student learning.

On the Teacher Survey, when asked to identify the types of professional development they had experienced in the recent past, a majority of the teachers described having opportunities within the past three years to observe other STEM teachers, and to collaborate with STEM and non-STEM teachers to integrate content across the disciplines (Table A-18). These ratings are in line with the comments of teachers and administrators during interviews and focus groups describing how they had worked together during instructional rounds, and the kinds of interdisciplinary projects being piloted in 10th grade, with potential to expand to other grades. Teachers were less likely to identify that they had used telecommunications to collaborate with educators at a distance, or having attended state or national conferences.

Table A-18

Number of STEM Teachers Participating by Type and Timing of Professional Development Experiences (N=11)

	Current Year	1 to 3 years ago	More than 3 years ago	Never	No response
1. Observed other teachers teaching S/T/E/M courses as part of your own professional development (formal or informal)	7	2	1	1	-
2. Collaborated with a group of S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	5	1	2	2	1
3. Collaborated with a group of non-S/T/E/M teachers with the express purpose of integrating content from diverse disciplines	4	4	1	2	-
4. Met with a group of STEM teachers	4	1	1	3	2

on a regular basis to study/discuss STEM teaching issues					
5. Attended a workshop on S/T/E/M teaching	2	7	-	2	-
6. Used telecommunications to collaborate on S/T/E/M teaching issues with a group of teachers at a distance	2	1	-	8	-
7. Attended a national or state S/T/E/M teacher association meeting	1	3	1	6	-

Teacher pathways. There didn't appear to be obvious pathways for teachers to move into different roles within the school. However, the administration had empowered the teaching staff, through the Instructional Leadership Team, to be mindful of student performance and to both think about and be open to making changes that might facilitate improvement in student success. The Instructional Teacher Leaders described the formation of groups to research practices related to homework and performance based assessments, and to suggest changes. In accordance with the Boston Teachers Union rules, teachers had to vote with a 67% majority to make any curricular changes, so even teachers not directly determining the directions of the school were in the position to contribute to the decision-making. Teachers were encouraged to participate in instructional rounds to observe and evaluate classroom practices to suggest over-riding changes, and to propose and design mini-courses to present to their peers as part of school-wide professional development. Teachers were able to choose the professional development courses that they felt would be most personally valuable.

School Collaborative Culture

At the time of the OSPrI site visit, there were apparently two camps at USA, caused in part by the relatively recent absorption of PATH. There was one group of educators who had been on board from the beginning, along with others who bought into the mission, vision, and educational approaches of USA. A second group that was less well aligned. The OSPrI team interacted with the former group, and by administrative design, did not cross paths with those misaligned. As a result, the OSPrI team saw the vision that administrators had for the school and heard from teachers who wanted it to be successful. This is the part of the school collaborative culture that will be described in this section as it represents how the school is working its way back to the school culture that existed when USA was recommended as a "School on the Move." Side comments will be included as they relate to the struggles or difficulties caused by the merger and the changes of the increased school and staff size.

Comments from all members of the USA community reinforced several characteristics of the school's culture. They described a strong college-going focus, and explained that the majority of the people were at the school because they believed in the school's mission and vision, and were committed to seeing it to fruition. They described a feeling of belonging, like being part of a team or in a family. And there was the sense that all were open to new ideas and were working toward continuous improvement.

One teacher described the environment at USA saying "A lot of what makes this school a school is probably nothing you would see on paper. There's a real family vibe here. Students really respect each other and the teachers." This family feeling was reiterated by others: one student explained, "This school is really good at including everyone in everything," and a student talking about AP classes said "They [the teachers] make it so that those groups of AP students are like a family, at least in AP Chemistry." An administrator described the "family feel" at USA. According to one administrator, this family feel influenced how teachers worked with each other saying, "They have respect for each other as people and see each other as people, so when people are coming up short, they respect them enough to say, 'You know, something must be going on,'" adding, "They really want to work together." Science teachers described the school culture saying:

> The genesis was a very small school to begin with, with maybe 35 instructors…you either fit in and you contribute a lot, and then you [become part of] that corporate culture, of being a volunteer, willing to stay afternoons, join this club, join this leadership committee…It's kind of contagious. People recognize this, not that it's required, but that it's encouraged. The people who are not here any longer may not have wanted to make that investment. Everyone wants to play on that tightly knit team. If this works for them they stay; if they don't they move on. You're either here or you've left. It's a dichotomy. We've taken on a couple of wonderful teachers, but since I've been here, I haven't seen too many people leave. I think it's similar to a class…if you have a critical mass of really good students it ends up being a good class. We have a critical mass of really good teachers who just work their butts off and it's really contagious.

One teacher explained that one of the most important aspects of the school's success could be attributed to "the staff and the way the staff communicates," adding "I think that the staff here is amazing and the communication is excellent." Describing the staff interactions, a teacher explained "This is a fun bunch; we actually like each other and spend a lot of time outside of work with each other. All of the teachers I work with are smart and have a ton of personality. The administration is really good at interviewing—they bring in great personalities."

Many teachers described going above and beyond the minimal expectations for teacher contributions to the school community. A science teacher explained "We are all invested in this school working," adding "I can't think of a teacher who doesn't have another project that they contribute to the school," and "Everyone has something extra that they do in addition to classroom duties; it's not something that we're required to do, but I think it's something that sets us apart." Teachers invested time and energy into the collaborative school culture, each other, and their students.

Challenging courses and support. Challenging coursework leading to college-going was an important aspect of USA's culture. One teacher explained, "Teachers get excited about the challenge and rigor. The teachers desire to see our students struggle to use their brains." The majority of the 11th grade students in a focus group explained that they intended to pursue majors in some aspect of science and suggested that attending USA was good preparation for that. One student commented, "I want to go to [university] for professional science, and this [school] was my first choice, and I really love it here." And another student explained his choice to attend USA saying "I think this school offers a lot better classes…Here I got a chance to do AP classes." And when the going got tough in some coursework such as in their AP classes, students described feelings of solidarity saying, “It’s like they’re together as a group, and when you’re in that class, you get work done, because you know you’re there for that reason.”

Students felt supported and safe. According to one parent, “At USA…students were free to express their individuality and there was no bullying.” And to navigate the challenges, one student explained, “I feel like the name ‘guidance’ they do a tremendous justice to the name itself; they help you not just academically—there are people who come here with family problems and they help them too.” Even though students described having “understanding teachers,” the collaborative environment was not just teacher-student directed. One student explained, “Since there is only one teacher, you have to depend on each other in that class because there is so much work; you have to collaborate with other students.” In addition, students described “team pair and share periods” during class when they could seek help from each other. Classes were challenging, holding students to rigorous, high expectations, but the family culture led all to support each other as they worked to continuously improve. One teacher added “We aren’t throwing you in the deep end and you have to learn how to swim; we will support you and you will have to work to be a proficient swimmer.”

Continuous improvement. As described in previous sections, teachers and administrators were always looking for ways to improve teaching to better meet the needs of the students within their walls. Students also saw USA as “adaptive,” noting that it was able to deal with problems as they came up, to “adapt to the problem and change.” This idea was also reinforced by one of the school’s business partners,

> [The leaders at USA are] very receptive to new ideas and have always been receptive to new ideas and to extension opportunities…. The administration is very receptive and excited to hear new ideas and is always looking for ways to improve what they’re doing and do more for their students. They have a model of continuous improvement there, and you really see it from the administration all the way down to the faculty as well.

Small School. The changing size of USA within the recent few years was still a topic of discussion during the OSPrI research visit. Comments from administrators and teachers identified challenges that were being addressed. One teacher said, “I would attribute a lot of our success to being a smaller school then [prior to 2011],” and another added,

> When you’re trying to promote community, the smaller you are, the easier it is to keep track of that—easier to keep track of students, too. Now that we’re bigger it’s harder to keep track of those students, especially those who need help.

However, it was clear that the administration and the teachers were working collectively to retain their feelings of family and community, and sought to restore USA to her former position of success.

Supporting Learning by Students Underrepresented in STEM

According to the OSPrI case study (Peters-Burton et al., 2014a), nearly 90% of the USA student body belonged to racial or ethnic groups underrepresented in STEM, and nearly 75% of the student body was classified as “low income.” There had been notable positive trends on such measures as student rates of retention, dropout, four-year graduation, and attendance in the first five years after USA opened, but these trends moved negatively between 2009 and 2012 in the period surrounding USA’s merger with

PATH. It was clear that USA was still in a transitional period at the time of the OSPrI site visit. However, even with these changes, it is notable that when disaggregated, African American and Hispanic students at USA were performing better on the SAT, and four-year graduation rates were higher for African American, Hispanic, and female students at USA than a local comparative school, and were nearly on par with Boston Public Schools overall.

Teachers responding to the Teacher Survey identified feeling relatively confident about their abilities to engage students using a variety of reform instructional strategies (see Table A-19). They could encourage students' interest in STEM, and engage students in hands-on, project-based, investigative work. In keeping with USA's inclusion model and its diverse student population, teachers also identified being reasonably confident that they could recognize and respond to student diversity and help students take responsibility for their own learning. They were less confident, although still slightly positive, about their abilities to encourage participation by underrepresented students in STEM. Parents were welcomed at USA, and teachers identified some confidence in involving parents in their students' learning.

Table A-19

Teacher Confidence in Utilizing Teaching Strategies (N=11)

I am confident in my ability to:	Mean Score[a] (1-5)
1. Encourage students' interest in S/T/E/M	4.2
2. Manage a class of students engaged in hands-on/project-based work	4.2
3. Recognize and respond to student diversity	4.1
4. Help students take responsibility for their own learning	4.0
5. Lead a class of students using investigative strategies	3.9
6. Use strategies that specifically encourage participation of females and minorities in S/T/E/M	3.6
7. Involve parents in the S/T/E/M education of their students	3.4

[a]1=Strongly Disagree, 2=Disagree, 3=Neither Agree nor Disagree, 4=Agree, 5=Strongly Agree.

Classroom Time

Teachers spoke of using inquiry-based practices, and changing their classroom approaches from day to day. Classroom observations demonstrated a mix of teacher led, individual, and small group learning. A calculus teacher explained that the students were assigned to groups "who can help them with information," but that they also moved around to partner with different students. Another teacher described helping students learn to engage in collaborative problem solving, and another spoke of peer-to-peer instruction saying, "We utilize the kids that already know and the peers teach [each other]."

During an algebra class, an OSPrI researcher commented on the "incredibly efficient use of time" during the class, noting "not a moment wasted," that the teacher was "businesslike but warm, friendly," and the students were "struggling but engaged most of the time, [with] lots of variation between students, some on the same page and some on a different planet." And added, "I feel like I watched a highly orchestrated class; the teacher is very comfortable and competent."

A geometry teacher explained that she teaches differently on different days. For example, she may start with a day devoted to a discovery activity, then a practice day, then a day extending the learning objective to different types of problems—described as contextualized real world vs. standard geometric representation—and then an assessment day.

BPS encouraged inquiry type learning and supported it with professional development opportunities. One teacher explained, "The curriculum in Boston Public is designed from elementary through high school to develop inquiry." A physics teacher added, "The curriculum I use is standard and based on inquiry." One teacher described striving for guided inquiry in class saying, "Guided inquiry would be the goal—where students come up with testable questions, and make hypotheses and then design [an] experiment."

According to an administrator, there were some limitations to engaging students in the lab sciences saying,

> Although the city spent $100,000 renovating one of our chemistry labs, there is still a limited number of classrooms on the campus equipped for lab-based science courses—five to be specific. Obviously, this limits the number of lab-based science courses that can be offered.

LFCOP (Lesson Flow Classroom Observation Protocol) data from the seven observed STEM classes showed that no one format for the use of classroom time was maintained for the entire period (see Table A-20). Teachers were the center of attention for an average of 43% of the time in these seven classes, but the time ranged from 13% in a psychology class to 70% in a chemistry class, and in only two of the classes was more than 50% of the time primarily focused on the teacher. In all of the observed classes, at least part of the class time was spent in either small group or individual learning activities.

Table A-20

Organizational Grouping and Percent of Class Time[a]

Class Type[b]	% Student-directed Small Group Focused	% Individual Student Focused	% Teacher Focused	% ONLY Teacher Focused[c]
M-Algebra I	34	0	66	66
M-AP Calculus	63	7	30	30
M-Geometry	0	48	52	52
S-Biology	63	0	37	37
S-Chemistry	3	23	70	70
S-Physics	50	15	37	33
[d]S-Psychology	24	10	46	13
MEAN	**34**	**21**	**48**	**43**

[a] More than one activity could occur at the same time, so percentages may add to more than 100.
[b] M=mathematics, S=Science, I=Integrated/Engineering.
[c] Small group, individual, and teacher led activities could be occurring simultaneously. This last column identifies time when all students were focused on the teacher as in a lecture class.
[d]USA considered psychology part of the science department.

Classroom projects. Designed to generate student interest, to help students learn how to do projects, and to provide opportunities for students to present their work, projects appeared to be an increasing part of the 9th and 10th grade curricula. Ninth grade math teachers described course level project assignments where students learned some of the basics of project-based learning. For example, students were asked to statistically analyze data, write about it, and, using a rubric, present posters or give PowerPoint presentations to their class. The math teachers described 10th grade interdisciplinary class projects "where a piece is expected from each subject and at the end they do an oral presentation." Students worked on a single project in all of their classes for a week. One project, entitled *Design for Justice*, had students design a house for immigrant farmers using a budget of $30,000, where they learned about housing designs in science, scale designs and budgeting in mathematics, and writing about justice in their humanities classes. Describing the process of project development, one teacher said that since this was a newer approach to learning, the focus was on getting students to "know what a project is, and give them experience with oral presentation." The success of the first interdisciplinary project led 10th grade teachers to expand this type of learning reform to once each quarter, and to explain that they were hoping to expand interdisciplinary projects into the 9th grade in the future.

Developing STEM Identity

Classroom strategies were designed to help students develop competence in their coursework with the ultimate goal of going to college. Ninth and tenth grade core courses were co-taught to support to a diversity of learners as students developed the skills necessary to learn more independently. Changes in grading to performance based methods meant students were provided multiple opportunities to master course content and pass assessments, and were not penalized for failing to complete homework or participate actively in class. Teachers' use of *backwards planning* in curriculum design helped students understand the anticipated learning outcomes as they began a lesson. A focus on coursework rigor led teachers to incorporate more opportunities for student higher order thinking in their lessons.

Students were also provided programs and opportunities beyond the classroom supported by BPS and community partners to help develop their interest in the STEM fields and to develop social, emotional, and learning skills that might contribute to their ability to be successful in college.

College-Going

A primary focus of learning at USA was on college-going, with the goal of ensuring that students were aware of their choices for the future and that their coursework was preparing them for the challenges of the college environment. The headmaster explained that over the years, the rates of college attendance for USA students had been steadily increasing and at the time of the OSPrI site visit approximately 90% of the students were expected to go to a two or four year college after graduation. USA placed an emphasis on course rigor, advocated for students to take at least one AP course, and encouraged students to participate in any of a number of programs designed to help them prepare psychologically and academically for college and the real world. Not all of these efforts took place in the classroom, or were the responsibility of the classroom teachers. Academic rigor was. Classroom teachers generally aligned their course curricula with BPS, and worked to meet the needs of a diversity of learners in the classroom. One teacher described:

> [I can focus on] information about whether the students are achieving these standards. I've had to have multiple versions of every assessment to allow students to retake them. Also [I] need to make sure I have time to give adequate feedback or make sure that I've managed to provide adequate feedback.

Opportunities for internships or to participate in programs that increased students' likelihood of going to college were funneled through the Family and Community Engagement Specialist who solicited and advertised opportunities for students, and also arranged for in-house programming. There were a diversity of programs—13-week long in-house health education program for 9th graders provided by college volunteers from the Public Health Exchange designed to help students with "decision-making" about their health and future goals; creative workshops led by a partnering organization leading to science fair project development for 10th graders that might help students "get a sense that science is for them;" and a College Bound program that focused on "reaching out to students who didn't see themselves in STEM careers" (Peters-Burton et al., 2014a, p. 37). Teachers sometimes served as mediators, participating in professional development with the partners and helping to facilitate programming within their classes or perhaps as instructors for off-site programming. One partner characterized the importance of the community coordinator saying:

> When our volunteers show up, [USA is] ready and expecting us. It's how organized and on top of things they are that makes it so easy on our end to execute the workshops on a weekly basis. I'm not worrying about whether they'll actually be there, or if it's the right room. It operates like a well-oiled machine.

Academic rigor. According to the OSPrI case study, the administration and faculty at USA were mindful of how they planned for and maintained rigor in their curriculum, particularly in STEM content areas. USA held high standards, supported the wide variety of students they served, and guided students to a "post-high school plan that would help them increase the likelihood of being successful in life" (Peters-Burton et al., 2014a, p. 16). Teachers commented, "We realize that we need more rigor and we are constantly working on that. It is not a subject we take lightly. We do not say 'Okay we reached a level and we are done.'" All classes at USA were described as being college preparatory. However, when teachers were asked whether their classes prepared students for the rigors of college, most agreed that their AP classes prepared students well, but that their lower level courses probably did not adequately do so. USA's goal was that every student would take at least one AP course, but preferably two or three. A guidance counselor explained,

> There are some schools that have requirements on who takes AP. We don't do that here at USA. I have students who may not be the typical AP recruited students. We don't limit that at USA. We allow everyone to take AP. If you have the interest and you're committed to learning, take the course.

To facilitate student participation in AP courses, many of the courses offered summer bridge programs that helped students prepare. The headmaster explained:

> Because for us, the philosophy for our AP program is that if kids express interest and their willingness to do summer bridge work, they are welcome to participate in the class. We try to eliminate gatekeeping mechanisms…knowing that kids that experience the rigor of college courses in high school do better in the college, period.

And added, "Just having the college level rigor, regardless of how they do on the AP exam, it is about having them have the college course experience." Science teachers concurred. In the science teachers' focus group, teachers explained that their introductory level courses in biology, chemistry, and physics didn't really prepare students for college level learning, but their AP courses did the job well. And even though many students who took the AP courses did not earn scores on the exams high enough for college credit, one teacher commented that alumni had returned to say, "They felt they were prepared for college." A chemistry teacher added, "At least they won't drop out of a college level course after taking AP chem." because they have learned what it feels like to be in a challenging, college level course.

Developing interest. An administrator identified the importance of connecting course content to students' lives saying, "When you make it relevant to the kids, the kids see that is doable. I think our teachers do a really good job of making science relevant to kids." A physics teacher explained that she used hands-on activities to "hook the kids" and to help them be more willing to engage in the necessary reading or math to help them understand physics. She explained that she wanted students to "be exposed to something different that they may not have known before entering the class…to connect with things in the real world," and added, "If they can remember that they learned something about how to understand their world a little better, and [are] able to think a little more creatively and scientifically, that's good."

Scaffolds for learning. Teachers and administrators worked to ensure that scaffolds were in place to make STEM learning accessible to all students. The co-teaching model in place in 9th and 10th grade provided space to address the needs of all learners. Changes to curriculum design to involve *backwards planning* helped students know the goals of a lesson before it began. Efforts were in place to help students develop skills that they could use throughout their time at USA, and teachers worked on common language across the disciplines to help students connect learning in their different classes.

One math teacher explained that the co-teaching model gave freshmen and sophomores "twice the perspectives and twice the brain power," adding,

> I may present the problem one way, and my co-teacher may present it a different way and the students' benefit. We both circle around and we can reach twice as many students that way. It allows us to support all the students so no one falls into the cracks.

A 9th grade teacher commented that for students "new to the high school, there are a lot of changes…there's a lot of newness," adding that even though "[each teacher] has their own classroom style…as 9th grade teachers, we all work together and try to have the same classroom rules" to provide consistent expectations. Another 9th grade teacher described teaching organizational skills, "In the beginning of the year it is very structured, but by the end of the year they should be able to do it on their own. This is the hope." A physics teacher described helping make learning visible, by

> constantly calling kids up to the board and having them put their work on the board [where] we can talk about common mistakes that we see. Some students may find a different way to do it and I like that, I encourage that. If you can find a different way that works for you. That's good."

During a 9th grade lab, one teacher explained to her class that to plant seeds of student independence, "I am not going to go step-by-step; you have to follow directions with your group members…go through the motions step-by-step," During class time, the teacher regularly reminded students how they should be engaging with the content, how they should be taking notes in their notebooks, and how they should be working with each other in lab. The teacher was attentive to students' work and behavior and spent time helping them learn how to engage more independently in lab.

Other supports included academic tutoring three days a week after school when teachers were available in their classrooms to meet with students for tutoring, extra help, or for just doing homework.

Summary—Learning by Students Underrepresented in STEM

Students at USA had opportunities to become interested in STEM and to learn about careers. While some opportunities took place in their classes through projects or teacher conversations and initiative, the majority of the connections appeared to be accessed through partnerships with outside organizations. Some programming through partners happened in the school and was offered on a school-wide or grade-wide basis, but many of the opportunities appeared to be limited to a specific number of students and not universally available. Students commented that there were many opportunities for activities such as internships, that the liaison was "always advertising" these opportunities, but that students had to take the initiative to apply and participate.

Students became competent in their STEM coursework through academic classes that scaffolded their learning ultimately preparing them to meet the challenges of college level work. Ninth and 10th grade co-taught classes met students where they were, helped them learn how to learn, to engage in projects and group based peer-to-peer activities, and to become more independent as learners. AP coursework provided opportunities for more advanced college-level learning. Performance based assessments provided for student mastery and the teaching staff engaged in regular, consistent efforts to adjust methods and strategies to better meet students' needs, to integrate academic rigor and higher level thinking into all lessons to help students prepare to attend college. Teachers identified a few opportunities for students to present their work as part of their project-based learning. Student participation in AP classes appeared to facilitate students' sense of belonging in a community of scholars.

Analysis and Discussion

USA was the only one of the four schools in this study that was directly connected to the public school system such that it used the same curricula and was subject to the same teachers union rules. Using the same curricula appeared to have the generally positive effect that teachers could take advantage of BPS professional development targeted to specific courses and initiatives such as inquiry learning. While the teachers union itself didn't appear to be particularly problematic—all teachers belonged—USA did not seem to have the same flexibility in teacher hiring that was afforded to the previous three schools described. This led to teaching staffs that were not completely aligned with the mission, vision, and goals of the school, and therefore required substantial administrative time to help all teachers become active and collaborative participants.

The administrators had a vision for USA, and where possible, teachers were hired who aligned with this vision. The most clearly articulated criterion was that teachers were interested in being part of a collective group working toward a common goal. Administrators worked intentionally with all teachers and teacher groups to help them learn to become collaborative contributors within their departments and collectively embrace a sense of autonomy in shaping their curricula and classroom practices toward the ultimate goal of helping their students successfully prepare for college. The majority of the teachers hired held bachelor's degrees and were certified in their subject areas, more than 70% held master's degrees most of which were in education, and most teachers had been teaching for more than five years.

Teacher professional development, both provided by the school district and designed in-house, appeared to be aligned with the school coursework, school reforms, and teacher and student needs. Teachers described ongoing time during the school day, week and year to engage with others, and teachers described both a collective and an individual voice in shaping their professional development experiences and their classroom practices. Certain practices such as performance based grading, an inclusion model, and co-teaching in 9th and 10th grades, were implemented at a school-wide level, and while not all teachers may have agreed with these practices, all teachers were responsible for engaging in them as appropriate to the courses and grades they taught.

"Professionalization"

Teachers. There was a collective spirit at work at USA and teachers who had bought into the school-wide reforms supported and encouraged each other. Teachers appeared flexible and open minded, and willing to try new approaches to student learning that were grounded in the research literature. Teachers appeared to feel very much in charge of their professional development and their learning. Two teacher leaders helped facilitate professional development experiences, but all teachers had the opportunity to contribute by participating in instructional rounds, gathering data and suggesting changes, proposing mini-courses that they could offer to their peers, and by participating in poster sessions to share their practices related to school reforms.

Teachers also felt empowered to adjust the curricula in their classrooms. AP teachers as well as teachers of some of the more specialized courses in computer science, forensics, and Urban Ecology had greater autonomy in their curriculum design, and teachers of the core courses had latitude to "tweak" their curricula. A physics teacher explained that while "the curriculum I use is standard and based on inquiry," teachers had opportunities to "supplement and make it your own." A biology teacher described his curriculum saying,

> It's a combination, mostly. A few years ago it would have been through the curriculum: BSCS using the 5 E model. A lot of the activities and the labs were

> taken from this, but a lot of others were taken from PD and courses I've taken. I took a contextualized content course that was a lot of alternative approaches to things in BSCS. We would take a topic and then take a few anchoring activities and build a unit from there. Also there were activities from the AP summer institute and I've changed to use here.

Meeting student needs. Teachers described being able to modify their courses to address the needs of the students in their classrooms. A teacher explained that because students were "missing some skill sets," teachers tried to give students different kinds of materials to help them "access the curriculum." One teacher described having to "change it from what is a typical level" by modifying the reading levels or writing responsibilities to meet the students where they were to help them progress in their learning. Another teacher described a department-wide goal of having students come up with their own testable questions, or testable hypotheses, adding

> I find I have to scaffold much more than I'd like to…[I am] still working on helping students figure out how to write a testable hypothesis; I'm still giving students a lot of up-front information, structuring this aspect of the lab.

A chemistry teacher reiterated this, explaining that when she tried to have students do more complex labs they were "missing some of the more basic skills," so instead focused on helping students design more basic experiments to get the idea of writing procedures. And speaking about her AP chemistry course, a teacher explained that she had the "feeling that I move at a much slower pace than other schools might" in order to try to accommodate students' learning. As a result, her students have had a "moderate to abysmal success rate" of passing the AP exam. The teacher added that while she had seen other AP chemistry curricula, she had not had opportunities to see other teachers teaching AP courses and was conflicted between "exposing my students to enough, and …completely overwhelming them with information."

Student Development. USA explained that they targeted high standards for students and provided the social and emotional environment, academic supports, and scaffolding to meet them. Within the school, OSPrI observers noted "evidence of a comfortable working relationship" (Peters-Burton et al., 2014a, p. 26) between teachers and students in a class, adding "students are polite and respectful of the teacher and their classmates," and when working in groups the "students seem to be cooperative and respectful" (p. 26). One teacher explained that the students "know…that you care" and "they seek you out for help." Co-teaching in 9th and 10th grades supported both teachers and students. Teachers had common planning time during which they could discuss problem areas and collectively design classroom activities, and students had two different perspectives from which they could learn.

Students were provided with a structure to become more independent and advocate for themselves. Commenting about USA and the teachers, one student said, "They make great individuals out of us." The special education coordinator explained that all students learn how to advocate for their own needs with respect to classroom learning, saying "Over time they have success…they practice that skill… little by little they are expected to be more independent," adding, "If they have been at USA since they were in 9th grade, they can self-advocate." Explaining that the opportunity for all students to take AP classes gives students "a chance to take a challenge," a student added that this participation “shows or depicts your level of self-discipline.” Students in AP classes also described feeling like “family.”

While the needs of a diverse student body were a significant driver of curriculum and instruction at USA, students themselves did not appear to play a particularly strong role in the directions of the school. One student made this comment about the accessibility of the administration when he had concerns,

> I was able to go speak to a higher power and let them know that I don’t agree with the grading policy; we had a meeting on it and spoke of it. … Honestly I felt like my voice was heard. It reassured [me] that this is a good school.”

However, comments such as these were not widespread, and evidence of student empowerment beyond individual choice and self-advocacy seemed limited. There did not appear to be school wide initiatives to drive the development of student autonomy or collective empowerment. Many opportunities existed for students to acquire career and college awareness and preparation, but it was not obvious that the school chose to ensure that *every* student would be prepared. Some programming was designed for an entire grade level, but many programs appeared to require student initiative and independence to participate.

Assimilation and Transition

For the year preceding the OSPrI visit (most data are from years 2011 or 2012, or the 2011-2012 school year) attendance rates were below 85%, the dropout rate nearly 9%, the retention rate over 14%, and a four-year graduation rate of just over 64% with about 62% of graduates attending college (Peters-Burton et al., 2014a). It appeared that at the time of the OSPrI site visit—a time of assimilation and reorganization—that USA was struggling to regain their previous success. Also, even though teachers and administrators said students were held to high standards, it appeared that standards for student work were lowered so that students could achieve them and pass. The articulated goal of ensuring that 80% of students attending school 80% of the time would pass, appears itself, to be a relatively low standard. The OSPrI team was also told that all courses were “honors level,” but teachers explained that their core academic courses did not necessarily prepare students for the rigors of college. And even with the AP courses, the majority of the students did not earn scores on the AP exams high enough to earn them college credit, although teachers indicated that student enrollment in AP courses helped them be better prepared for their college coursework. In addition, even though the goal was that every student would take at least one AP course, but preferably more, at the time of the OSPrI visit, one administrator explained that only about 50% of the students had accomplished this goal. One thing worth considering is that USA was in the “third tier of selectivity” among Boston Public Schools.

The bones of a successful model appeared to be present: administrators had vision, and much of the teaching staff was aligned with this vision. Teachers were empowered to discover and respond to student needs, and appeared to work hard to meet the students where they were and help them make progress toward success. Teachers also took responsibility for and actively engaged in professional development that was designed to address collective concerns. Student needs were at the center of all motivations for change, and there were opportunities for students to develop autonomy in their learning. However, with the increasing school size, challenges of hiring teachers aligned with the school’s vision, and even perhaps a reduction in student alignment with the school's focus because of the absorption of some of PATH's student body, it appeared difficult to ensure that all students were on track to achieve this goal.

Appendix D – Codebook

Codebook from conceptual and operational definitions for each aspect of the model described in the conceptual framework

Aspect of Model	Conceptual/Theoretical Definition (Literature-based)	Codes, Coding Names, Operational Definition (keywords, phrases and concepts)
STEM Teacher Academic Background and Experience **(ACAD)** **(EXP)** **(COS)** **(PROF)**	Teachers prepare to teach STEM courses by completing academic coursework, earning degrees in STEM, participating in teacher preparation programs and becoming certified to teach. Teaching experience and professional STEM experience also contribute to teacher quality.	Content coded under this aspect of the model will focus on the training and experience that teachers bring to their positions in the ISHS to include: • Academic background including subject-area coursework, college or university attendance, degrees, majors, content knowledge **(ACAD)** • Teacher training including college or university programs or degrees, certification, type of certification including traditional, emergency, alternative, special programming, in-house **(ACAD)** • Teaching experience, years of teaching, pedagogy, pedagogical content knowledge **(EXP)** • Teacher cosmopolitanism as measured by type of college or university, location relative to ISHS **(COS)** • Professional experience including former non-academic positions and research experience **(PROF)**
Teacher Professional Development **(PD)** **(CORE)**	Effective professional development is focused on relevant content and pedagogical content knowledge that is coherent with teacher and student needs or school reforms, involves active learning, is intense and sustained, and involves teachers in collective or collaborative practice (Desimone, 2002). The content focus and educator expertise of	Content coded for this aspect of my model will include descriptions of the actual professional development experiences including: • Administrators' perceptions of professional development—what is offered, why it is offered, intent of the experience, school reforms tied to professional development **(PD)** • Teachers' perceptions of professional development experiences—how they relate to

	STEM-targeted experiences may be significant.	their needs or student needs, how they relate to school-wide mission or reform goals, relevance to subject-area content **(PD)** • Duration and extent of provided professional development; type of learning experience **(CORE)** • Time available for meeting with other teachers to discuss teaching and learning **(CORE)** • The existence of collective or collaborative practices among teachers **(CORE)**
School Collaborative Culture **SCC** **(ENV)** **(COLLAB)** **(TRUST)** **(TAUTO)**	A collaborative school culture may contribute to the enhanced effectiveness of teacher professional development through greater diffusion or professional learning and the perpetuation of desired school reforms. A collaborative culture may provide greater opportunities for such activities as reflective dialogue, visible classroom practice and group decision-making.	Content coded under this aspect of the model will include both descriptions of how collaboration occurs at the ISHS as well as participant's perceptions of the school environment as collaborative or supportive, to include: • Teachers', administrators' or students' perceptions of the school environment **(ENV)** • Relational trust, support for trying out new activities, procedures, lessons **(TRUST)** • Teacher feelings of autonomy (but not necessarily independence) **(TAUTO)** • Reform practices in the classrooms, student-centered learning, student dialogue **(REFORM)** • Collective participation, collaborative decision-making **(COLLAB)** *(I think I intend this to be teacher collaboration, but it could also be collaborative decision-making involving students about the direction a lesson or class will go rather than students just working together on a project which should fall under IDENTITY)*

Teacher Professionalism **TPROF** **(TAUTO)** **(RESP)** **(DECIS)** **(LEAD)**	Teacher professionalism or professionalization may involve teacher autonomy and decision-making capacity both in the classroom and in the school, opportunities for leadership positions or involvement in a distributed leadership capacity within the school.	This aspect of the model is partially subsumed under school collaborative culture, but data specifically reflecting teachers' autonomy, decision-making, and opportunities for leadership will be additionally coded. This will include: • Collaboration in decision-making **(DECIS)** • Collective responsibility for decisions and results **(RESP)** • Leadership structure, distributed leadership, flattened hierarchy **(LEAD)** • Teacher empowerment and autonomy both in the classroom and in the school **(TAUTO;** note: this overlaps with autonomy through school collaborative culture**)**
Learning by Students Underrepresented in STEM **(IDENTITY, includes: interest, comp, present, recog)** **(SEL)** **(AST - autonomy supported teaching or student-centered teaching)**	Both classroom practices and the socio-cultural environment in a school have the potential to affect student learning. Student learning can be enhanced when their teachers hold student-oriented beliefs (DeVries et al., 2013), engage in autonomy supported teaching practices (Roth & Weinstock, 2013), support student development of a growth mindset (Dweck, 1999), and when schools otherwise have active social and emotional learning programs (Durlak et al., 2011). The development of a positive STEM identity can lead to greater participation in STEM. Classroom practices that better support the development of STEM identity involve opportunities for students to become interested and competent in STEM and also	Content coded under this aspect of the model will include those social and emotional factors or classroom practices identified as having the potential to influence learning by students underrepresented in STEM. These may include: • Classroom practices related to project-based or problem-based learning, inquiry learning, student dialogue, student-designed investigations or projects **(ID-PBL)** • Collaborative or cooperative classroom activities **(ID-Collab)** • Classroom learning that focuses on STEM careers, applications of classroom content to real world issues, or underrepresentation in STEM **(ID-Interest)** • Experiences that particularly encourage students to be successful in STEM fields **(ID-Enc)** • Classroom activities that

	provide contexts to facilitate student performance and recognition of their STEM abilities (Carlone & Johnson, 2007; Hazari et al., 2010).	demonstrate teachers' use of autonomy supported teaching, student-centered teaching through evidence of student independence in learning **(ID-AST)** • Classroom practices that support learning *how* to work in groups, on teams, dealing with social and emotional aspects of group work **(AST)** • Professional development that targets social and emotional learning, mindsets, theories of learning, stereotype threat **(SEL)** • Classroom learning targeting SEL, evidence of SEL practices or philosophies **(SEL)** • Evidence of student development of autonomy, agency, or self-regulation **(SAUTO)**