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Becoming a STEM-Focused School District: Administrators' Roles and Experiences

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Abstract: Science, technology, engineering, and mathematics (STEM) schools and districts continue to emerge, and while some research highlights critical components to be included in STEM schools, there is a need to learn more about the process of becoming a STEM school or district. In this study, we investigated a rural United States school district's development and expansion of its STEM education focus, which started in the years leading up to the district's first STEM school opening in 2012. We addressed the research question: How is a district-wide STEM education vision developed, enacted, and sustained by various administrative stakeholders? We interviewed 11 participants, all of whom had some level of administrative responsibility related to the district's STEM mission, coded interviews based on the critical components of STEM schools, and used narrative inquiry methods to describe the district's STEM transition from these administrators' perspectives. Our analysis revealed that several key critical components were central to this district's STEM mission. These components included elements related to leadership, reform-based instructional strategies, and teachers' professional learning. By focusing on different elements at different times and prioritizing several key components throughout, this district was able to achieve its goal of providing STEM instruction to all of the elementary and middle school students.

Keywords: STEM education; STEM school; distributed leadership; school administration

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1. Introduction

Science, technology, engineering, and mathematics (STEM) education continues to receive educational emphasis in the United States and in many countries around the world. Within the United States, the *Next Generation Science Standards* (NGSS) [1] provide policy guidelines for STEM education through the inclusion of engineering practices and the promotion of the integration of mathematics and computational thinking within K-12 science learning contexts. At this time, 44 states have either adopted the NGSS or developed their own educational standards based on *A Framework for K-12 Science Education* [2], which was the foundation for NGSS development. With this widespread influence of the NGSS reaching over 70% of US students [3], it is clear that the country has shifted from the rote memorization of scientific facts toward the authentic engagement of students in STEM practices.

The President's Council of Advisors on Science and Technology pointed to STEM education as the determining factor in responding to the challenges of the 21st century, and called for the creation of STEM-focused schools [4]. A large number of STEM schools exist and continue to emerge, but there is a lack of clarity about what it means to be labeled as a STEM school. The Committee on Highly Successful Schools or Programs for K-12 STEM Education identified three different STEM school types: (1) selective STEM high schools, (2) inclusive STEM high schools, and (3) STEM-focused technical and career readiness schools [5]. In addition, some STEM schools focus on providing strong instruction in each of the separate STEM disciplines, while others focus on STEM integration, merging the disciplines. This lack of consensus extends to the conceptualization or definition of integrated STEM education [6–12], with researchers also questioning the relative emphasis placed on mathematics and technology compared to science and engineering [13–15].

Despite the range of approaches to STEM education, it is clear that school-level systems and supports are needed in order to sustain STEM education efforts [16–18]. STEM schools and districts continue to emerge, and while there is some research highlighting the critical components to be included in STEM schools [17–19], there is a need to learn more about the process of becoming a STEM school or district. In this study, we investigated a rural school district's development and expansion of its STEM education focus. In particular, we addressed the research question: How is a district-wide STEM education vision developed, enacted, and sustained by various administrative stakeholders?

2. Literature Review

A variety of STEM schools have emerged in the US, utilizing a range of admissions procedures and criteria [5]. Selective STEM schools are often highly competitive and tend to have a low enrollment of minority students [20], which is concerning given the ongoing underrepresentation of minorities and women in STEM fields [21]. In contrast, inclusive STEM schools have an explicit focus on equity, and focus specifically on serving historically underrepresented youth [18,22]. These schools operate on the premise that STEM skills and practices can be developed for all students, and that students from traditionally underrepresented groups need to experience opportunities for STEM development [23]. Non-selective admissions policies allow students who may not have experienced past success in science or mathematics to attend inclusive STEM schools, with the goal of developing their interest and ability in STEM.

There remains a need for additional research on STEM schools, but some promising results have emerged from studies of inclusive STEM schools. Comparing the achievement outcomes of students attending inclusive STEM high schools to those attending traditional high schools in Texas, Young et al. [23] found small but statistically significant effects that favored students who attended STEM schools. The outcomes included increased student attendance rates, as well as higher performance on standardized tests of reading, mathematics, and science. Using a longitudinal dataset of students attending New York City public high schools, Wiswall et al. [24] found that students attending a STEM high school outperformed those who attended schools without a STEM focus on tests of mathematics and science. However, once prior performance was accounted for, this advantage was greatly reduced.

Although the findings regarding the presence and magnitude of achievement outcomes linked to inclusive STEM high school attendance are mixed, various studies have provided evidence that the benefits of attending an inclusive STEM high school extend to interest in STEM [20,25,26], confidence in pursuing higher education [20], the completion of advanced mathematics and science coursework [23,26], and STEM career aspirations [26], with students attending inclusive STEM high schools demonstrating more favorable outcomes than their peers attending traditional high schools. Notably, two studies [24,27] found that the benefits of inclusive STEM high schools are greater for students from traditionally underrepresented groups, and that inclusive STEM schools may contribute to increased equity in STEM.

While these results are promising, the majority of the positive findings have had small effect sizes, and may not have adequately accounted for students' prior academic achievement. Research by Eisenhart et al. [28] suggested that the initial successes of STEM schools may be difficult to maintain over time. Indeed, Gnagey and Lavertu [29] found that inclusive STEM high schools were sometimes associated with negative effects on both STEM and non-STEM achievement. The researchers attributed these negative effects to a focus on problem-based, personalized learning at the cost of science and mathematics content.

The majority of studies, including those already described in this section, focus on established high school contexts and student outcomes associated with STEM school attendance. There remains a gap in the research base related to the process of becoming a STEM school or district. Within this limited research base, the most prevalent studies explore the initiation of STEM programs within a school, for example the addition of (a) after-school STEM programs [30,31], (b) robotics and makerspace curricula [32,33], and (c) STEM projects [31,34–36]. A small number of studies have systematically explored the opening of a STEM school. For example, Sikma and Osborne [37] identified tensions between top-down approaches to education and the need for teachers to redesign STEM curricula within an elementary STEM magnet school. Siegel and Giamellaro [38] used a phenomenological approach to explore how STEM was defined in a school district, particularly focusing on teachers' adoption and appropriation of "STEM", emphasizing teachers as co-designers of school innovation. In a follow-up study, Siegel and Giamellaro [39] explored the work and contributions of the non-STEM teachers in the district. The use of the engineering design process to support the implementation of STEM was central for non-STEM teachers to incorporate STEM into their instructional practices. Slavit et al. [34] explored the work of teachers during the start-up process and first year of an inclusive STEM middle school. The teachers needed more specific support to successfully develop integrated STEM projects because a vision for STEM and problem-based learning was not solidified during the first year as a STEM school. Most critical was the willingness of the teachers to work collaboratively as curriculum designers and to take risks, an attribute also noted by El Nagdi et al. [40] in their study of an emerging STEM program in an urban middle school. Finally, Rissman-Joyce and El Nagdi [41] reported on lessons learned from the initial two years of Egypt's first STEM school; the central needs were the teachers' professional development, the development of rubrics for better assessment within project-based learning environments, and ways to address the range of English language and computational skills within the student population. El Nagdi and Roehrig [42] explored the development of the first Egyptian STEM school for girls through retrospective interviews with teachers, revealing the need for ongoing professional development over multiple years to establish both the understanding and implementation of the STEM mission. This involved significant changes in beliefs and practices for teachers to transition from traditional pedagogical approaches to integrated STEM.

In addition, while inclusive STEM schools are undoubtedly doing important work, it is important to consider the development of STEM-focused missions within public school settings in which students attend neighborhood schools. These neighborhood schools, which may or may not explicitly focus on equity and inclusion, can support efforts to achieve the goal of making quality STEM education accessible to all students. The present study, with its focus on the process of developing and implementing a district-wide STEM mission from the perspective of district and school administrators, contributes new perspectives to the research base.

3. Theoretical Framework

School leaders take on a range of responsibilities, which can be categorized into four key domains: setting directions, building relationships and developing people, developing the organization to support desired practices, and improving the instructional program [43,44]. Distributed perspectives of leadership point out that these responsibilities do not reside within a single individual, but rather are dispersed for a collaborative approach [45]. This distribution of leadership roles and responsibilities can be important for sustaining change in schools [46], and may even be able to support a school's social justice agenda [47].

Distributed leadership theory draws upon distributed cognition and activity theory to emphasize the importance of the social context in learning and activity [48]. A variety of contextual factors, ranging from school histories and teacher experiences to budget and legal requirements, impact the work of school leaders [44]. School leaders take on both macro-functions and micro-tasks [48]. The macro-functions include large-scale organizational tasks, such as constructing a school vision or developing structures for teacher collaboration. Micro-tasks involve the day-to-day work of leaders, such as conducting classroom observations or engaging in Professional Learning Community meetings with teachers. These macro-functions and micro-tasks are distributed across a variety of school leaders, resulting in the need to consider leadership at the collective level [48]. The tools, artifacts, and organizational structures that surround this leadership work must also be considered [48].

Since its inception in the early 2000s, a number of empirical studies have explored the effects and impact of distributed leadership, with evidence of positive results related to both organizational conditions and student outcomes. For example, in a longitudinal post-hoc study of distributed leadership for school improvement in 197 elementary schools, Heck and Hallinger [49] found that distributed leadership was significantly related to school improvement capacity and student learning outcomes. Other studies have found distributed leadership to be linked to student achievement via teacher motivation [50], professional community [51], or by building capacity for academic improvement [52]. This study utilizes distributed leadership theory to frame our work, considering the roles and perspectives of a range of district- and school-level leaders in the process of developing and enacting the district's STEM mission across its schools.

4. Analytical Framework

With ongoing uncertainty about what it means to be a STEM school, two key studies sought to highlight the characteristics of exemplary STEM high schools, using two different strategies to distill the critical components (CCs) of effective STEM schools. LaForce et al. [17] studied 20 inclusive STEM high schools from across the US, and identified eight CCs of the schools based on school leaders' and teachers' descriptions of their school's STEM model. The eight elements include: the personalization of learning; problem-based learning; rigorous learning; career, technology, and life skills; school community and belonging; external community; staff foundations; and external factors. Notably absent in this list of CCs is any explicit connection to STEM.

Peters-Burton et al. [18] conducted a literature review to identify 10 CCs of exemplary STEM schools based on existing research. Following the subsequent data collection and inductive analysis of exemplary STEM high schools, four additional CCs were identified [19]. These 14 CCs are the basis for *CC1*–*CC14* in Table 1. In their case study of eight exemplary STEM high schools, Lynch et al. [19] found that while all of the components were present to some extent across the schools, different schools emphasized different components based on their missions. Given the focus of the present study on school and district leadership, the CCs identified by Peters-Burton et al. [18] and Lynch et al. [19] are well-aligned with our research question. In particular, *CC9* (flexible and autonomous administration) and *CC12* (innovative and responsive leadership) focus explicitly on school leaders. However, we also modified some of the CCs to increase their relevance to the current study. For example, the original *CC1* is focused on college preparation through a STEM-focused curriculum; given the current study's span from elementary through to high school, we removed the college preparation element from this CC (see Table 1 for operational definitions of all of the CCs).

Table 1. Critical components (CCs) adapted from [18,19,53].

High School CC	CC Operational Definition in This Study	Related Elementary School CCs
CC1. STEM-Focused Curriculum	Science, technology, engineering, and mathematics are explicitly, intentionally integrated across the curriculum.	STEM is integrated throughout school curricula School schedule includes more than required minutes of science instruction School programs are coherent and supportive of STEM School builds college awareness, college-going culture, and career awareness
CC2. Reformed Instructional Strategies and Project-Based Learning	Instructional practices are informed by research for active teaching and learning, immersing students in STEM content, processes, habits of mind, and skills. Project-based learning situated in an authentic context is encouraged.	Instructional approaches include project-based learning and other reform strategies Teaching and learning emphasize inquiry or design thinking Students participate in service learning or other community activities
CC3. Integrated, Innovative Technology Use	Technology is used to connect students with information systems, models, databases, research, and teachers.	Technology is integrated into activities of both students and teachers
CC4. STEM-Rich Informal Experiences	Students have opportunities for STEM learning outside of the formal school day.	Out-of-school programs and resources provide STEM-rich experiences
CC5. Business Partnerships	Partnerships with business and industry increase the school's capacity for STEM programming.	External partners deepen the school's STEM capacity
CC6. College and Career Readiness	Students develop an awareness of college and career options as well as the skills that will support their success in these areas. Teachers facilitate student knowledge of and interest in STEM careers.	School builds college awareness, college-going culture, and career awareness Students learn and use workplace and life skills Teachers facilitate student interest in STEM
CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff	Teachers are highly qualified and have advanced STEM pedagogical content knowledge and/or practical experience in STEM careers. Teachers have opportunities for professional development, collaboration, and interactions with STEM professionals.	Teachers are supported in STEM through collaboration, training, and resources Teachers are open to innovation and continual learning
CC8. Inclusive STEM Mission	The school provides STEM learning opportunities for all students, who are representative of the local community.	School population represents district or local community
CC9. Flexible and Autonomous Administration	The school has autonomy from the school district to address the goals of its innovative STEM program.	School administration is flexible and autonomous
CC10. Supports for Underrepresented Students	The school provides supports (tutoring, advisories, and special classes during and outside of school hours) for students to strengthen their STEM content knowledge and skills.	
CC11. Data-Driven Decision Making for Continuous Improvement	Assessment and data systems support continuous improvement in teaching strategies, student supports, professional development, and resource allocation.	Dynamic assessment systems inform instruction Staff use evidence in continuous improvement process of school model or programs

Table 1. *Cont.*

High School CC	CC Operational Definition in This Study	Related Elementary School CCs
CC12. Innovative and Responsive Leadership	School leaders are proactive and continuously address the needs of teachers, students, and the greater community through innovative solutions, open communication, and uplifting leadership. School leaders allow for teacher agency in planning and implementing instruction.	School leadership is inclusive and focused on instruction
CC13. Positive School Community and Culture of High Expectations for All	A culture of high expectations for students and staff is maintained in a school environment built on trust and respect. Students and staff feel a sense of personal, intellectual, and social-emotional safety.	Trust and respect are shared among staff and students
CC14. Agency and Choice	Students have agency and choice in their learning. Teachers have agency and choice in their teaching.	Students experience autonomy in learning
CC15. Community and Family Involvement	Families and the community have a voice in decisions and are included in the school. The school establishes and maintains a community presence.	School establishes and maintains a community presence Parents are included in classrooms and the school
CC16. Sustainability	STEM programs are designed with attention to sustainability, scalability, spread, and flexibility.	Program designs include sustainability, scale, spread, and flexibility

Since the identification of the 14 CCs deemed essential for effective inclusive STEM high schools, additional studies have explored the relevance of the CCs at different levels. For example, Crotty [16] applied the CCs to three different middle school contexts, focusing on their relationship with teacher leadership. Peters-Burton et al. [53] conducted a case study of an effective STEM elementary school to identify CCs that were characteristic of the school, resulting in 24 CCs for this school. In the comparison of the elementary and high school CCs, we identified some clear areas of overlap (see Table 1). However, there were three elementary CCs that were not fully captured in the existing set of high school CCs identified by Peters-Burton et al. [18] and Lynch et al. [19]: (a) the school establishes and maintains a community presence; (b) parents are included in classrooms and the school; and (c) the program designs include sustainability, scale, spread, and flexibility. Because of the potential importance of these elements in the present study, we added *CC15* and *CC16* to our analytical framework (see Table 1).

5. Materials and Methods

Narrative inquiry positions lived experiences as a key component of knowledge and understanding [54,55], allowing researchers and participants to collaborate as they tell and retell individual and social stories [56]. Dewey's [57] theory of experience underpins narrative inquiry because of its focus on interaction and continuity enacted in situations [56]. This focus on experience is a defining feature of narrative inquiry [58], with experience itself serving as the phenomenon of study [59].

Narrative inquiry offers a pragmatic way to frame individuals' experiences within social, cultural, and institutional narratives [58]. Personal, practical, and theoretical justifications are necessary for narrative inquiries [60], and interviews serve as the primary method [61]. The analysis of narratives involves collecting stories as data, then analyzing those stories using a paradigmatic process, resulting in a set of themes or findings that are consistent across the stories [62].

Narrative inquiry includes three "commonplaces" across studies: temporality, sociality, and place [56,59]. First, temporality refers to the timing of the events or experiences being studied. These are seen in "temporal transition" [59] (p. 479) with a past, present, and future. Experiences are informed by what has already taken place, occur in the present moment, and are also carried into the future [58]. Narrative data that include information about the temporality of events and experiences are classified as diachronic; in contrast, synchronic data are categorical responses in the present with no reference to development over time [62]. Second, sociality refers to concern for both personal conditions, such as feelings, hopes, and morals, and social conditions, such as the environment and surrounding factors [59]. This dual focus means that narrative inquiry does not focus solely on a person's thoughts and feelings or, conversely, on the social conditions; rather, it is the integration of both conditions that defines narrative inquiry. The relationship between participant and inquirer is another element of the sociality commonplace [59]. Third, place refers to the boundaries of where the experience takes place, which may include a sequence of places [59].

The present study is fueled by the researchers' personal interest in the development of STEM-focused school districts, the practical need for the understanding of how the layered elements of the school district led to a STEM vision over time, and the need for theorizing and knowledge centered on the development of a STEM-focused district. We conducted interviews with the goal of understanding the experience of a school district developing a focus on STEM instruction. We considered multiple individual narratives and how they were woven together as a collective narrative of the school district in which these individuals worked.

The present study attended to the three commonplaces of narrative inquiry by focusing on the temporal aspects of the development of a STEM-focused school district. We considered what happened and when, with careful attention to the precursors and the events that followed. We considered the broad social context of district policies and decisions, as well as individual administrators' personal responses to the social conditions. Finally, our study was bounded in place by the school and administrative buildings within the district. The specific places changed across time as the STEM mission expanded across the district, and our interviews were also conducted within these district places.

5.1. District Context

This study took place in a rural school district in the Midwest United States. The district serves approximately 5000 students, and is composed of four elementary schools, one middle school (previously an intermediate school that housed sixth grade and a junior high school that housed grades 7–8), one high school, and alternative learning centers that serve students whose needs are best met outside of the traditional school setting [63]. Approximately 73% of the students are White, 15% are Latinx, 9% are Black, 2% are multiracial, and 1% are Asian. Roughly 10% of the students are English Learners, and 13% of the students receive a free or reduced-price lunch. Approximately 16% of the students have an Individualized Education Plan.

5.2. Participants

This study included 11 participants, all of whom had some level of administrative responsibility related to the district's STEM mission. A summary of the participants' positions in the district at the time the interviews took place and their associated pseudonyms can be found in Table 2. It should be noted that the fourth author of this study was also a participant, being the district STEM coordinator. Our relationship was developed through graduate studies and ongoing collaboration related to this and other projects. This long-standing relationship led to connections with others in the district.

Table 2. Study participants.

Position at Time of Interviews		Pseudonym
Superintendent		Mike
Director of Teaching and Learning		Lisa
STEM Coordinator		John
Elementary School Principal		
	Elementary A	Daniel
	Elementary B	Jennifer
	Elementary C	Heather
	Elementary D	Kelly
Middle School Principal		Laura
Former Administrator		
	Former Principal of the Intermediate School	Eric
	Former Principal of Elementary A	David
School Board Member		Tammy

5.3. Data Collection and Analysis

Because of the fourth author's position as district STEM coordinator and his ongoing collaboration with the other authors throughout the time of the study, the data collection was ongoing, and included both formal and informal observations. However, the primary data source for this study was in-depth interviews conducted with each of the participants. These interviews used a semi-structured interview protocol with items prepared for each participant based on their role in the school district in order to allow for consistency across the interviews while also providing the opportunity for follow-up questions tailored to each individual [64]. The key topics of the interview protocol included the individual's history in coming into their role; the mission and vision of the school or district, and how STEM fits into that mission or vision; the STEM opportunities available to students and teachers; community and business connections; teacher preparation and professional development; and the response to the STEM initiative from teachers, students, parents, and community members. These interviews were conducted over the course of several years.

Through consultation with John, the district STEM coordinator, we created a timeline of key events in the district's STEM mission development and implementation, such as the adoption of the STEM mission by additional schools. This timeline was used to frame the narrative inquiry. With the timeline in place, the interviews were transcribed and deductively coded in Google Docs based on the CCs in our analytical framework. We also wrote detailed memos about the big ideas from each interview. Using the coding and memos, we mapped key critical components to the different phases of development. This allowed us to integrate the narrative shown in the timeline with the critical components framework. We utilized constant comparative analysis [65] and continually returned to the interview transcripts and memos, extracting quotes that supported or refuted the CCs deemed most critical in each phase. We also referred to meeting minutes from the school board for additional details related to the key decisions.

6. Results

In our analysis of the interview data, we identified key CCs that were emphasized at different points in the district's STEM timeline. In this section, we use a chronological narrative to describe the events happening in the school district, as well as the CCs that featured most prominently in each time period. The key events in the district's STEM timeline can be seen in Figure 1. Wherever possible, we include multiple individuals' perspectives related to the CCs in each time period; where space limitations make this impossible, precedence was given to the individual who expressed a shared idea most clearly and concisely.

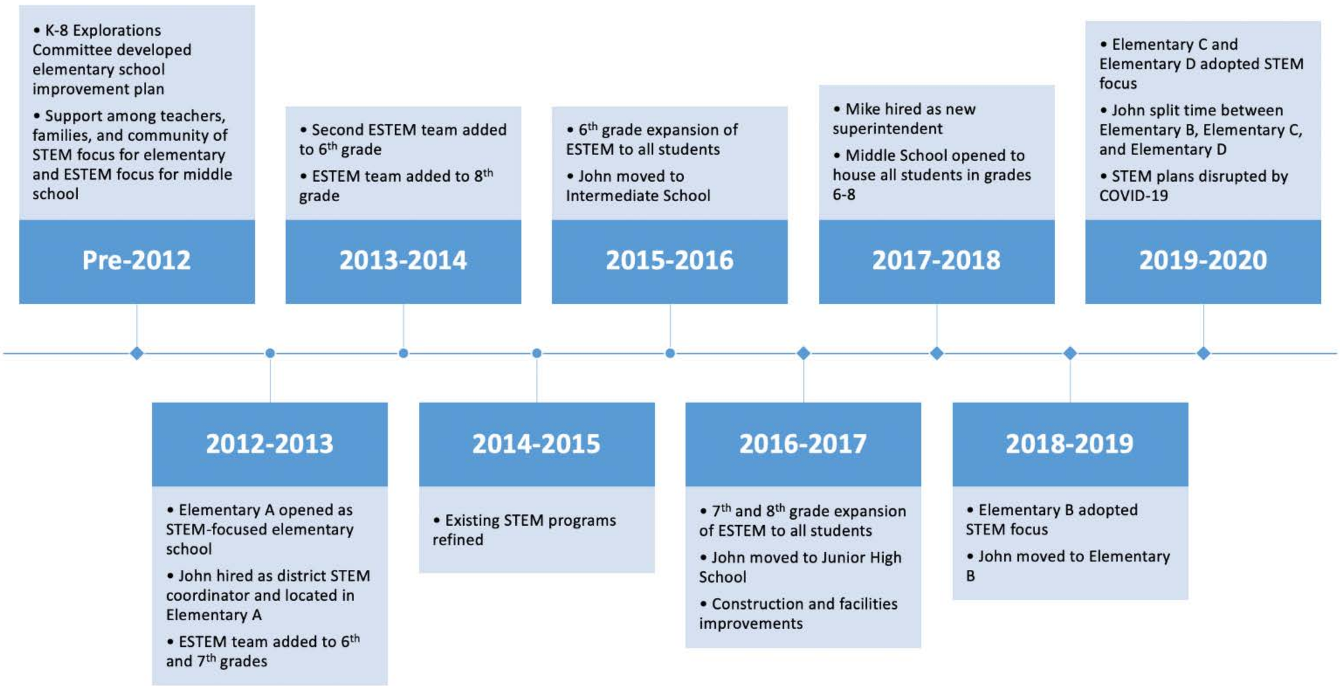

Figure 1. District STEM timeline.

6.1. Pre-2012

In the years leading up to the district's adoption of a STEM mission, the schools in the district faced a number of challenges. With concerns about accountability related to the No Child Left Behind Act, the failure of two elementary schools to make adequate yearly progress (AYP) on standardized tests left them at risk of being taken over by the state department of education. John, a veteran science teacher in the district and the STEM coordinator starting in 2012, described the following:

> [Elementary A] and [Elementary D] were on the verge of being taken over by the state because their students were not making AYP [adequate yearly progress]. [Elementary A] in particular had been suffering from white flight from the school. The atmosphere was toxic. I mean . . . teachers had the highest request to leave [Elementary A] to go to other schools. That was happening during like 2009, 2010, 2011.

With the need to develop a school improvement plan, the superintendent at the time put together a K–8 Explorations Committee to explore possibilities for the improvement of the elementary schools. Demonstrating *CC12. Innovative and Responsive Leadership*, the superintendent sought input from other administrators and teachers to meet the needs of the schools through innovative solutions. David, who was the Principal of Elementary A at the time, explained that "It got to the point where they put together a task force that consisted of elementary teachers and elementary principals. There were three principals that really led the charge on this."

This committee ultimately recommended making the four elementary schools into choice schools with different foci: STEM, environmental education, project-based learning, and the traditional approach. The committee solicited feedback on the school options from teachers. John recalled:

> When the K-8 Explorations Committee brought these ideas to the schools themselves, teachers all went, 'No!' except [Elementary A]. [Elementary A] teachers said, 'We want to do STEM!' And so, then the school district said, 'OK we've got one school, we have one idea . . . ' [Elementary D] decided to stay on a more traditional instructional pathway, with the district investing in more faculty support

> with educational assistants, paraprofessionals, Response to Intervention faculty, and a special education teacher to focus efforts on the group of students with the greatest need for additional support. Experimenting with a single school out of four was safer than trying STEM with two schools.

David also described this enthusiasm for the STEM-focused elementary school among Elementary A teachers:

> Our staff came back overwhelmingly, they wanted to do STEM . . . Out of all the schools that were surveyed, our school was the only one that said we're willing to change. We would have never been as successful as we were, I think, if we wouldn't have had the buy-in from the staff.

Demonstrating *CC15. Community and Family Involvement*, the teacher surveys were followed up by surveys of the parents and community. John explained, "And so then they put the ideas out to the community members and to the parents and the neighborhood area. And it was overwhelming. It was like 85 percent of the community members said, 'We want [Elementary A] to be a STEM school.'"

With the idea of the Elementary A STEM School receiving support from the teachers, parents, and community, the district leaders started to perform research to explore existing STEM schools and create their vision for Elementary A. David recalled:

> We started doing some research . . . We also did tours of other buildings around the metro. What we found is we didn't want to be like them because we didn't want to teach science, technology . . . engineering, and math. We didn't want to just teach those subjects. I did not want to have STEM be a stand-alone class. I didn't want a STEM teacher. We wanted STEM to be embedded throughout the entire curriculum. We kind of joked around. I said, "We're going to STEM-ify our curriculum."

While the environmental education and project-based learning approaches were not taken up by the elementary teams, the environmental STEM (ESTEM) focus was of interest to the sixth-grade team at the Intermediate School, largely given its proximity to a 27-acre natural area. This decision resulted in an ESTEM focus also being brought into the middle school for the purpose of continuity. John explained:

> [The Intermediate School] had a nature area that ran out the back door. So, when the teachers were asked, they wanted to do environmental STEM. Since [the Intermediate School] was already doing it, we viewed it as a natural extension to run the ESTEM program all the way through middle school.

This district vision for STEM across all of the disciplines continued to gain momentum and was further refined in the ensuing years.

6.2. Academic Year 2012–2013

The 2012–2013 academic year marked a major transition in the district's implementation of its STEM mission. Elementary A opened its doors as a STEM-focused elementary school. In addition, one ESTEM "house" or team (out of four teams at each grade level) was added to the sixth grade and seventh grade. *CC12. Innovative and Responsive Leadership* continued to be critical during this transition as the infrastructure was put in place (e.g., installing a garden in the Elementary A courtyard) and hiring decisions were made. One key decision was hiring John as the STEM coordinator, and locating him in Elementary A to respond to teachers' needs and provide ongoing support. David recalled this decision, sharing, "When we became STEM, I said, 'We need a STEM coordinator. Not a STEM teacher. We need a coordinator that's going to instruct our teachers how to instruct and help them.' John was a guy that I had in mind right from the start because I knew he's phenomenal."

Another key decision was pairing STEM and literacy coaching at Elementary A. David described:

> We had those two people [STEM and literacy coaches] who are instructing our teachers how to teach together. I allowed them then to develop our program at [Elementary A]; how are we going to not let go of our reading to teach all this new STEM stuff and how are we going to continue teaching the STEM techniques in our reading, in our math, in everything else? I think the biggest thing that we did is we combined those two. A lot of times you'll see in other buildings, you'll see they're separate. They're in totally separate areas. That was huge.

This decision also supported John as a high school science teacher shifting to a position in an elementary school. John recalled:

> When we started, [an elementary teacher] was asked to be an instructional coach to team with me because I was a secondary teacher, and her role was to work with me in determining how to implement STEM in K-5. We worked really well together, and once they [district administrators] started seeing how well this was working and how teachers were benefiting from instructional coaching, they expanded the instructional coaches.

In a further demonstration of *CC12. Innovative and Responsive Leadership*, some level of teacher agency was maintained despite the teachers being asked to shift their instructional practices. The school and district leaders allowed the teachers to adopt STEM instruction at different paces. They also provided them with the option of moving to another school or team if they did not want to participate in the STEM mission at all. John recalled the experiences of an Elementary A teacher who considered moving to another school:

> She was terrified of the idea that [Elementary A] was going to be a STEM school. She thought she was now going to have to be a science teacher but decided that she wanted to do something different and was trusting that it would be OK. By the end of the second year, she came to me and to David … and she said she wanted to thank us because she said, "I was terrified. I was thinking about transferring to [Elementary C]. I wasn't sure if this was going to be it. Now I can't imagine teaching any other way." Many people started out very scared and uncertain, but with support, they changed.

In preparation for the implementation of the STEM mission, there was a newfound focus on *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff*. The district held a multi-day professional development event for teachers over the summer prior to the opening of the Elementary A STEM school, and also provided substitute teachers during each trimester of the school year so that the grade-level faculty could engage in STEM unit and lesson planning. Professional development opportunities were provided to all of the teachers, not just those responsible for teaching the STEM disciplines.

Despite these trainings, there was some resistance among the Elementary A teachers. David explained, "We had some growing pains when we decided we were going to do this. Because we had some teachers that were just loving it and others that were scared to death because they were going to have to change." Similarly, Eric, the principal of the Intermediate School, which housed the sixth-grade STEM team, described teachers' resistance to change:

> Some of them [teachers] took it very personally, they're like, "I've been teaching for 22 years. How dare you come in and tell me that I'm not doing it right?" And I'm like, "No, no, no, it's not a matter of right and wrong. It's a matter of trying something." And he's like, "No I've been doing this for 22 years. You don't seem to understand. I'm highly respected."

These shifts in teaching reflected an emphasis on *CC2. Reformed Instructional Strategies and Project-Based Learning*. While some teachers fully embraced STEM instruction, others made more limited changes. For example, these teachers complied with the STEM initiative by participating in cross-disciplinary projects that included all of the teachers at that grade level. However, when their students were not participating in a specific STEM project, these teachers would rely on traditional instruction and utilized lessons they had taught in previous years. These initial collaborative STEM projects served as starting points for a way to develop a shared understanding and a shared language around STEM teaching and learning. Eric explained:

> The approach we took, it's really about the teaching style. It's not a STEM class or a STEM project, or it's not like you all of a sudden shift gears, and now we're going to do our STEM project. It's about, you know, maybe switching your mode of teaching into one where the students do more journaling, more observations, more explorations, realizing there's a growth mindset ... some teachers, you know they've had their worksheets laid out for 16 years, and "I've gotta do this worksheet at this time. And I've gotta mark all the right and wrong answers" and that sort of thing. And they really struggle to get out of it. So, they would implement some projects that were cross-disciplinary to make sure that everyone was kind of using the same language to do that.

While the vision of STEM as a cross-disciplinary pedagogy was consistent across the administrators, there was less clarity around *CC8. Inclusive STEM Mission*. The very nature of only including some students and teachers in ESTEM houses in the Intermediate School was divisive. Eric recalled:

> It ripped the building apart, even as far as morale and everything else, because ... everyone applied for STEM, and then some teachers were called STEM teachers and other teachers were not called STEM teachers, so it was, "Oh, you're better than us, we're not as good as you." It's the haves and have-nots. The people who were accepted into STEM received a lot of paid training during the summer, and they also received unbelievable amounts of technology.

John explained that the perception of inequity among the teachers extended across school boundaries as well:

> The other schools saw the amount of professional development the STEM teachers were getting, and that also brought along some jealousy. Some have and have-not feels ... Teachers at the other schools first saw it as, "I'm glad it's not us." Now [in 2018] they are saying, "Why can't it be us?"

Reflecting on these issues with the egalitarian nature of schools, John recognized tensions in district practices and messaging that may have contributed to these perceptions of inequity. District-level leaders believed that all schools should implement the district curriculum to provide similar instruction across sites. With this message, the freedom for certain teachers to deviate from the district curriculum could be perceived as inequitable. However, the school-level leaders were also afforded some level of ownership of their schools to create unique school cultures, but it is possible that this autonomy was overlooked by teachers if it was not further distributed to them.

In addition to these issues with inclusivity among the teachers, Eric also saw problems in the ways in which the students were viewed and treated:

> I felt like when I came into the building, just equity-wise, we were writing kids off really fast. Teachers would give me a list of kids they planned to leave behind on an upcoming field trip, not because of a specific incident, but because they had been a pain for a while. And I was like, "No, no, no. We're not going to function that way. Every student in this building is coming along. We had a lot of those things going on, where it was like students were being held back or pushed aside or divvied up.

6.3. Academic Year 2013–2014

In the second year of the STEM program implementation, the STEM mission continued to expand to include additional teachers and students. A second ESTEM team was added to the sixth grade at the Intermediate School, and an ESTEM team was also added to the eighth grade. *CC8. Inclusive STEM Mission* continued to be critical, now in relation to the demand for places in the STEM sections of grades 6–8. Tammy was on the district's school board at the time, and explained:

> Once the one building was identified as a STEM school, we were doing some boundary changes . . . There was discussion of an open enrollment phase and so on. It was clear that the STEM school was a big draw, so it continued to get more and more attention. I would also say it's interesting because from my perspective, I'm not sure that those people who sought it really understood what they were seeking. You know what I mean? I mean it had a good reputation, you know you hear about it [STEM] in national and state news, I mean the issue is out there. So, I think that kind of bought into that, not always sure that they fully understood what it was they were buying into.

With this high demand for STEM education, the district leaders had to make difficult decisions about how to allocate the limited number of STEM positions. The students who attended Elementary A were guaranteed a position in one of the two Intermediate School ESTEM houses, but that left Eric to decide how to fill the remaining positions:

> All of a sudden, I had far more applicants for STEM than I had here. We knew it was coming, but yet we weren't responding. And so, we stayed two [STEM] houses and two [non-STEM] houses. So, then we went into a lottery system. And again, if your parent is feeling like their child is not getting an equal opportunity for an education, they're not going to be happy. So, I had a lot of office visits before that year started with parents crying, parents yelling, and parents screaming, "Why are you denying my child this opportunity that will lead to them being a successful engineer?" Or you would hear people say, "My child is one of the smart ones. They belong in STEM." And I would say, "You do realize that STEM . . . applies to all kids. It's not for the gifted and talented, it's not for the disengaged, it's for all kids."

Seeing this demand for STEM instruction and realizing that additional resources would be needed to expand the reach of STEM education, John began to focus on *CC5. Business Partnerships*. These connections were largely structured to provide funding for supplies and professional development to teachers, rather than providing students which access to industry approaches or opportunities. John recalled one of his first meetings with a local company interested in supporting the STEM mission:

> They approached the school district and said, "We have a community grant fund that we want to support STEM education." And so, the district administrators were going to go to that meeting. My principal said, "Well you should probably come, too." And we went to the [company] office and were talking to the director of the community resource grant fund . . . and she said, "What are you envisioning for STEM?" One after another, people named stuff. "We want a FAB Lab. We want 3-D printers. We want robots. We want stuff." And I'm listening to this and thinking, "Nobody gets it." If you just buy stuff and throw it at teachers, it'll sit there. They need to know how to do it. So, then I asked if any of these funds could go towards professional development, and she said, "That's the primary thing we want to do! We really want to work with teachers!"

This meeting resulted in a grant of approximately $35,000 in each of the ensuing years to pay for teachers to complete a graduate STEM certificate program from a nearby university. Similar partnerships provided funding for professional development related to STEM and arts integration, as well as the implementation of STEM notebooks. By pursuing external funding, John continued to emphasize *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff*.

6.4. Academic Year 2014–2015

After two years of major transitions, the 2014–2015 academic year provided a period to refine existing STEM programs, continue teacher professional development, and prepare for more transitions in the following year. John continued to provide support focused on STEM instructional strategies for teachers at Elementary A.

In addition, *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff* was evidenced in the work being performed by the Elementary A art teacher. She received a grant to focus on arts integration, and in addition to professional development, she collaborated with teachers to bring arts into their STEM instruction. This effort was ultimately recognized by the National Endowment for the Arts and the Obama administration in 2015.

6.5. Academic Year 2015–2016

In the fourth year of the STEM program implementation, the seventh and eighth grades maintained the same number of STEM houses. However, the Intermediate School expanded its STEM focus to include all four of the sixth-grade teams, becoming an ESTEM school. With this shift, John moved from Elementary A to the Intermediate School to provide on-site support for teachers, continuing to emphasize *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff*. Eric recalled John's critical role in supporting teachers:

> [John] was tremendous . . . because he has a reputation for not being judgmental. He doesn't come in and say, "You're doing it wrong, do it this way, do it that way." He just comes in, and sometimes he'll model a lesson. He's comfortable doing that on many different levels. He'll talk to teachers outside class, and he'll sit while they do it [teach STEM]. Sometimes he'll come in and teach and say, "Let me show you what I mean by this." So, he's very gifted that way because the teachers didn't find him threatening at all.

This focus on *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff* also included collaboration among teachers. Eric sought opportunities for teachers who were new to ESTEM to learn from those who had more experience. The teachers also continued to work together through Professional Learning Communities to establish a shared understanding of STEM instruction.

With David moving to a new position in the district, Daniel started as the principal of Elementary A. He had worked in the district since 2005, first as an elementary teacher at Elementary A and later as a Teaching and Learning Coordinator. Because of this role, he already had experience working with principals and teachers within the district, as well as an understanding of the district dynamics. He also received his STEM certification with the first cohort of teachers from Elementary A. He described the shared visioning process as he stepped into the role of Elementary A's principal:

> When I started in this position, it was all over the board with what was happening. So, it was a STEM school, but I would have a conversation with someone who would make a comment that STEM was the curriculum, and then across the hall, their teaching partner would say, "It's not a curriculum." It was completely opposite conversations, so we did some work my first year to identify our elevator speech. When we see people in the community, what do we believe as a school? And from that, we came up with growth mindset, higher-level questioning and thinking, and then real-world integration.

These conversations again highlighted *CC2. Reformed Instructional Strategies and Project-Based Learning*, and solidified the earlier emphasis on STEM as a pedagogical approach rather than a curriculum.

6.6. Academic Year 2016–2017

In the fifth year of the district's STEM program implementation, the STEM mission again expanded. Rather than having a single ESTEM-focused team for grades 7 and 8, all of the seventh and eighth grade teams began to focus on ESTEM. With this shift, John transitioned to the Junior High School location to provide support for these teachers. As the teachers became more comfortable with STEM, they focused on *CC2. Reformed Instructional Strategies and Project-Based Learning*, developing new projects for their students. For example, Intermediate School sixth-graders participated in engineering days twice in the school year, and had numerous outdoor learning days in the nature area. The teachers designed a "cardboard arcade" event that challenged the students to design a functional arcade game using cardboard and limited materials, collecting and analyzing data related to the odds of winning the game.

With an approved tax levy for building construction, there was also a major focus on district facilities. John recalled:

> I had been meeting with architects a lot to help design classrooms, science labs, and things like that. The goal was to open the new middle school in the fall of 2017, so they were doing a lot of remodeling. [Elementary A] was going to move to the old [Intermediate School] building, [Elementary B] was going to move into [Elementary A's] old site, and then [Elementary C] and [Elementary D] were both getting additions. This was all happening in a matter of about eight to nine months, so there wasn't a lot of extra curriculum development happening. It was really focused on creating 21st century learning facilities.

6.7. Academic Year 2017–2018

Two key transitions occurred in the sixth year of the district's STEM program's implementation. First, Mike was hired as the district's new superintendent. Second, building on the transitions from the previous years, grade 6 (previously housed in the Intermediate School) moved to the newly remodeled middle school, creating a single school building for grades 6–8. The expansion of the school included a bigger cafeteria, a new flexible performance space, and a focus on collaboration through central gathering areas and breakout rooms for small groups. In the new physical environment, the school was deemed an ESTEM school, with all teams of all grade levels focusing on STEM. Elementary A also shifted physical location, moving into the remodeled building that previously housed the Intermediate School. With this move, the district also shifted its focus from STEM to science, technology, engineering, arts, and mathematics (STEAM), based largely on the Elementary A art teacher's extensive arts-integration efforts starting in the 2014–2015 academic year.

With this reorganization, some changes were made to the school-level leadership. Eric, previously the principal of the sixth-graders at the Intermediate School, became the principal of the Alternative Learning Center. Laura, who was previously the principal at Elementary D, was brought on as the principal of the middle school. John also moved locations to the middle school to support those teachers in STEM instruction. He recalled Laura's leadership in relation to *CC12. Innovative and Responsive Leadership*. John said, "[Laura] was beloved at [Elementary D] and is an amazing teacher. And that was a big decision to bring [Laura] to the middle school as they went through this transition. [Laura] is really supportive of her teachers, and I think that reflects how people teach kids."

In her new leadership position, Laura emphasized *CC12. Innovative and Responsive Leadership* by seeking teacher input, as well as *CC14. Agency and Choice* by soliciting input from students and parents about what elective courses to offer. She described:

> When we started, we asked parents, "What do you want?" And we asked kids, "What do you want?" We asked teachers, "What would you want to teach?" And then once we came together with a list, we did a survey of the kids . . . We have 40 electives that kids had the chance to choose from this year, which is crazy at the middle school level.

Also attending to the needs and wants of students, the elementary schools started makerspace programs. Heather, the principal of Elementary C, explained her school's approach to the makerspace:

> We added a makerspace, and I have two teachers that really took that on and ran it. One day after school is how they started, and kids signed up and came. So, the kids were thrilled with it, and then we brought the kids into a staff meeting so they could share with the teachers how to use all the tools. And that was really a fun staff meeting. And so, then the teachers have been dabbling in that.

Kelly, the principal of Elementary D, described a different approach to the structuring of a makerspace and the utilization of educational assistants (EAs) to guide students:

> I introduced a makerspace this year here ... and the students love it. That engagement and problem-solving and collaboration that they're experiencing has been really beneficial ... I have educational assistants that help supervise it. And we come together and we try to align some of the activities with what's in the science curriculum or what they might be learning in math so it can be reinforced but also give them a different learning experience.

Laura utilized a media-focused EA to bring makerspace opportunities into the middle school, and Jennifer, the principal of Elementary B, also utilized EAs for the makerspace:

> We have EA support in there to help them, and they work with John on some creative ideas. But there's everything in there. Simple things like Legos, and Ozobots, and engineering tile. I mean there is just all kinds of manipulatives in there. And he [John] helped us ... we didn't have this the first half of the year, but then we added a makerspace journal the second half of the year. So, they document and keep track of some of their findings ... If you ask kids, they'll say that's a favorite time of the day.

In a third approach, Daniel created a makerspace cart that was mobile and could be easily brought into different classrooms. With these three different approaches, all four elementary schools emphasized *CC3. Integrated, Innovative Technology Use*. Even Elementary B, Elementary C, and Elementary D, which did not have formal STEM designations at this point, responded to the demand for STEM instruction and provided this opportunity for students to begin engaging in design.

Notably, John highlighted the importance of *CC8. Inclusive STEM Mission* in the use of the makerspace:

> This was a sticky issue because some people wanted to limit the enrollment in a makerspace club, and the kids had to have certain grades and certain attendance and things. And I said, "You know, honestly, if you want kids working with Ozobots, it's your special ed. kids and your kids that aren't participating in school well who probably would benefit most. Your gifted and talented kids are going to be gifted and talented anyway, but if you want to engage kids who are struggling, this may be one way." At [Elementary A], we believe STEM is good for every kid and all kids.

In his first year as superintendent, Mike also brought increased attention to *CC8. Inclusive STEM Mission*. Tammy recalled:

> Under his leadership, I think the conversation is moving forward, and we're recognizing, first of all, we've just recently redone our mission to really focus on meeting the needs of every learner. So, we look at STEM education and we say, "Well, if STEM education is great for this building and it's good enough for that other building, then why isn't it in every building?" Because we ought not be having kids kind of shop around town, thinking they're going to get a different education because that's not what public school ought to be.

Heather similarly described Mike's role in the expansion of the STEM mission to include all elementary schools:

> [Mike] came on board this year and supported that idea of moving schools to STEM, and really looking at what are the characteristics of a STEM school and

> sitting back and going, "Why wouldn't we want that for all our kids?" We want students to be engaged. We want them using science, technology, and engineering ... And we want them being to be able to question and to be able to collaborate and design and problem solve, all of those things that are part of STEM. So pretty soon it was, "Let's all try to make this happen for all the kids ... because pretty soon the equity is just going to be really tipped."

Further highlighting equity in student learning opportunities, Lisa, the district's Director of Teaching and Learning, said, "We believe that your address should not dictate the education you get in our district." Laura brought this equity focus to her work at the middle school. She said that "Equity work is high on our list as well. We're fairly diverse, but I think we do a lot of things that are probably a disservice or ... unintentional disservice, but things that we could definitely do to be more of a service."

In addition to thinking about equity in relation to student opportunities, Jennifer considered equity and inclusivity among the teaching staff. She said:

> Well, we have a [school] mission statement that is empowering leaders for life ... how do we empower everybody, not just the kids, it's the adults that work here, too. How do we empower absolutely every individual for life? All four elementary schools need to be doing this [STEM] so we don't have any haves and have-nots. We're all in it together. Because I think then the power of it will be tremendously different. The feel of it in our community will be tremendously different.

6.8. Academic Year 2018–2019

The 2018–2019 academic year marked the district's seventh year of implementing STEM programs. The STEM mission expanded to include Elementary B, which coincided with John's move to that school to provide support for STEM instruction. With the second elementary school adopting the STEM mission, *CC9. Flexible and Autonomous Administration* received new emphasis. As the principal of Elementary B, Jennifer described working as a school staff to develop their own mission and vision collectively:

> Even when the board came to us and talked to us about becoming STEM, they were like, "You know, you won't be like [Elementary A]. And we're not asking you to be like [Elementary A]. We're asking you to navigate your path and figure out what works for you." And obviously there are certain pillars of the [STEM] program that we all will have that are important to our district, but what does it look like in-house here? It may be a little bit different than other buildings. So, we're ready for the adventure!

The district-level administration provided autonomy to each school to determine the ways in which their STEM focus would be enacted. John reiterated the importance of this autonomy, stating that "We don't want the teachers at [Elementary B] or [Elementary C] or [Elementary D] to feel like this is the [Elementary A] STEM that they now have to do. We want to build a shared identity." Heather also discussed the importance of this flexibility:

> I think our current superintendent gives us a lot of autonomy. I think he wants things [to be] equitable, but it doesn't have to be the same. My building here has much different needs than the other buildings in town, like we don't have a large EL population, so things look a little different. So, I think he is certainly looking for us to make it our own but yet make sure that we're moving together as a team.

Although there was some level of autonomy granted to each school site, there was also a need for some level of consistency in STEM across the grades and buildings. While discussing the approach to STEM instruction, John said, "We've got to make sure that that's pretty consistent across grade levels." Tammy also explained:

> Just based on what I know today, I would say it's intended that it [STEM instruction] would be fairly similar [across schools]. Clearly the learning objectives in

> each of the buildings are the same. We know teachers are different and the way they approach those objectives are different. But the way they use the STEM method, I would expect it would be similar. I don't know why it wouldn't.

As the second elementary school was brought more fully into the STEM mission, *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff* was again emphasized. As in previous years, the teachers received numerous professional development opportunities over the summer and during the school year, some of which were funded through industry and business partnerships. John also continued to be a key asset in preparing and supporting the district's teachers, but with more schools implementing STEM instruction, there was some concern about how a single STEM coordinator could support teachers at multiple sites. Thinking about her schools' transition to a STEM focus in the following year, Heather described:

> He [John] was tied to [Elementary A] the first few years, and he was on-site at [Elementary A]. So, he was really working with teachers helping them design lessons . . . he was the expert on staff, and now he's been spending a lot of time at the middle school and at [Elementary B] as they roll out . . . but I don't know how that's going to roll out, that he can support all of the schools. So, I think that's a piece of it, is how do we support each school? We are bringing on instructional coaches at each elementary building, and so that is going to be one of our vehicles to help teachers.

The instructional coaches continued to provide a unique opportunity for support in both literacy and STEM instruction. Lisa, the Director of Teaching and Learning, stated that "We always have to be looking at literacy." John further explained the role of the instructional coaches and how they were utilized as STEM teaching resources. He shared:

> They [coaches] are primarily literacy, but what's interesting is I've got them both in the STEM cohort, so they are now seeing school beyond reading and writing . . . Literacy doesn't have to be just straight language arts. It can be technical literacy and scientific literacy and mathematical-inspired literacy.

With several years of STEM experience, the teachers at Elementary A also had expertise to share both within and beyond their building. Within Elementary A, the teachers collaborated to integrate STEM instructional strategies into their curriculum. Heather, the principal of Elementary C, recognized the value of Elementary A teachers. She said, "It would be awesome if we could tap into [Elementary A] staff for that and get them teaming up with our grade level teams." Teachers at Elementary B took initiative in seeking out an opportunity to meet with Elementary A teachers to collaborate. Jennifer, the Elementary B principal, recalled, "I have teams that have reached out to [Elementary A] grade level teams. We did a light and sound unit in third grade, so my third-grade team reached out to theirs and said, 'What have you done? And how did it work?' And so, they implemented some of that."

In general, the emphasis on *CC12. Innovative and Responsive Leadership* was maintained. For example, Daniel sought teacher input in renewing Elementary A's vision, asking, "What are our priorities moving forward? I'm going to be getting input from people on where should [Elementary A] be in five years? Where should we be in 10 years?" John further explained that teachers need to feel empowered through the STEM mission:

> Fundamentally, in order to make the STEM program successful, teachers and administrators need to see the benefit for kids. The community sees the benefits for kids because they hear it from their own children. But then the other key element is empowering faculty and working with them as they shift their instruction and also feel empowered to take on leadership.

However, in a counterexample of *CC12. Innovative and Responsive Leadership*, the district administration made a decision to adopt a new literacy curriculum that required a high fidelity of implementation, which teachers struggled to align with STEM instruction. John described:

> Since we STEM-ify, we take our literacy and match it with our science and with our math, et cetera . . . and teachers were just expected to pick it up and run and fit it into their STEM curriculum, but it wasn't a perfect match... And so that in particular hit the [Elementary A] teachers hardest because one thing is that we've had the permission to experiment with our instruction.

In this seventh year of STEM implementation, John continued to maintain relationships with key industry partners, but he also recognized the need to broaden the application of *CC5. Business Partnerships*. He explained that:

> One of the things they [teachers] felt weakest about was . . . Many of them said, "I don't feel comfortable trying to make connections between STEM and careers." And that's a new initiative this year. In particular, our school district wants to be more college and career ready, so I'm hoping to see that our teachers are trying to more explicitly say, "This is what it would be like in a STEM career" or "These are the kind of things you should study if you want to go into being an engineer or a scientist or if you want to do work in a company that builds computers or something." So, kids can start envisioning these jobs in the future.

6.9. Academic Year 2019–2020

As the district entered its eighth year of STEM program implementation, the final two elementary schools (Elementary C and Elementary D) formally became STEM schools, with John splitting his time between these two schools and Elementary B. In the summer of 2019, Elementary C and Elementary D teachers and principals participated in a five-day professional development event to prepare them for STEM instruction in the upcoming school year. Although this was a positive learning experience, John described some challenges in the expansion of the STEM mission to the final two elementary schools:

> I think part of the challenge was, when one school gets to be the focus, they feel a lot of pride. When it's two schools, it's like, "Well, I guess we get to finally get there." And then there was a significant number of staff that weren't available, so I think we were only able to train about 60 to 70% of the staff at each school.

Combined with principals feeling tension between STEM and other initiatives focused on literacy and mathematics, there were some barriers to STEM implementation. Despite these challenges, the teachers at both Elementary C and Elementary D began STEM instruction. However, this was disrupted because of the onset of COVID-19 in early 2020.

With STEM reaching all of the elementary and middle school students in this school year, the district continued to plan for the expansion of the STEM mission to the high school, connecting to *CC6. College and Career Readiness*. Part of this process included the approval of a bonding bill, and a $104 million bond was approved by voters so that the district could build a new high school. Mike described the design of the high school, saying that it would "be built specifically to help prepare our learners for their next step, which includes a lot more areas that will be career-oriented, so industrial technology, engineering areas."

The district administrators agreed that high school students needed some type of STEM instruction, particularly given the student demand for ongoing STEM opportunities. Laura explained, "Our eighth-graders that left here last year were so disappointed when they went to the high school because as ninth-graders, it's so structured. They don't have many elective choices." However, STEM at the high school level will look different than it does at the elementary and middle school levels. Lisa explained, "At the high school level, we're looking at career pathways." John described the possibilities for the high school, saying, "The plan is to have career-focused academies, including things like health sciences. I think it would be good if they had an academy that was labeled as STEM-focused because a lot of kids are familiar with that language from elementary and middle school." Again, because of COVID-19, the plans for the high school were put on pause.

7. Discussion

In the exploration of this school district's development and expansion of a STEM mission, the CCs identified by previous researchers [18,19,53] received different levels of emphasis at different times across the nearly decade-long narrative described here. *CC12. Innovative and Responsive Leadership* was frequently discussed as being central to the STEM mission in the district. The entire focus on STEM education was in response to community, parent, and teacher demands, and the district leaders adopted a vision for STEM that also allowed for responsiveness to teachers' needs. District and school administrators attended to both macro-and micro-leadership tasks, and distributed these tasks among individuals [48], resulting in structures and processes that involved teachers as leaders in the STEM mission. The teachers were allowed to take up the STEM mission at their own pace, and in some cases, could even elect to transfer to another school if they did not want to adopt the STEM focus. As the STEM mission expanded to include new schools, the principals experienced agency in the determination of the way in which their STEM focus would be enacted. They were not expected to adopt the same approach as other schools in the district, further connecting to *CC9. Flexible and Autonomous Administration.*

Across all of the participants, STEM was viewed as a pedagogical approach that could be implemented across disciplines. It was not connected to a specific curriculum, and instead focused on fostering student engagement, developing 21st century skills, and developing a growth mindset. Defining STEM in this way had several implications for the district and leadership decisions. There was less need to invest in an expensive curriculum and equipment, and instead a focus on building teachers' professional capacity for the implementation of STEM instructional strategies. This is evidenced by the rare discussion of *CC1. STEM-Focused Curriculum* in the interviews. Although this may seem alarming at first glance, given the district's STEM focus, STEM was adopted into the existing curriculum as teachers made use of STEM instructional strategies (*CC2. Reformed Instructional Strategies and Project-Based Learning*), which were more prevalent in the interviews. Both David and John referred to the idea of "STEMifying" the existing curriculum by making it more aligned to reformed instructional strategies. This is consistent with LaForce et al.'s [17] findings that STEM school leaders view STEM as being grounded in instructional practices, rather than being specific to disciplinary subjects. Leadership was distributed to teachers, who were responsible for collaboratively developing STEM lessons and units, and the district administrators both trusted and expected quality STEM instruction from teachers. While it was not often explicitly discussed, *CC13. Positive School Community and Culture of High Expectations for All* was implied in relation to the type of work that was expected of teachers and their students. School and district leaders saw STEM instructional strategies as being synonymous with high expectations, such as the use of higher-order questioning and the real-world applications they associated with STEM instruction. They also pointed to the belief that all students should receive rigorous STEM instruction, speaking to the belief that these high expectations should extend to all students. A positive school community was implicitly addressed through comments related to a growth mindset and a belief that both students and teachers should be allowed autonomy and support in trying new things.

Notably, discussion related to *CC3. Integrated, Innovative Technology Use* focused almost entirely on makerspaces. Given the widespread disagreement about the role of technology in STEM education [15] and the fact that newly adopted technological tools often align closely with what is already done in classrooms [66], it is perhaps unsurprising that technology received little explicit discussion. Indeed, Holmlund et al. [67] found that few teachers, administrators, or STEM professional development providers discussed the use of technology as being key to their conceptualizations of STEM. However, it is also important to note that the administrators in this district viewed technology as an integral part of teaching and learning, rather than as a separate entity. As such, technologies including computers, coding, digital notebooks, and online collaborative tools were integrated into the daily instructional approaches through the use of reform-based teaching practices. Therefore, while the common discussion of *CC3* centered on the implementation of makerspaces within each school, the focus of the makerspaces was on *CC2* and the provision of quality learning experiences for students, rather than the specific technologies themselves.

With the foundation of flexibility and responsiveness associated with *CC9* and *CC12*, as well as the need for all teachers to become experts in *CC2* to enact the STEM mission, district leaders continually emphasized teachers' professional learning. This was financially possible because of the low level of curriculum investment needed with the view of STEM as a pedagogy, as well as through funding from *CC5. Business Partnerships*. Professional development and STEM certification opportunities were provided to all of the teachers and staff, even if they did not have the primary responsibility for teaching STEM disciplines. For example, art, music, and physical education teachers, as well as school principals, were STEM-certified, illustrating the shared responsibility for enacting STEM education. This commitment to *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff* was reemphasized each time a new school adopted a STEM focus, both through the provision of professional development opportunities and the positioning of John in the newest STEM school to provide on-site support. The relationship between John and the well-prepared faulty allowed for collaboration in designing, implementing, and evaluating STEM-focused lessons and units based on the existing district resources and materials.

Conceptualizing STEM as a pedagogy was also related to *CC12. Innovative and Responsive Leadership*. Some level of resistance to change is expected in educational reforms, particularly when teachers view new initiatives as threatening [68]. However, in this district, teachers were not asked to adopt a new STEM curriculum or completely abandon their current instructional materials. Rather, they were encouraged to "STEMify" their teaching by utilizing research-based best practices. Evidence of positive results can actually be more important than initial teacher buy-in [69], which was the case with this district. By the time the students reached middle school, both teachers and administrators could identify students who had attended Elementary A based on their mindset and approach to learning compared to the students who had attended the non-STEM elementary schools. This qualitative, observational data informed their decision to expand the STEM mission, which was related to *CC11. Data-Driven Decision Making for Continuous Improvement*. District leaders' approach to the promotion of change and growth among teachers who may have otherwise been resistant to the STEM mission allowed for change to become visible through observable benefits to students.

CC16. Sustainability was attended to on many occasions as the district's STEM mission expanded to include additional schools. The distribution of leadership among administrators and teachers promoted sustained change [46], and John became a key individual in spreading a consistent approach to STEM across the district. By physically locating his office in the newest STEM schools, the teachers who were least familiar with STEM had direct access to him for coaching and other support. His shifting office location also served to support the distribution of leadership responsibilities among the teachers at the established STEM schools. Once John moved from a school location, the teachers were more reliant upon one another and the expertise located within their buildings, allowing STEM teacher leaders to emerge. A focus on *CC16. Sustainability* can also be seen in some of the district hiring decisions. Two of the current principals received their STEM certifications through the district when they were teachers, and by hiring them to fill leadership positions, there is increased continuity and alignment in relation to the STEM mission. In addition, these key decisions highlight *CC12. Innovative and Responsive Leadership*. The school and district leaders were proactive in ensuring that teachers and students had the support they needed. For example, by combining literacy and STEM coaching, the instructional coach position was more resistant to changes due to shifts in funding or district initiatives. In another example of both *CC12* and *CC16*, some principals chose to reassign teachers in their schools to different grade levels or cross-curricular teams. While these decisions were not necessarily popular with the teachers, they served to distribute STEM expertise among the staff with the goal of fostering the spread and sustainability of the STEM mission.

An interesting connection between *CC16. Sustainability*, *CC15. Community and Family Involvement* and *CC8. Inclusive STEM Mission* emerged in this study. Because elementary school enrollment was determined based on students' home addresses, students in the Elementary A zone received first access to STEM instruction. However, families of students attending the other schools expressed strong opinions in the determination of whether their children would have a STEM-focused education, and advocated for a more inclusive approach. It quickly became apparent that limiting STEM education to one elementary and select middle school teams was not sufficient to meet community and family demands, pushing the district to scale the STEM focus. Interestingly, the path to inclusivity differed from what often occurs in education. In this case, Elementary A had a student population that was more socioeconomically disadvantaged than the other elementary schools, and given its "failing" status on standardized tests, it was the first elementary school to adopt the STEM mission. It was the parents and teachers at the more affluent schools that pushed for more STEM schools, and district administrators recognized the need for inclusion. Multiple participants in this study expressed the sentiment that a student's home address or zip code should not determine the quality of education they received. With a firm belief that STEM instruction was beneficial to all students, the district moved forward in ensuring access to STEM for all students.

With 11 different administrators participating in this study, the distributed nature of the leadership within the district was readily apparent. Each individual played different, but important, roles in the development, enactment, and sustainability of the district's STEM mission. While some leaders focused primarily on macro-functions, others also performed micro-leadership tasks [48]. Tammy and other school board members provided macro-level support for STEM, making sure that the structures were in place for the mission to be carried out. With these structures in place, the school board allowed others to attend to the specifics of the STEM mission. Mike became the district superintendent after the STEM mission was already underway, but one of his key leadership contributions was bringing attention equity at a macro-level. This included revising the district's mission statement to explicitly focus on equity, as well as advocating for the expansion of STEM to all schools and all students in the name of equity. Mike also distributed responsibility for STEM-related decisions to the school-level teams, allowing each school autonomy in the development of its specific approach to STEM instruction. As the district's Director of Teaching and Learning, Lisa maintained a macro-level perspective of the curriculum and instruction across all of the content areas. For example, she attended to literacy in the school district, ensuring that the STEM focus did not detract from literacy initiatives. Perhaps more than any other individual, John was a consistent STEM advocate in the district. As the STEM Coordinator, he attended to both macro- and micro-leadership functions. At the macro-level, he established business partnerships that led to funding for STEM efforts and organized formal professional development opportunities like STEM certifications for teachers. However, he also led at the micro-level, working with individual teachers to provide day-to-day support related to STEM instruction. While John undoubtedly played a central leadership role in the district's STEM initiative, he, too, ensured that the principals and teachers shared in the leadership responsibilities.

Each school principal held key responsibilities in advancing the district's STEM mission at both the macro-and micro-levels within their schools. David provided school-level leadership for the district's first STEM school (Elementary A), including researching approaches to STEM instruction and fostering the belief that STEM should be embedded in all disciplines. He also distributed leadership to key individuals in the school, including his innovative approach to instructional coaching that included pairing literacy and STEM coaches to support teachers as a team. Daniel became the leader of Elementary A after it had already been designated as a STEM school. While the mission was already being enacted at the school, Daniel focused on developing a shared vision for STEM instruction, including emphasizing a growth mindset, higher-order thinking, and real-world applications across disciplines. There was a parallel transition of leadership at the intermediate and middle schools. Eric was the first school leader, and faced unique challenges related to teachers' resistance to change and concerns about equity for both students and teachers, given the school's split focus, with only some sections focusing on STEM. Eric's key roles included overcoming these obstacles; for example, he developed a lottery system for admission to the STEM sections of the intermediate school. As the intermediate school was reorganized as a middle school with grades 6–8 in one building, Laura became the school leader. She led the school community through this transition, including assessing the needs of various school stakeholders (teachers, students, parents). Jennifer, Heather, and Kelly were already serving in principal positions when their schools adopted the STEM focus. However, even prior to the formal designation as STEM schools, all three of these elementary principals started some level of STEM programming, such as makerspaces. As their schools became more fully immersed in STEM instruction, these leaders replicated key aspects from Elementary A while also determining how STEM education would be unique at their schools. This included capitalizing on the experiences of Elementary A teachers to support teachers at Elementary B, C, and D. For example, teachers from Elementary A worked with colleagues teaching the same grade level at the other schools, and shared lessons, instructional techniques, assessments, and encouragement. The expansion of the STEM mission also included distributing leadership to teachers at Elementary B, C, and D, and providing them with agency in determining the nuances of their own approach to STEM instruction.

8. Limitations

Like all studies, there are limitations associated with this research. First, the views highlighted in this study are those of administrators. It is possible that teachers, students, family members, and community members would emphasize different CCs when talking about the district's STEM mission. Leadership responsibilities were certainly distributed across teachers and other individuals within the district, but a full examination of these individuals' views was beyond the scope of this study.

Second, the CCs were originally developed based on STEM high schools that had already been established as exemplars of STEM education [18,19]. The schools involved in these previous studies were defined as inclusive STEM high schools, with an explicit focus on equity and an application process for admission to the schools. We also included CCs developed for elementary schools [53] in the present study. The contextual differences between the original CC research and the current study likely contributed to some of the patterns we saw. For example, there was no mention of specifics related to *CC10. Supports for Underrepresented Students*. While this is a central component of the inclusive STEM high schools, given their focus on historically underrepresented youth who may be unprepared for rigorous STEM instruction, it may be less apparent in schools with attendance based on neighborhood school zones.

9. Conclusions

Given the dearth of research on the process of developing, enacting, and sustaining a district-wide STEM mission, this study addresses a gap in the literature and provides insight that may be useful to researchers, as well as other schools or districts, developing a STEM focus. The CCs, while not an explicit part of the STEM visioning process for this district, provided a useful lens for the consideration of the shifting importance of different elements throughout the process.

Our use of the CCs in a public school district developing a STEM mission and admitting students based on attendance zones rather than an application process represents a new application of the CCs. With 16 different components, it was impossible to give equal attention to all of the components simultaneously. Through this study, we have identified several CCs that were central to the development of the public school district STEM mission. First, *CC12. Innovative and Responsive Leadership* was clearly central in developing, enacting, and sustaining the district's STEM mission. Strategic decisions that responded to the needs of students, teachers, families, and the community ensured widespread support for the

STEM mission. Second, *CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff* was critical throughout the period of study. Teachers, administrators, and school staff had access to a number of STEM-focused professional development opportunities with the goal of developing a well-qualified staff who shared joint responsibility for the STEM mission. Finally, *CC2. Reformed Instructional Strategies and Project-Based Learning* received ongoing focus. As the teachers modified their instructional practices and curriculum to better align with the STEM mission, reformed instructional practices were emphasized across all of the disciplines.

While these three CCs received ongoing focus and were particularly important in advancing the district's STEM mission, some CCs identified in the original studies of exemplary STEM high schools were less central in this district. For example, *CC4. STEM-Rich Informal Experiences* was rarely discussed. Perhaps this CC is more critical at the high school level than at the elementary or middle school levels. As previously described, *CC10. Supports for Underrepresented Students* was also less explicit than the other CCs. Again, the context of the present study likely related to the reduced emphasis on this element. By focusing on different CCs at different times and prioritizing several key CCs throughout, this district was able to achieve its goal of providing STEM instruction to all students in grades K–8. Although each school had agency in determining its own approach to STEM, John's role as the STEM coordinator working closely with teachers ensured consistency in the overarching district philosophy of STEM education as a pedagogical approach. This view had implications for which CCs were emphasized, and ultimately provided a roadmap for how the district moved forward with its STEM mission. As schools and districts develop, enact, and sustain their STEM mission, it is important to consider the contextual factors that may influence the relative importance of the CCs. As shown by this district, it is possible to create a STEM school that meets the goals of its stakeholders without explicit attention to every CC originally identified by Peters-Burton et al. [18] and Lynch et al. [19].

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