Exemplary STEM Learning

LESSONS FROM OUTSTANDING NEW YORK SCHOOLS & TEACHERS

Jonathan Eckert, Ed.D

Cover image: Jonathan Eckert, Ed.D

Biography

LEAD RESEARCHER

JON ECKERT, Ed.D., is Professor of Educational Leadership and Copple Chair at Baylor University. He has taught and coached intermediate and middle school science students outside of Chicago and Nashville for 12 years. After completing his doctorate at Vanderbilt University in 2008, he was selected as a Teaching

Ambassador Fellow at the U.S. Department of Education where he worked in both the Bush and Obama administrations on teaching quality issues. For the past eleven years, he has been preparing educators and leaders.

His research interests include collective leadership, teaching effectiveness, evaluation and strategic compensation to enhance that effectiveness, and science education. Eckert has conducted research for the U.S. Department of Education, the Carnegie Foundation, the National Network of State Teachers of the Year, the National Institute for Excellence in Teaching, and the Center for Teaching Quality.

FELLOWSHIP LEAD

JUNE TEISAN, is a National Board-certified teacher and career STEM educator. Dr. Teisan served as 2008 Michigan Teacher of the Year, Albert Einstein Distinguished Educator Fellow in Washington, D.C. at the National Oceanic and Atmospheric Administration, received the White House Presidential Award for Excellence in Science Teaching and is a National Teacher Hall of Fame Inductee. Dr. Teisan is a visiting lecturer at Oakland University teaching future educators and also coordinates school programs and educator initiatives at Detroit's historic Belle Isle Aquarium, our nation's oldest

aquarium. She serves on the leadership team of the Michigan Teacher of the Year Network and with the National Association of Research in Science Teaching.

Dr. Teisan is actively involved in education policy and advocacy efforts at the state and national level. She is passionately committed to widening opportunities for under-represented and under-served students in the STEM fields and to supporting urban and early-career educators with rich, innovative professional development.

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Executive Summary

Science, technology, engineering, and math (STEM) are approaches to help us to understand and improve our world. Therefore, as a country, we need to develop more STEM literate citizens through exemplary STEM learning in schools (Committee on STEM Education, 2018). Through a grant from 100Kin10, in partnership with the National Network of State Teachers of the Year, we asked these four questions that we answered through five case studies. Here is what we found in four succinct answers to our research questions:

Q: WHAT IS EXEMPLARY SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH (STEM) LEARNING?

A: Exemplary STEM learning is a multi-disciplinary, integrated approach that addresses global and local challenges through the development of critical thinking, problem solving, teamwork, communication, and empathy.

Q: HOW DOES THE COLLECTIVE LEADERSHIP OF TEACHERS AND ADMINISTRATORS FACILITATE EXEMPLARY STEM LEARNING?

A: Collective leadership is the work of teachers and administrators toward shared goals. In schools demonstrating exemplary STEM learning, collective leadership is evident in the work of teachers and administrators who have a clear vision, support each other, have structured their work in order to best facilitate student learning, and have a "figure-it-out" approach to leadership and learning.

Q: WHAT CONDITIONS SUPPORT EXEMPLARY STEM LEARNING?

A: Four antecedent conditions—vision and strategy, supportive administration, resources including initial teacher capacity, and work design—are necessary for supporting STEM learning. If these conditions are strong, then three additional conditions should also show evidence of that strength—social norms and working relationships, shared influence, and orientation toward improvement—increasing the likelihood of exemplary STEM learning. See Figure 1.

Q: WHAT ARE THE BARRIERS TO EXEMPLARY STEM LEARNING?

A: The primary barriers to exemplary STEM learning are lack of a shared vision of exemplary STEM, lack of time for preparation and collaboration, lack of initial teacher capacity, and lack of resources.

After analyzing survey data, interviews, focus groups, and site visits to five schools, and working with an identified STEM Fellow who was a teacher leader at each school to provide additional context and expertise at that school, we were surprised by what we found. Perhaps we should not have been given what we know about STEM (For details on our research and methodology, see Appendix A).

Schools with strong STEM cultures are more likely to improve by innovating to meet the needs of their students and communities.

We found this to be true because exemplary STEM learning occurs in schools that are:

- **Supported by "STEM cultures" of leadership and learning.** In each school, students, teachers, and administrators described their approach to leadership and learning as a STEM culture. Problems were not insurmountable; they were just interesting challenges to solve. Individuals who had expertise and insight were all necessary contributors to the process that would lead to a solution.

- **Catalyzed by administrators who see teachers and students as drivers of innovation and improvement.** In science, a catalyst accelerates a reaction; it is not the focus of the reaction. Schools led by administrators that see themselves as catalysts who come alongside and support the good work of teachers and students create vibrant learning communities that grow.

- **Supported through creative fundraising, strategic budgeting, transparent communication about resource use, and a wide range of leaders with varying degrees of capacity.** District and school leaders who access grants, community resources, and partnerships develop the capacity of essential teachers and administrators who improve learning experiences for all students.

- **Structured for collaboration and flexible problem-solving.** Because the innovative work the schools are doing drives the way they design physical spaces and work time for teachers and administrators, leaders are able to collaborate in flexible ways to address problems in real-time. Teachers and students do not have to wait for permission before they act; they just have to collect evidence of need and progress.

- **Characterized by supportive relationships, predicated on trust, with clear-eyed leaders who honestly appraise challenges, opportunities, and progress.** A primary aspect of flexible problem solving is the collection of evidence of

impact. This occurs through honest conversations around that evidence and allows leaders to challenge one another to dig deeper for more impactful opportunities for improvement.

- **Enhanced by purposeful collaboration, interaction, and support through the shared influence of students, teachers, administrators, and community members.** Across all five schools, teams of people supported various initiatives. Sometimes an individual leader will take primarily responsible for a task, but that leader is never alone and seeks the input and feedback of others to move forward faster.

- **Improved by students and teachers who apply an engineering mindset to problems: identify, prototype, test, collect evidence, and revise.** Risk, learning from failure, and improvement are expected and welcomed. Implicit in STEM cultures is the notion that failure is a necessary component of designing solutions. All five schools have adopted this STEM mindset and apply it to their school improvement efforts that move far beyond STEM.

A team of 15 accomplished STEM educational leaders and six researchers found this, and more importantly, how five schools are doing this every day. Read the case studies of two elementary schools, one middle school, and three high schools (See Appendix B for the schools' demographics) If you are a policymaker, district administrator, school administrator, or teacher, there is something for you. Policymakers can support schools and districts in the effort to expand exemplary STEM by learning from these schools.

District leaders can learn from three schools that are in the same district about how exemplary STEM builds through vertical alignment. Schools can learn about the conditions and strategies that advance exemplary STEM for improved student outcomes. Teachers can integrate strategies within and beyond their classrooms. Before we get to the case studies, let's explore the basics of collective leadership.
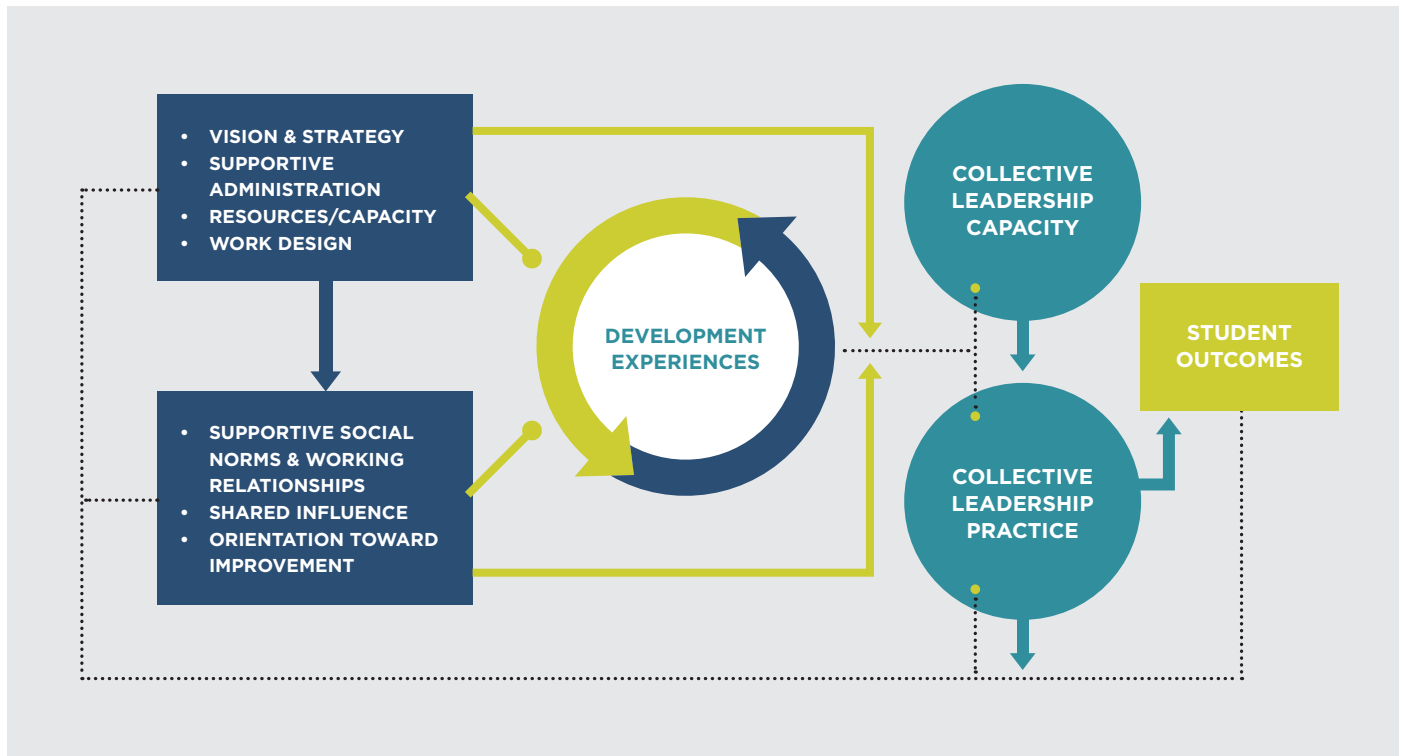
COLLECTIVE LEADERSHIP DEVELOPMENT

FIGURE 1: Collective Leadership Development Model

SHARED VISION AND STRATEGY

Collective leadership is work toward shared goals (Eckert, 2018, 2019). For schools to improve, there needs to be a shared vision and mission in order to create a cohesive approach for school improvement. Strategies must be in place to propel that vision forward. Leadership can certainly be occurring in a school without a shared vision and strategy, but if 30 different teachers and administrators are leading without any followership or coherence across initiatives, the school will make very little organizational progress.

Shared vision and the associated strategies are not created by one leader with the expectation that others will "buy-in" to the vision. Instead, shared vision is developed through the collective expertise of school leaders, both teachers and administrators. Shared vision and strategies drive instructional improvement and are the foundation for continuous school improvement. The collective expertise that drives the shared

vision is best developed by creating opportunities for teachers and administrators to work together.

WHAT THIS LOOKS LIKE

People with the right skills and expertise are leading, not because of position, but because their skills are the best-suited for the work. All of those leaders are working toward the shared vision of the school using common strategies.

SUPPORTIVE ADMINISTRATION

Administrators, and particularly principals when considering individual schools, are absolutely essential to any collective leadership development efforts (Eckert, 2018; Smylie & Eckert, 2018). The collective leadership development model begins

with the principal's development and support for teacher leadership. Of course, all of this occurs within community, district, state, and national contexts that support or constrain the school's efforts. This is why effective district administrators are so important for bridging and buffering challenges that might impact the school (Day, Zaccaro, & Halpin, 2004; Murphy, Smylie, Mayrowetz, & Louis, 2009; Smylie & Brownlee-Conyers, 1992; Van Velsor, McCauley, & Ruderman, 2010). At the school level, an effective principal is essential to sustained leadership development because she needs to allow leadership to grow from the classroom. Teaching and learning are at the core of every school, and therefore, administrators have to support the instructional leaders who are doing the work of improving student outcomes.

Additionally, administrative support facilitates shared development experiences of administrators and teachers together. By participating in shared learning experiences, administrators and teachers better understand different perspectives and are more likely to develop coherent improvement plans. In fact, one of the most important ways administrators can support teachers is through the shared development of school improvement plans which should be an essential annual learning experience.

WHAT THIS LOOKS LIKE

Administrators support teachers by providing them with the encouragement, financial support, and exhortation they need to grow. Administrators see their job as highlighting and catalyzing the great work going on in classrooms.

RESOURCES AND CAPACITY

Time, space, and financial resources catalyze or constrain collective leadership development. Leaders need time to develop together and this requires financial resources that make space for co-learning and co-leading. Moreover, if teachers and administrators are going to innovate productively, then they need some margin in order to tolerate risks for initiatives that might not be immediately successful.

Another consideration is the capacity of teachers and leaders. Teachers' capacity for leadership work is central to the transformation of a school. Capacity is contingent upon many factors, such as preparation (Darling-Hammond &

Bransford, 2005; Jensen, Roberts-Hull, Magee, & Ginnivan, 2016), professional development (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Jensen, Sonnemann, Roberts-Hull, & Hunter, 2016), or colleagues (Hattie, 2015; Jackson & Bruegmann, 2009; Ronfeldt, Farmer, McQueen, & Grissom, 2015). If teachers are already at capacity with their instructional responsibilities, then adding additional work — even if it is meaningful — will not necessarily improve outcomes for students (Eckert, Ulmer, Khatchatryan, & Ledesma, 2016). Teachers cannot do more than their capacities allow. Their initial capacity, as well as capacity that can be developed, must be considered in this model. In practice, this means not allowing a beginning teacher to take on so many responsibilities beyond the classroom that this work becomes detrimental to his or her instruction. On the other end of the spectrum, this means not expecting the 25-year veteran teacher to just keep adding more leadership work without support.

Capacity is malleable and can grow through deliberate practice. Deliberate practice is not just experience; it is practice that includes feedback, reflection, and opportunities for improvement (Ericsson, Krampe, & Tesch-Romer, 1993). In schools, we know growth occurs best with other educators (Kraft & Papay, 2016).

WHAT THIS LOOKS LIKE

Physical space is available for collaboration and teachers have regular time meet. Additionally, they have the financial resources to try new ideas, and they have the preparation, development, and capacity to grow.

WORK DESIGN

The way work is designed for productivity impacts every work sector (Hackman & Oldham, 1980). The way schools design the work of teachers and administrators often determines how successful their improvement efforts will be. Effective work design that we have observed in schools includes co-teaching, collaborative planning time, analysis of student work, reciprocal observation where teachers observe each other, peer feedback, job-embedded professional learning for teacher and administrators together, professional learning communities built around identified needs, and hybrid roles for teachers and administrators. If leadership is about work toward shared goals, then the work must be designed around those shared goals in

order to the support the people best suited to do the work. In general, any work design that allows effective teachers to spread their expertise is useful. Specifically, that looks like teachers designing learning experiences and assessments together, observing one another teach, and examining student work collaboratively. When administrators also engage in this work, they can catalyze school improvement by facilitating coherence and learning from and with teachers.

SUPPORTIVE NORMS AND WORKING RELATIONSHIPS

The previous four constructs are typically necessary for supporting the final three constructs. As schools attempt to develop collective leadership, they are best served by leveraging vision and strategy, supportive administration, resources/capacity, and work design in the service of supportive norms and working relationships, shared influence, and orientation toward improvement.

Supportive norms and working relationships refer to how teachers interact with each other and with administrators. In schools where these norms and relationships are strong, teachers and administrators seek and provide feedback to each other that is respectful, improvement oriented, emphasizes student outcomes, and communicate clearly. This does not mean that everyone always agrees. In schools with supportive norms, teachers and administrators celebrate and support each other as they risk and learn, but they also challenge one another when they disagree or have divergent ideas about how to improve.

SHARED INFLUENCE

Schools that demonstrate high levels of shared influence between teachers and teachers and teachers and administrators are exemplified by open door policies. Teachers can come to administrators with challenges or suggestions, and classrooms are open for reciprocal observation and administrator walkthroughs. These types of schools are not hierarchical and leadership is not "distributed" as if leadership is a series of tasks that an administrator doles out. These schools emphasize collective teacher efficacy, the belief that each student in a school can learn because of the effectiveness of each teacher (Hattie, 2015), and they depend on the collective expertise of the entire faculty and administration, particularly as it relates to teaching and learning. Schools with strong shared influence do not operate in a top-down manner, nor do they operate as in an exclusively grassroots, bottom-up manner. Leaders work together in a relatively flat organization where shared goals drive the work. Strong schools leverage the expertise of all to determine shared goals, track progress toward those goals, and aggregate feedback from members of the team.

ORIENTATION TOWARD IMPROVEMENT

Risk-taking should always be informed by reflection. Taking risks does not mean a school will be successful. The reward for risk-taking is not necessarily success. The reward is learning (Heath & Heath, 2017). Therefore, schools with a strong orientation toward improvement tolerate risk because it is necessary for learning. Through this orientation, productive struggle will lead to impactful innovation.

WHAT THIS LOOKS LIKET

Teachers are encouraged by administrators to test innovations in curriculum, pedagogical delivery, or assessment with each other and track the relative success of those changes. Teams of teachers and administrators meet regularly to assess progress based on observable evidence to reflect, make course corrections, and determine what is most beneficial to students.

Exemplary STEM Case Studies

The following five case studies of schools are a cause for hope. Students are engaging with STEM in remarkable ways. After visiting five schools, analyzing documents, school-level data, conducting focus groups and interviews, these seven conditions are present.

Sometimes driven by administrators and sometimes driven by teachers, there is a shared vision of what leadership for STEM learning should be. Administrators are remarkably supportive with some principals functioning as "storytellers-in-chief" and others doing everything possible to connect district and community resources with innovative ideas that come from teachers and students. Teachers and administrators are identifying resources in the form of initial teacher capacity for the necessary work as well as financial and material resources including one teacher who has established his own 501c3 to make fundraising easier for his solar car team. Supportive social norms and relationships are increasing the influence of teachers and administrators both within and beyond the classroom. These conditions create an orientation toward improvement that supports "failing forward" in support of incredible student outcomes.

Staten Island Technical School

Staten Island, New York

RELEVANT DATA	• #10 Public High School in U.S. (The Best Schools) • #39 Best High School in U.S. (U.S. News & World Report) • #5 Best School in U.S. (Niche) • Selective Enrollment (340 Seats per year – 15,490 students applied 2016/2017)
STEM EMPHASIS	• Staten Island Tech Guild • Solar Car Team • Backpacks to Briefcases • Underwater Robotics • Summer and School-year Internships • Student Run Enterprise • Staten Island Borough-wide Hackathon
COURSE OFFERINGS	• All students take Living Environment, Chemistry, and Physics • All 9th and 10 grade students take Engineering and Robotics, CAD, and Audio-visual Engineering • All students learn Russian (50% take AP Russian) • All 12th graders take Calculus, AP Calculus AB or BC and/or AP Statistics with Multivariable Calculus available
ACHIEVEMENT	• Completers with Regents Diploma: 100% • Completers with Advanced Regents Diploma: 98% • Completers to Four-year Colleges: 99%
COLLECTIVE LEADERSHIP WORK STRUCTURES	• Hybrid roles, common planning time, co-teaching, and peer observation
PRINCIPAL	Mark Erlenwein
STEM FELLOW	Dr. Jared Jax

Background

"I give up my lunch period because solving problems is fun."

FRESHMAN GIRL, FRESHMEN MATH TEAM, STATEN ISLAND TECHNICAL HIGH SCHOOL

The quotation above is indicative of the kind of energy for problem solving that permeates Staten Island Technical High School (SITHS). Teachers and students willingly meet over their lunch hours because of the enjoyment they derive from solving hard problems together. Set in a quiet neighborhood on Staten Island is a nearly hundred-year-old building that is now home to one of the best high schools in the U.S. Founded at the end of the Cold War in 1988, SITHS has required all students to learn Russian and focus on STEM for the past three decades.

The current principal, Mark Erlenwein, is a 1992 graduate of SITHS as are three of the other five administrators. Approximately one quarter of the teachers are also alumni. Because of this, there is great pride in what SITHS has been and what it has become. Most students graduate with 30-60 hours of college credit and 42 percent of students participated in paid internships. As one of the top-ranked high schools in the U.S., SITHS is one of eight selective admissions high schools in New York City. Approximately 29,000 students from across the city and as far away as China sit for the entrance exam. According to Erlenwein, of the 180 selective admissions schools in the U.S., New York City is the only one that bases placements entirely on a single test score. For the 6,000 seats available annually, the top 6000 scoring students are able to rank their choices, with higher scoring students receiving preference.

Given the selective nature of admissions to SITHS, it would be easy to dismiss what they have done as simply a product of having strong students. This would be a mistake. Much of what teachers and administrators have done can be translated to other schools. To facilitate this transfer, Erlenwein "replaced every wall in this school with glass metaphorically. I am the

storyteller-in-chief. At district principals' meetings, I don't get those comments of, 'If I had his kids, I could do what you are doing' anymore." Erlenwein insists, "It is my job to document everything that is going on here. All teachers and students have signed off to let me take video and pictures. If you want to know what is going on, just follow my Twitter feed." In the spirit of openness and access, every Tuesday, SITHS hosts a VISIT (Visit In Staten Island Tech) program. Elementary and middle school students visit classes, the Makerspace, robotics, 3D printing, the comfort dog, and receive advice on college readiness. The entire visit is led by alumni of the schools attending.

Conditions that Support Exemplary STEM

SITHS is significantly more positive about the conditions that support collective leadership development for STEM than the other four schools. This is particularly true for supportive administration, work design, orientation toward improvement, and outcomes. In a survey given to teachers and administrators directly responsible for facilitating STEM learning, the average responses from 19 SITHS educators were consistently near the top of the scale with a range of average from 3.17 to 4.61. SITHS responses were significantly higher than other schools for supportive administration, work design, orientation toward improvement, and outcomes (See Figure 2).
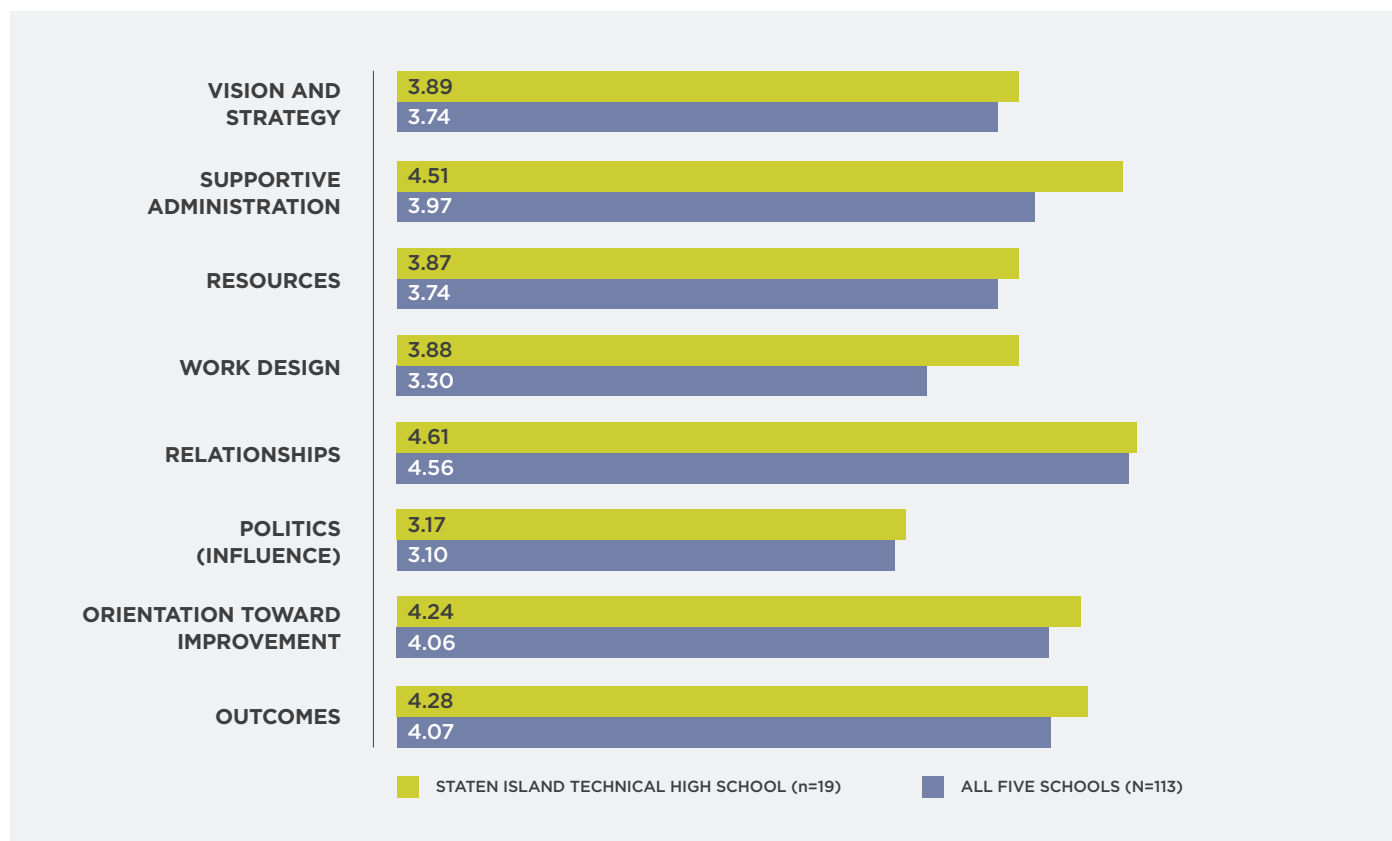

FIGURE 2 Conditions and Outcomes for Collective STEM Leadership * significantly greater (<.05) than other schools based on one-way ANOVA (5-point scale ranging from "strongly disagree" to "strongly agree")

VISION AND STRATEGY

The vision and strategy for STEM learning leadership is evident in the founding of the school, but that vision has evolved. Given its highly academic student population, in previous years the focus had moved more exclusively toward math and science, and the integration of technology and engineering had wavered. In the last few years, through the leadership of Assistant Principal of Career and Technical Education, Joseph Manzo, and Assistant Principal of Math and Science, John Davis, technology and engineering have been emphasized. With the elevation of Dr. Jared Jax to a hybrid role that allows him to continue to teach but affords him two periods a day to support other teachers as the Career and Technical Education Coordinator, the integration of all four areas of STEM has increased. This increase is represented in the participation of different disciplines in the Makerspace as well as integration across STEM classes.

SUPPORTIVE ADMINISTRATION

"Storyteller-in-chief" Principal Erlenwein has been a SITHS student, teacher, and assistant principal. He and the rest of the administrative team are extremely supportive of the work of teachers and students as well as the ideas they propose.

Assistant Principal Manzo describes how ideas are "very organic:"

When teachers have an amazing idea, I ask, 'how can I support that idea.' In fact, it was students who initiated the idea of our AP psychology class. They were saying that they had heard Ms. D'Anna might be willing to teach it. It is now one of our most popular classes.

Without exception, all 15 teachers interviewed described remarkably supportive administrators. Bianca Brandon, AP biology and forensics teacher, said:

I don't think I have ever had Mark [Principal] say no to any of my insane ideas no matter how insane they were including decomposing roasting chickens outside underneath the bleachers. Yes, flies, maggots, everything, you name it. He is very open to new ideas and our department head, Dr. Davis, is as well. So, when I ask, can I do this cray [crazy] project that I want to do, the response has just universally, in my experience, been: "How can I help you to get that done what kind of materials do you need? This sounds really great I can't wait to see how this rolls out." The level of enthusiasm for doing things that are different or innovative. For me that is a big plus in this building. To have that freedom as a teacher is terrific.

FIGURE 4 Joe Buro's renovated classroom

RESOURCES

The nearly 100-year-old building is well-maintained but does present challenges for space needs and modern labs. Teachers and students are extremely invested in their classrooms. Joe Buro, a technology teacher, described his actual investment:

Just like you walked into my room today, three periods after you walked into my room, a student tour walked in my room. I have tours coming through my room all the time, so does Mike, so does Everton, and like I said Joe and Mark pretty much assured me that I am not moving anywhere and since I spend that much time in there, I took the money out of my own pocket, about three grand. Two grand for the floor and a thousand for everything else [He did the work with students over the previous summer]. Well worth it. I feel so much more comfortable in there. With it came an intangible ownership of the space. I felt before as I was a guest where I would have to ask to hang something on the wall that was significant or to do something with the furniture. Once I started revamping things, I was taking furniture apart, throwing things out that had been there for 20 years, and I was just met with smiles and applause every time from the administrators and from the custodial staff. Our custodial staff is also just as unheard of as our administration is, or at least parts of it used to be. We have a couple of guys now that just kind of keep their heads down and do what they got to do, but one guy in particular that had left recently, he helped us running more electrical connections and hanging things we weren't supposed to hang up like different pieces of equipment all the time, so we had a lot of help. I would not have been able to do it without them really being in my corner, so I felt the monetary investment was worth it.

Significant resources have been invested in particular programs, particularly a high-tech television studio. However, teachers do not believe this is the source of their success. According to Buro, "I always tell them [students] that this is the same crappy DOE [Department of Education] building as any other school on the island, and we have the same number of licensed teachers in the same amount of licensed areas." The greatest resource that SITHS has available is its highly knowledgeable students, faculty, and administration. Educators from around New York, other states, and other countries regularly visit SITHS to learn from them. Because of their highly capable students, a high level of expertise is needed for STEM teachers in particular.

FIGURE 5
Laser cutting created in Buro's lab of Principal Erlenwein

Bianca Brandon, the AP Biology and forensics teacher, is a DNA expert was a forensic DNA analyst in New York City during the 9/11 terrorist attack. She takes students on an annual field trip to the 9/11 Museum and teaches openly about her experience identifying remains for two years after the attacks.

Michael VanBuren is a well-respected video production expert that has been teaching for ten years. During his first period, students at three different levels work on various production products in three different rooms, including a studio. He moves seamlessly between these groups as beginning, intermediate, and advanced students develop different projects and use him as a consultant.

An exchange between two technology teachers, Michael VanBuren and Everton Henriques, captured in a focus group describes the power of high capacity teachers:

HENRIQUES: One of the biggest assets that help us advance our STEM goals is our cohort of people who, simply put, know what they are doing. I continue to be surprised with how knowledgeable our staff members are. I think Mark [the principal] makes a big deal of that. He just seems to know how to seek the right people out. When you talk about CAD, for example, and consider Mr. Buro here, he's one of the best. He is teaching CAD principles and 3D fabrication applications to the master teachers of MfA [Math for America] tonight, for example, in Manhattan. He's one of the big guys out there in the field and of course he's here. You talk about a TV studio, but who's going to actually run a TV studio? We got the guy who can do it and has done it professionally. People straight-up know what they are doing and it is pretty cool to be a part of that. I think I have learned more from the folks here than I have from anywhere else in the ten years prior. I think that is why we are able to progress so well, because everyone is committed. They know what they are doing to get the job done, given the needs and available resources.

VANBUREN: That's a really good point. When I was first coming here to interview for the job. Someone said, "This is a great school. The teachers are amazing, and we do things differently here," but I remember thinking, "Yeah, but you get the smartest kids." But actually, you're right, that year when we taught each other what we are doing in our classes, I remember being amazed by how much was happening in each class, there is so much that kids gets get exposed to in four years.

Other teachers describe their administrators as "very knowledgeable in technology and instrumental in programming" as well as "cooperative." Teachers view the technical as well as managerial expertise of administrators as tremendous resources as well. As Joe Buro asserted, "It's really nice to have those people behind us all the time."

Jared Jax summed up the similarities and differences between SITHS and other good high schools after having started his career at a high school in the Bronx.

At both schools I found that the best ways to build internal capacity is to put teachers in positions where they are able to capitalize on their strengths and personal experience. When given the freedom to create and teach content that is meaningful and relevant to both students and the outside job market, teachers feel empowered to innovate and push students to achieve better outcomes.

However, SITHS resources provide some tremendous advantages.

The most glaring differences between the schools came with regard to access to resources and time spent on task. Due to the resources and reputation that were present at the school in Staten Island businesses, parents and alumni were always willing to come to the school and try to find ways to help contribute to the success of the school. This came in the form of work-based learning opportunities such as guest speaking and internships, grants and donations, as well as access to human capital in sharing ways to better prepare students for college and the workforce. Additionally, the school was able to build capacity by devoting more staff other than classroom teachers towards their CTE department, allowing extra time to be spent with stakeholders, teachers and students to create more opportunities, address concerns or issues, and bring in more equipment and supplies. In the Bronx, more of the teachers' day-to-day time was spent focusing on getting students to pass classes and address behavioral problems. This led to it being more difficult to get access to equipment and supplies, and as many people being able to invest time into the school and to help with the same types of initiatives that were present in Staten Island. As such, there were less opportunities for students to get involved in outside of class, and less time for teachers to innovate and push the limits of what was possible in the classroom.

WORK DESIGN

While teachers describe some limitations based on time, space, and class sizes, they describe opportunities that are not as prevalent or well-received at most schools. Administrators have ensured that each disciplinary team has common planning time for 42 minutes each day. Both teachers and administrators cite this as invaluable for moving forward collectively. Additionally, teachers across disciplines describe "inter-visitation," more commonly known as a peer observation. Math teacher, Kaitlyn Lang, described the way inter-visitation works:

Usually, in each observation they [administrators] will recommend a teacher that you might want to go observe if there is a particular aspect of the lesson that you want to focus on. We all pretty much have an open-door policy if you want to come in and observe anything we are doing, you are welcomed to do that. This is done in any prep period—any free period you have. If it works with your schedule, you kind of just see if it would be cool with the other teacher. Usually the answer is always, "Yes."

Stephanie Partnow, a math teacher, cited the changes that have occurred in school-led professional development and some of the ways teachers are working across departments. "Our professional development period used to be the assistant principal talking about very generic stuff. This year, they started to have a couple of teachers telling us some of their best practices, so we are getting to talk a little bit more to the other departments now."

Teaches describe an increase in opportunities to lead over the past five years. Two hybrid teacher leadership roles have been created to support CTE and writing. These positions have been filled by recognized teacher leaders who were repeatedly praised for the support they have provided to others. Additionally, multiple committees to explore mastery-based learning and culturally responsive teaching have formed to collect input and expertise as SITHS tries to better serve its students. One teacher summarized the increasing leadership experiences, "There has definitely been a lot more opportunity where if you wanted to take a leadership position you could do that."

SUPPORTIVE SOCIAL NORMS AND WORKING RELATIONSHIPS

The level of relational trust, the organizational property consisting of socially defined reciprocal exchanges among participants (Bryk & Schneider, 2002), between teachers and administrators is high. Jen D'Anna, biology and AP psychology teacher, described the way organic collaboration occurs because of teachers' and administrators' awareness of what is occurring in classrooms.

When I approach Mark [Principal] or John [Math and Science Assistant Principal] about any of the things that I want to do in my classroom, they always come back and say, "So and so is doing this as well, maybe you can collaborate and get some ideas." The administration kind of knows what is going on in every classroom and tries to set up times where we can collaborate with each other.

Across all departments, teachers are working together in areas like the school's Makerspace. The Makerspace is led by Charlie Dazzo who has been teaching for the last 14 years since ending his career as a sheet metal working at age 55. Teachers and students are invited to the Makerspace to design anything that they want for their units. On the day of the site visits, students were in the space during a free period building artifacts from ancient Egypt for a social studies class. The space stays open until 5:00 each day.

The relational trust between teachers was evident in the way they discussed peer observation. Teachers were very positive about these opportunities to observe others. This science teacher focus group interaction demonstrates these healthy working relationships:

Bianca Brandon: I love peer observations. I try to stick my head into my colleagues' classrooms whenever I get the chance to…. I am constantly stealing people's ideas and reworking it. Because sometimes you see something, and it sparks an idea even if you don't do the same thing. You just think, "Oh wow, this type of activity would be really applicable in this one particular situation." I think it just opens up opportunities for collaboration and for coming up with new and fresh ideas to do things that you have been doing already.

Jen D'Anna: I completely agree with that. You don't need to reinvent the wheel. You can just collaborate and come up with and share ideas and be able to go into the rooms and see other people at their craft and how they do it has really enhanced, you know. I spend a lot of time in Bianca's room.

Felicia Giunta: It is nice to see how other people do things—especially as a relatively new teacher at the time. And even now as the years have gone on, I think it is good because it gives you different perspective. I would like to spend more time in different disciplines.

SHARED INFLUENCE

Perhaps it is not surprising that there is shared influence given the supportive administration, strong working relationships, and high degree of relational trust. Teachers and administrators agree that organizational politics have improved over the years with the continuity of leadership and the consistency of support. If there are issues that arise, teachers bring them to a consultative council that has one representative from each department. The United Federation of Teachers representative also will bring issues forward. However, teachers feel that lines of communication are open with administration and described an "open forum" for discussion.

Several math teachers described the autonomy that they have:

We have a consultative council – we bring our general concerns to the council when necessary. There are a variety of issues. Mr. Ferringo, the UFT rep, will voice our concerns to the principal. The staff here just kind of goes with the flow. We are open to finding out what works best for students. We are most interested in what will help our students in the new world. We can't keep teaching the same way that we were taught. The skills that they need are different. The jobs we were prepared for are not there anymore. We have such an innovative principal, and he is thinking outside of the box. Our principal is always looking out for our students. He is very open-minded. He will let us try anything out of the box that somebody might have felt was crazy. He has always paid for any PD we want. For example, the principal paid to have all staff participate in a team building escape room. We go and learn about new things. When we come back, if we want something tried, we do that with the support of administration.

Lisa and I had gone to Brooklyn Tech, and we observed a cool new way to assess students. When we brought it back, we put it in place. Now a number of us use this group assessment. They are allowed to use their devices and their notes which is something where if they were in a real-world situation they would be doing.

Additionally, teachers cited numerous opportunities to influence colleagues beyond their school buildings. Math for America was one organization that was frequently cited as a great resource for ideas, professional support, and also as a venue to present their ideas. Teachers described what they considered to be "significant pay to lead workshops" for other teachers. This ability to spread their influence beyond their classrooms was highly valued by teachers and administrators alike.

ORIENTATION TOWARD IMPROVEMENT

A "STEM Culture" permeated SITHS as well as the other middle and high schools in this study. Experimentation, data collection, course correction, and a tolerance of risk drove the work of administrators, teachers, and students. For example, several years ago, SITHS started a one-to-one iPad initiative. While this was successful, the program became cost prohibitive so they tried to use cheaper tablets. Dissatisfied students began bringing their own devices to school. Recognizing that most students had devices they preferred, the school discontinued providing devices to all students and made them available for students who needed them. This type of flexibility represents the STEM culture that drives SITHS improvement.

Teachers repeatedly described the autonomy they feel to try new ideas to meet the needs of a changing world. Lisa Asher, math teacher, described the staff this way:

I find that the staff here, we "go with the flow" and that we are open to learning new things and seeing what really will benefit the students. All of us care about the students. They are going to go out into the world, and we want to learn all the best practices that will help them move forward beyond college. We care about what their needs are going to be in the world. It's not how it used to be. We cannot continue to teach the same way that we learned because the skills they will need going forward are not the same as what was needed years ago.

This orientation toward improvement that benefits students comes from administration. Math teacher, Kaitlyn Lang shared,

I feel like it is easy to be a school that is ever changing because we have an innovative principal. He is always thinking outside the box. The core of everything for him is what is in the best interest of students. It is easy to be open to change when you know it is coming from a good place.

Students demonstrated this type of orientation toward improvement as well. In a multivariable calculus classroom, 34 students worked in groups of students where peer mentors checked work one-on-one with each other. At first glance, the teacher was not immediately evident in the room as he bent quietly over one group after another offering feedback and answering questions. Students worked calmly and with a purpose on mathematical equations that move beyond the capabilities of most high school students and adults.

Because SITHS is a magnet school for STEM, perhaps it is not surprising that there is a strong orientation toward

improvement in STEM subjects. However, this approach to improvement transcends all aspects of the school. For example, freshmen teachers recognized a need for students to improve oracy – proficiency in expression and comprehension. Jennifer Fitzpatrick, work-base learning coordinator and technology teacher, now teaches a class to all freshmen to improve their verbal and non-verbal communication in coordination with their English and social studies courses. Acknowledging the need for this type of support, Jalen, a senior student, comes to school early to help support Fitzpatrick as a volunteer intern.

OUTCOMES

SITHS rankings, #39 (U.S. News & World Report) and #5 Best High School in the U.S. (Niche), do not fully capture what is happening for students. Of their students, 98 percent graduate with an Advanced Regents Diploma, and 99 percent go on to four-year colleges. In the summer of 2018, 42 percent of SITHS students participated in internships, most of which were paid. Their Solar Car team, led by Charlie Dazzo took second in the nation in the advanced solar car competition from Texas to California traveling over 540 miles at over 60 miles per hour in a student-driven vehicle. The Staten Island Tech Guild, Backpacks to Briefcases, Underwater Robotics, Student Run Enterprise, and the Staten Island Borough-wide Hackathon are just some of the remarkable STEM opportunities available to SITHS students due to the collective leadership and expertise of administrators, teachers, and students.

Students value the STEM culture of SITHS for three reasons. They believe it 1) creates an environment that gives students choice; 2) giving students the opportunity to create hands-on projects; 3) translating what is taught to their own interests outside of class time. One student described the open environment his engineering teacher created. "Mr. Henriques gives you the basics and then he makes you get to the end point on your own Flexible deadline." Another student described the benefit of hands-on projects. "I like learning more hands-on, at my own pace. In AP Environmental Science, we had to build our own wind turbine. I learned stuff that I would not have learned traditionally by creating something." Learning outside of the classroom is an expectation at SITHS according to students. One student described it this way: ""It's half about the teacher introducing supplementary materials, the other half is found on my own." Another student described how this works in Forensics. "Mrs. Brandon assigns group projects, but has us do our own research in our own time to build our own crime scene. She also gives us multiple opportunities to rework our project and add to our knowledge."

Barriers to Exemplary STEM

In order to achieve the STEM success that SITHS has realized, they have overcome several barriers and still have additional barriers to address. Many of these barriers have been overcome by savvy, supportive administrators. One teacher shared the way the principal has overcome numerous district challenges. "There are certain things the superintendent wants done, and we don't fit the mold of what they want done, so Mark has to appease them while we maintain the rigor of what we expect in our school. We have to say that we are doing what they want in a nice way." Due to SITHS' success, they do have a wide degree of latitude to pursue schoolwide goals, and teachers and administrators are often looked to for leadership across the district.

Another barrier is the Regents exams at the end of June. Teachers of Regents classes often feel constrained by the exam requirements and find it difficult to include more creative Makerspace projects as test deadlines loom. The balance between standardization and autonomy is certainly felt at SITHS; however, due to the performance of their students on Regents exams, there is probably more latitude at SITHS than at most high schools.

Other teachers cited the changing demographics of the school. One teacher who was also a graduate of SITHS described the demographic shift:

The fact that the population of the student body is ever growing and changing is also a bit of a challenge, not necessarily a barrier. I have a different frame of reference because I am an alumnus of this school, so I can say this is very different from when I went here…. I feel like kids in society are so much higher strung than when I was in high school. More kids are commuting from Brooklyn because it is an easy bus commute. This leads to kids from Brooklyn who might not want to stay after school and participate in programs since they just want to get home rather than stay after school and do things.

As is the case in many U.S. schools, the most common barrier to exemplary STEM learning is time. While teachers do have daily common planning time, there is always a desire for more. Several math teachers described their collaboration as "open" and "pretty informal" and acknowledged that they did not know if they would ever think they "have adequate time to collaborate." However, they do feel that the time they have to collaborate with the two hybrid teacher leaders was adequate. Additionally, teachers feel that outside organizations such as Math for America help expand their time for collaboration beyond SITHS, and they appreciate these opportunities.

Collective Leadership for Exemplary STEM

Of the five schools in this study, SITHS teachers and administrators shared the most closely aligned perspectives on collective leadership. When asked the following questions teachers and administrators' responses were almost identical.

1. **On a scale of 0-10, how much of the exemplary STEM work has been led by teachers (10 being total control, 0 being no control)?**
2. **On a scale of 0-10, how much of the exemplary STEM work has been led by administrators (10 being total control, 0 being no control)?**

Responses to the first question were typically sevens and eights, and the second question's responses were threes and fours. Typically, these responses will differ between teachers and administrators, but not at SITHS. This response was representative of both teachers and administrators: "It is the teachers in the school that make it. The administrators give us the power to do what we want to try, but we come up with the ideas."

Teachers and administrators cited multiple examples of collective leadership. One that came up frequently was a recent change to the grading system that now incorporates learning progress in qualitative ways. They refer to the new system as "Everything Counts," and it has been implemented as a universal grading policy. The team that put forward the

recommendation was a group of teachers and administrators that built the policy collaboratively when issues with differing grading policies arose. This collaborative approach was typical according to three math teachers:

PARTNOW: The math teachers went to the administration and said we are having a problem in geometry. There were students who were advancing and starting with geometry as freshman but shouldn't be because they were lacking algebra skills. So, they listened to what we said and created the new class for students that already took algebra but don't have the skills they will need in the future.

LANG: And that was determined by a placement exam which was our idea. We said we need to be giving these kids a math placement exam before they come in as freshmen so we know exactly what their skills are and what they might be lacking.

ASHER: Our AP, John Davis, was open to it, and Mark [the principal] was open to it. We collaborated and made the test ourselves over the summer. We came in July to go through the exams, and we determine which kids could come into the algebra class. This was a collaborative effort between staff to do what was best for student learning. We had a strong voice in that. If it wasn't for the AP, that wouldn't have happened. He could have easily said, "No, we are not doing that," but he did not.

Teachers at SITHS recognize how strong the collective leadership is at their school. They attribute much of this to Principal Erlenwein.

As invested in these kids as we are academically, we are invested in them as people. We want to make sure their best interest is being met. Mark [the principal] has his finger on the pulse of what is best for the students. He has a good sense for what the needs and the desires of the staff are, and he works it make that happen as best as he can."

Another teacher added, "It doesn't feel like things are force fed. Everything is always a discussion. He is the principal and has the ultimate decision in things but we feel that he values what we think." A teacher summed up the good fortune that teachers feel about being at SITHS:

I was talking to a friend of mine that is a teacher in another school and she was complaining that she doesn't feel respected by her administration, and I was thinking to myself how terrible it must feel to go to work every day and feel that lack of respect from your boss. I feel fortunate that Mark does respect us and values our opinion on things. He has an open door policy if you want to chat about things. That helps a lot. It makes our job a bit easier.

Boardman Elementary School

Oceanside, New York

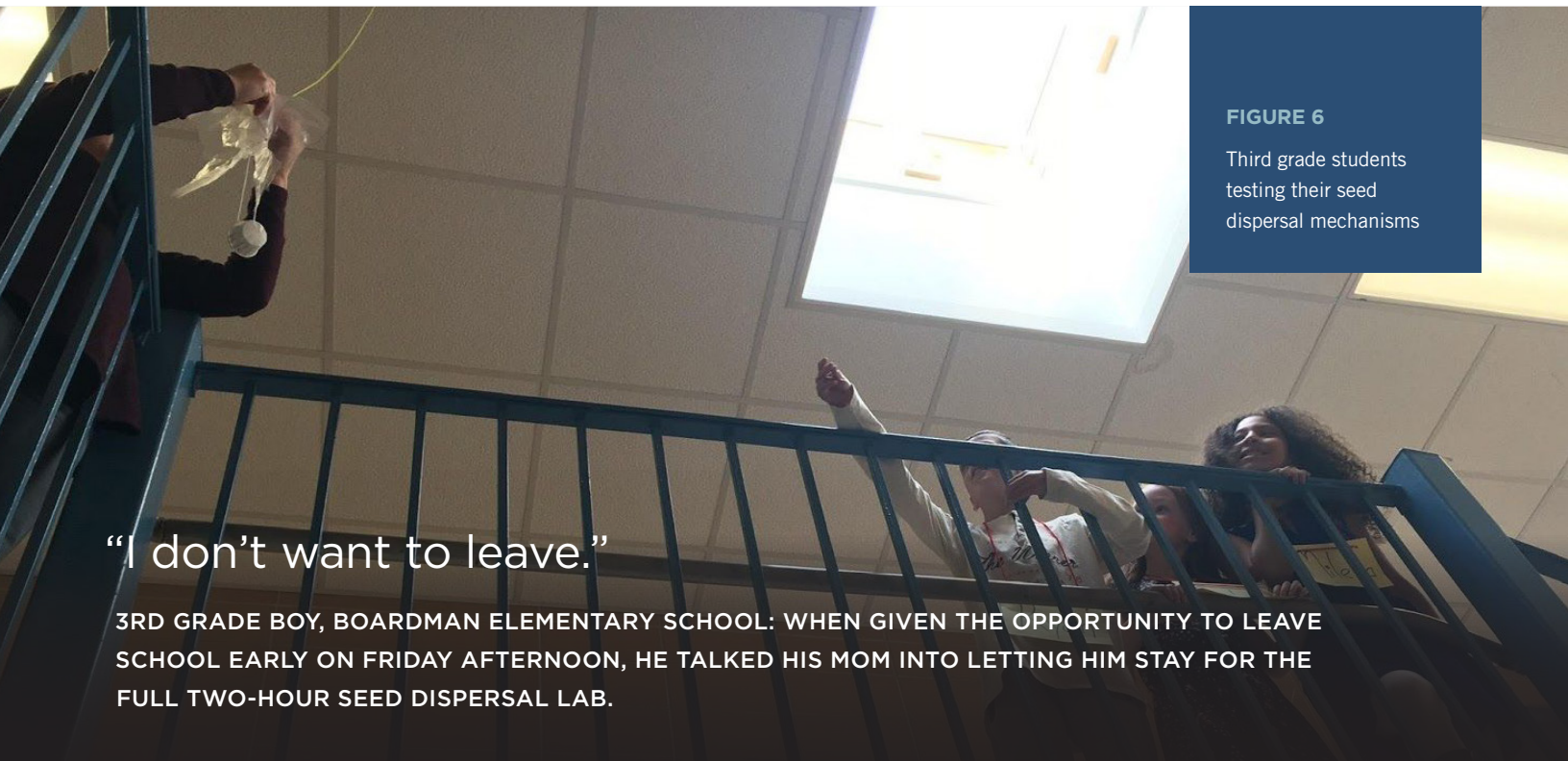|	
RELEVANT DATA	• #155 of 2,467 Best Public Elementary School in New York (Niche) • #136 of 49,485 Best Elementary Public School Teachers in U.S. (Niche)
STEM EMPHASIS	• Makerspace • Integrated STEM Units
COURSE OFFERINGS	• Makerspace offered for all students • 3rd-6th Integrated STEM units
ACHIEVEMENT	• Percentage of 4th graders proficient or advanced in ELA: 56% (NY average: 47%) • Percentage of 4th graders proficient or advanced in Math: 59% (NY average: 48%) • Percentage of 4th graders proficient or advanced in Science: 93% (NY average: 88%)
COLLECTIVE LEADERSHIP WORK STRUCTURES	• Master teacher, common planning time, co-teaching, and peer observation
PRINCIPAL	Josh McPherson
STEM FELLOW	Danielle Chiera

FIGURE 6

Third grade students testing their seed dispersal mechanisms

"I don't want to leave."

3RD GRADE BOY, BOARDMAN ELEMENTARY SCHOOL: WHEN GIVEN THE OPPORTUNITY TO LEAVE SCHOOL EARLY ON FRIDAY AFTERNOON, HE TALKED HIS MOM INTO LETTING HIM STAY FOR THE FULL TWO-HOUR SEED DISPERSAL LAB.

Background

"I knew I was a scientist deep inside."

2ND GRADE GIRL IN THE MAKERSPACE, BOARDMAN ELEMENTARY SCHOOL

When a third-grade boy does not want to leave school early on a Friday afternoon, it is clear that teachers are doing something right. When students are engaged in a two-hour seed dispersal lab, and the biggest management challenge is that students are too passionate about their modifications to their seed dispersal mechanisms, something remarkable is occurring. Third grade teacher, Danielle Chiera, was co-teaching a seed dispersal with STEM specialist Donna Migdol in a full-inclusion classroom. They worked their way around the room going from group to group assisting them in a design challenge that required them to create a mechanism to deliver a seed as far as possible from a "plant" that would release the seed from the second floor of the building (See the picture above.). The office called her room, letting her know that one of her students on the autism spectrum needed to come to the office because his mom was here to take him about 90 minutes before the end of the school

day. He walked to the door, put his hand on the knob, and said, "I don't want to leave." Ms. Chiera encouraged him to go to the office. By the time he reached his mother and the office, he was sobbing. His mother asked him what was wrong, and he replied, "I don't want to leave science." She was so moved by this response that she told him that he could go back to class. He opened the door the classroom and raised his hands over his head and announced, "I get to stay." Ms. Chiera went to the office to be sure this was fine, and she found his mom crying in the office. She told Ms. Chiera, "He usually does not like school. Whatever you are doing, I am so grateful."

The passion that students at Boardman Elementary school demonstrate for STEM is inspiring. From second graders in their Makerspace to all grade levels integrating STEM, they are developing a STEM culture filled with problem solvers and

creative analytical thinkers. Located on Long Island, Walter S. Boardman Elementary School, built in the 1960s, looks like many elementary schools across the U.S. On the outside, it is relatively non-descript in a quiet neighborhood. What goes on inside, however, is far from typical. Donna Migdol, described by several as a "force of nature" and as a "beacon" by Boardman's principal, is one of two STEM specialists in the district who serve its six elementary schools. Over the past decade, by co-teaching STEM labs and developing Makerspaces, she has transformed STEM learning in Oceanside, New York.

Conditions that Support Exemplary STEM

Boardman's principal, Josh McPherson, distributed the collective leadership for STEM survey to all of the teachers directly responsible for STEM learning at Boardman. These school leaders are significantly more positive about the conditions that support collective leadership development for STEM than the other four schools in relation to supportive administration, school orientation toward improvement and initial outcomes for students. In a survey given to teachers and administrators directly responsible for facilitating STEM learning the average responses from the seven educators were consistently near the top of the scale with a range of average responses from 3.46 to 4.86 (See Figure 7).

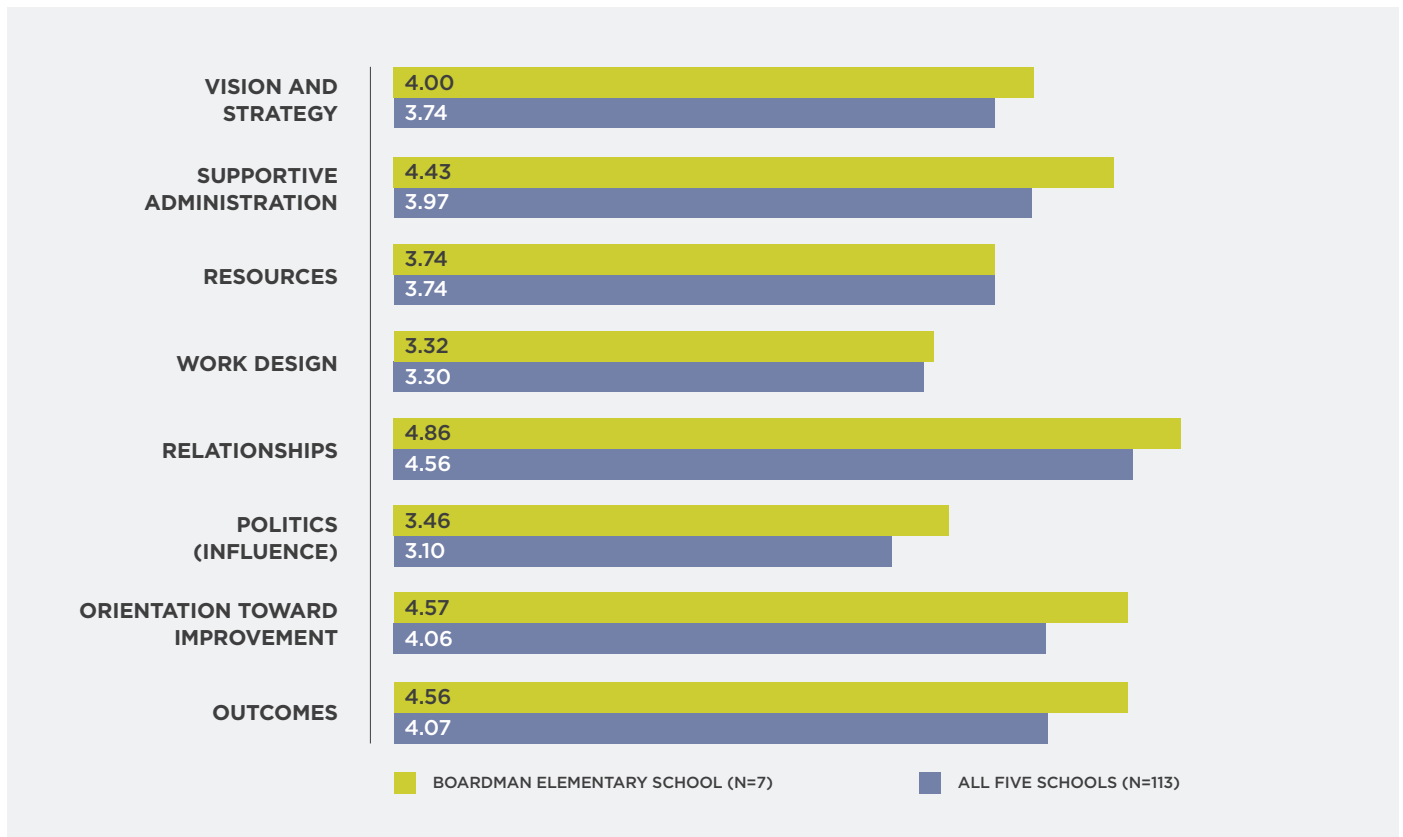|	BOARDMAN ELEMENTARY SCHOOL (N=7)	ALL FIVE SCHOOLS (N=113)
VISION AND STRATEGY	4.00	3.74
SUPPORTIVE ADMINISTRATION	4.43	3.97
RESOURCES	3.74	3.74
WORK DESIGN	3.32	3.30
RELATIONSHIPS	4.86	4.56
POLITICS (INFLUENCE)	3.46	3.10
ORIENTATION TOWARD IMPROVEMENT	4.57	4.06
OUTCOMES	4.56	4.07

FIGURE 7   Conditions and Outcomes for Collective STEM Leadership * significantly greater (<.05) than other schools based on one-way ANOVA (5-point scale ranging from "strongly disagree" to "strongly agree")

VISION AND STRATEGY

The theme for the year that applies to all subject areas at Boardman Elementary is "Wonder." Principal McPherson said the theme "transcends STEM," but also sees the discussion and questioning techniques as grounded in inquiry. This focus across grade levels and subject areas demonstrates the STEM culture that has begun to permeate the school.

When we asked via an anonymous initial survey what made the school successful in developing STEM, a teacher leader responded, "Boardman has a shared vision of the value of STEM in the classroom and growing curious thinkers who problem solve and create innovative solutions." This shared vision was a recurring theme in interviews and speaks to the STEM culture that permeated all five schools we studied.

Teachers, the principal, and superintendent administrators credited Donna Migdol with creating much of the STEM vision in the district at the elementary and middle school levels. Her passion and energy for the work were allowed to flourish because of their desire to support her vision. Administrators and teachers articulated this vision and strategy in terms that allowed Ms. Migdol to influence others as she co-taught with teachers and brought Makerspaces to the school.

Migdol described the power of having a vision for STEM leadership:

I think that is also key, having that vision. I was talking to someone the other day and they said, "You know what we're doing in STEM is kind of like what we're doing in language arts now, and kind of what we're doing all around." Oh, it was Josh [Principal McPherson] who was saying that yesterday. Josh was saying that and it really hit home. You can really see that the vision is real because you can see it in almost every subject area. And that takes a lot to create, like one big Makerspace.

Principal McPherson believes that Migdol was essential for developing the vision but that "You can have it start with just a small group, and I think they can collectively, maybe three or four people, can match Donna's enthusiasm and start pushing things forward. And then, ultimately, you still have that same evolution in terms of the gradual release." With "gradual release," he is referring to the way the vision for STEM has spread at Boardman and in the district as Migdol plans and co-teaches with teams of teachers.

Another teacher described the way they influence STEM through the collective leadership of teachers and administrators, "You can really see that the vision is real because you can see it

in almost every subject area. And that takes a lot to create— like one big Makerspace." The school has become "one big Makerspace" as teachers expand the vision of what it could be even beyond traditional STEM projects.

Matt Christiansen, the district science director, described the common vision that manifests itself in who leads the work:

We need to have a common vision to make sure that we can do that within the constraints that we have while also allowing the kids to be successful with the endeavors. I think it's a joint shared vision with bringing in the teachers to be a part of the process. And Danielle, the person you're going to see, led professional development over the summer after she did all the summer curriculum writing with both the seed dispersal and the new NGSS unit, which are embedded together."

SUPPORTIVE ADMINISTRATION

In Oceanside School District, supportive administration begins with Superintendent Phyllis Harrington who has been in her role for six years. She inherited a pull-out model for gifted students and saw what Donna Migdol, one of the gifted pull-out teachers, could do. She recognized her STEM skills and determined that she could have greater impact as a STEM teacher who pushed into classrooms. The work began in fourth grade with a roller coaster unit and spread to more grades and more units through the gradual release model of grade level teachers taking over the work. She heard things from teachers such as, "I can't believe what this special ed kid is getting out of this." Harrington said, "It [STEM teaching] is opening people's minds to what students can learn and do."

Harrington continued:

Makerspace became a big deal. We went through several hurdles with that. We thought that the librarians could make this work. That did not work. Some teachers cannot deal with the prep and the management of materials. Makerspace was the perfect place to go. We had Donna pick it up. Donna is always in whirlwind, and she would have driven principals out of their minds if they did not see what she produces.

Principal McPherson described his support this way:

Ultimately, I think the administrators do not have as deep of an understanding of the curriculum as, say Donna, or the teachers who teach it, but we understand the bones of the programs of each individual unit, and we're able to work with her to figure out what else needs to be in place to make it successful.

When asked if the STEM success they have experienced is more dependent on teachers or administrators, administrators given the credit largely to teachers. On a 10-point scale with 10 meeting "total responsibility," administrators rate teachers at 7. Administrators take some credit for getting the right personnel into position and developing cohesion by providing and collecting feedback, but the work of improving STEM education has been left to teachers. Teachers attribute much of the support they feel to shared professional development that they did with administrators several years earlier. Teachers also cite a lack of "rigid restrictions" and "flexibility" on the part of administrators to shift schedules and experiment with new ideas.

RESOURCES

Boardman addressed resources and capacity in several ways: space, time, materials, and expertise. This year, they were able to dedicate a classroom to their Makerspace which made access and storage of the materials far more available. School and district representatives have visited other schools to see where they have made space to make the best use of their buildings and have observed Makerspaces as converted computer labs or as portions of libraries, but having a dedicated room has been most beneficial for Boardman. This dedicated room has increased the amount of time that students can be in the Makerspace.

Through grants, partnerships with manufacturers, and local resources, Boardman has secured a number of materials that have facilitated the development of the Makerspace and the STEM units. In the Makerspace, second grade students were using modular robotics called Cubelets, Snap Circuits, Keva Planks, and mPie coding tools. The materials the second-grade class was using cost more than $1000, but they were all re-usable, and Ms. Migdol received some of the tools as prototypes to test with students from companies like Microduino for their product, mPie. In addition to the expense of the materials, the lessons and units need to be created by teachers. Based on feedback that teachers were not entirely comfortable with some of the science content, teams of teachers worked with each other to develop curricular materials for STEM units and the Makerspaces. One teacher shared, "these curriculum documents that you have in front of you have greatly evolved over time to make it a lot more supportive for the teachers."

In order to continue to develop expertise, Boardman leaders cited the need for teachers to have time to learn together. Teachers cannot be dependent on one person, whether it is Donna Migdol or a principal. Kristin Stea, 5th grade math and science teacher said,

We went to the National Science Teachers Association conference last year. We didn't walk out with a STEM program, but there are some really, really great national organizations, I think, we should be pointing toward, that's why those organizations exist. We need to be pointing them in the direction of cohorts, of networking, that you can go to problem solve when it's not working the way you want it to work, 'cause Donna [Migdol] may not answer her cell phone or text you that one time.

Ms. Migdol went on to explain the need to create networks.

We have created a hub, a consortium, of districts around you where you can have a toolkit, where you can actually have a Google Hangout and meet together, and you can look at best practices in their district and your district, and then meet together and talk about curriculum writing. I don't see why it has to be isolated to one school district, why you can't branch out and work together.

WORK DESIGN

The gradual release of responsibilities through job-embedded professional learning dictates that the work at Boardman happens a bit differently. Teachers have the opportunity to plan STEM units together as grade levels based on materials and discussions with educators who have been designated as district master teachers. There are three master teachers for the six elementary schools. One master teacher is responsible for grades kindergarten to second grade, another for third and fourth grade, and the third teacher covers five and six. Additionally, Ms. Migdol meets with teachers during the school day, on weekends and co-teaches lessons with classroom teachers until teams are teaching independently. This type of co-development provides many opportunities for professional growth as one teacher described, "It also gave teachers opportunities to go visit those classes that were doing those projects, and get time with Donna [Migdol] to ask her questions. This requires time in our schedule to make it work."

Making that schedule work is a significant challenge particularly with teachers shared across six schools. Principal McPherson explained:

So, I was actually really integral in the first year or maybe the second year of helping to draft that schedule. Joanna Kletter was as well. The schedule is a behemoth. It has, at this point

it's color coded with Donna going from here to there. We have to look at the scope of the year. We have to do it in advance of the start of the year obviously, and then we have to share it with teachers, building administrators and get that feedback. The gradual release model has allowed us to find the space and the time for this to happen when it comes to teachers in each building, and even Donna's time. She only has so much time. But like I said, initially we started with fourth grade. Her time was devoted to fourth grade, and now she's been able to take, you know, three years later take that step back. And they're comfortable reaching out to her if they have questions, but I think they can fly on their own and they really have been. But it's no easy undertaking. It's a shared Google calendar that all of our administrators have access to.

Matt Christiansen, the district science director, also provides this type of support. "I was actually just meeting one-on-one with a third-grade teacher about the seed dispersal unit. So we try to have some sort of a coaching model along with it. It's not just teachers doing it on their own. So they receive support through Donna, through myself, and through our teaching and learning coaches." He went on to describe how the coaches were selected. "They are very well-respected by their colleagues and were identified as effective teachers in the district. Teachers have no problem reaching out to them and asking for assistance. And they [the coaches] have residencies in each building, so there are dedicated times where they can reach out and meet with their PLCs."

All of this collaboration is an acknowledgment that as one Superintendent Harrington said, teaching is a "highly intellectual activity, and it's incredibly hard work because of that. And to do it alone, and to do it in isolation, is impossible to do well. And that the only way to make that happen is to do some sort of supportive coaching model."

Boardman uses paraprofessionals creatively to support STEM. For example, they use two library aides on a six-day cycle where three days of the six for each are used in the Makerspace while the other aide addresses library needs. This provides an extra pair of hands in the Makerspace while still covering checking out, book talks, and read alouds in the library.

Much of the work design is about implementing slowly, getting feedback, and then flexibly making changes. Each year, a new grade level pilots a new unit and Makerspace time. However, as teachers become more comfortable leading the STEM work, this frees time for more support of new grade levels and units.

SUPPORTIVE SOCIAL NORMS AND WORKING RELATIONSHIPS

As teams of teachers have developed STEM units and Makerspace experiences, they have developed and improved working relationships. They have written and revised the curriculum as well as providing professional learning to other teachers. As third grade teacher Danielle Chiera described the iterative nature of their work:

Teachers are learning from teachers. It has a little bit more of a personal connection because no one's really nervous that they're going to make a mistake or that it's something that we know, it's constantly evolving. We do our best to make the best of what we have and the resources we have around us that we really think help us the most.

Obviously, supportive administrators are key for these working relationships to flourish. Superintendent Harrington made this explicit:

As administrators, we also accepted certain things very openly and willingly. So, for example we needed to accept the fact and work within the fact that there were going to be a lot of teachers that were going to be a little bit uncomfortable with this because, to be honest with you, I mean when she starts talking about aerodynamics and the physics and all that, I mean it's not a comfort level for me. I don't have that, honestly, that level of knowledge. There is a vulnerability there in particular, for elementary teachers. But I'm proud of the fact that we went into this recognizing that people would need support, different people different amounts, and for a variety of reasons. But deep down inside, I think it really did come from the fact that there were some people that were really uncomfortable and vulnerable. But they've opened their doors and have come so far in that regard. The other thing that, in terms of us accepting feedback, even if we might not have agreed with it, we worked with it and made it work.

Vulnerability around content was needed, but so too was flexibility around scheduling. Harrington provided another concrete example of how supportive relationships and trust supported a change in the way teachers thought about their time:

So I'll give you a concrete example. You hit bumps along the way when you do things like this. One of the first bumps we hit, from a scheduling perspective, is that there were upper grade teachers who were feeling uncomfortable with the fact that

we created a year-long schedule, and some people ended up having Donna come into their classroom a week or two prior to the state assessment. And they were very uncomfortable about that. Now we all know the reality is that a week, give or take, is not going to make a difference on how students do [on state assessments]. But we accepted the fact that it doesn't matter. It's how they [teachers] feel. So we very intentionally worked around that as best as we could. And, you know, even from Donna's, 'what do you mean? That's craziness. What do they value?' So we were managing it from both ends because, we have just accepted the fact that this is going to be a block that doesn't make sense. It doesn't make sense to push the envelope on this. So we have those kinds of dialogues all the time, and we're always reflecting and taking that input. So on that, I'm proud of the fact that people are comfortable and willing to give it, and the fact that we have a team of administrators who don't take the, 'It's my building. It's the way we're going to make it. It's my department,' or whatever attitude. That is really the key. It really is.

These supportive social norms are extending to students. Another teacher described the way students are working together differently:

I have a lot of kids who, especially the higher-level kids, want to do things completely on their own. And for me it was interesting, a very good friend of my son went to Harvard years ago, and his mother came back and said, after the initial orientation, she said, 'the biggest problem at Harvard is that the freshman class do not want to work together as a team on anything.' You're getting the brightest of the bright, and they just want to do it on their own. And you do see that. You see a lot of the higher level kids like, 'I'll do it myself.' And this forces them to work with other people, which is a really good thing, and see the benefits of it. And after we finished ours last year, this is like a silly thing, but we were talking about playing at indoor recess. And I have all these games. And they asked me if I could purchase all the things that they worked with in Makerspace. So now, I went out and I got Lincoln Logs, I have more Legos, I have more things like that that they choose for indoor recess, instead of just playing checkers, for example. And they asked me to get those things.

SHARED INFLUENCE

The type of supportive social norms described above, typically lead to strong organizational politics that allow for healthy influence between teachers and administrators. All of the

teachers who were interviewed described administrators as supportive of their work. This included their development and implementation of curriculum as well as the feedback they had for structural changes to schedules and physical space. Teachers described collective leadership as a primary driver of their STEM work. For example, one classroom teacher shared, "So it's nice to not only have the leadership from the administration and then obviously master facilitators, but working with multiple teachers and then teachers learning from teachers." Other teachers described the autonomy that they felt in the school.

And I think like the autonomy part too is, so we work with Donna on whatever the Makerspace, the task, the quest, but then we're free to pull from that and bring back to our class what we feel will help our children best grow past the tasks of the Makerspace. So really that's where I find that. We take back what works best for our class.

Another teacher shared, "We all had a say. It [the STEM curriculum] was designed by teachers, and then given to us and we had a say in what was going on."

Again, this speaks to the gradual release of responsibility. A master teacher like Ms. Migdol influences other teachers and administrators with the vision she has for STEM. Those teachers co-teach lessons and design curriculum. Over the course of three years, the teachers begin to own this process. When new teachers come to Boardman, they have "turn key" curriculum and support from their peers that continues to evolve.

This influence continues to spread beyond their school and district. This interaction below in a focus group captures that influence:

Fourth grade teacher, Kristin Stea: "So two years ago I was fortunate enough to represent Oceanside. I went with Donna and our current assistant superintendent to Washington, D.C. to a STEM conference where I got to meet with physics teachers and mechanical engineers and professors and all these amazing people. We discussed the important role that school districts play in STEM and how important STEM is inside of the classroom. But, for me, it was great because I was, I think, the only elementary teacher there that was actually involved with the special ed and gen ed learners. And just to talk to them about, not just the impact on the upper level kids, but how it just impacts every single person."

Donna Migdol: "It was a convening by the National Academies. I was a chair of a committee on enhancing teacher voice in

STEM, and STEM policymaking. So what grew out of that was, we had to leave there by coming up with a plan, so our plan was to reach out to neighboring districts, so we did that. We had a consortium here two years ago where we said it was two teachers and one administrator, first come first serve, and they would come and look at our STEM program. They were adult learners. They had to do the roller coaster physics themselves. Then we shared all of our curriculum with them on a Padlet, and then we had a meeting of what they were going to do back in their districts."

Kristen: "And we met with them. Like we each split up, and we sat with different districts, and we guided them on how they could implement this in different schools and different grade levels."

Donna: "And we're doing it again on November 9th, and within a week we had 40 people, 10 school districts coming to the same type of gathering."

Second grade teacher: "And how great is it that people are starting to listen to elementary people? You're not waiting until middle school or high school to get into that kind of learning, or they're seniors in high school and they're deciding, 'uh what's an engineer? What's an architect? What am I gonna major in?' These kids know this now."

ORIENTATION TOWARD IMPROVEMENT

Improvement is built into the system at Boardman. First, teachers collect survey data annually from students about how they are deepening their STEM learning and comparing results from year to year.

Second, the gradual release model allows opportunities for curriculum to evolve based on feedback. As a second grade teacher shared, "At the end of each unit, there's always time for reflection to see what we could tweak, what we could add, what went well, what didn't go well, what we could change." Another teacher added, "Every time we do something, we tweak it. And we're given the opportunity to meet and write curriculum to make it better the following year. As we keep learning and growing, the program keeps learning and growing, so that's important."

Third, this orientation toward improvement is evident in students. Kristin Stea said, "They [students] are willing to take risks. I taught ICT [integrated co-teaching] twice, three times actually, doing this. And just to see how comfortable

the children are at all levels, that they'll just take risks in all classes. They're not scared to take a risk in any subject. Because after STEM and they see that there's no one right answer, and just working through it as a team, I just see such a change in the way they behave and interact with each other."

OUTCOMES

Boardman is beginning to see positive outcomes of the STEM culture they have created. The outcomes can be categorized as pedagogical, social-emotional, and academic. The district science director, Matt Christiansen, highlighted the way things are changing pedagogically:

You're going to see some wonderful pedagogy in the Makerspace too, because, you know, I'm coming from a district where the Makerspace was basically just a creative space, and you went in and did something. Whereas this one, there's that creativity, but there's the intentionality. And there's specific instructional teacher moves that she does to really probe to see whether or not they are getting those 21st century skills that we're really focusing for the kids to have those collaborative skills, those communication skills, those creative thinking skills.

The social emotional lessons that students are taking from their STEM experiences are powerful. To illustrate, in the third-grade full-inclusion classroom working on the seed dispersal lab, one group was really struggling. One girl was doing most of the work on the lab with another boy who was partially invested, and one boy with some significant learning needs who was not engaging. When Ms. Migdol observed this, she asked the team, "What does good team work look like?" The girl who had been managing all of the materials immediately pushed them into the center of the group and asked the two boys what they thought they should do. Ms. Migdol said, "I like the way you pushed the materials into the center and asked a question. That is how scientists learn together." They continued their work together with Ms. Migdol and the classroom teacher returning to them frequently to continue to encourage collaboration and inclusion. After the first seed dispersal test, the groups had to re-design their seed dispersal mechanisms, but they could only change one thing at a time. After briefly discussing this as a whole class. Ms. Migdol claimed that there was "a group in the room that had been doing a great job collaborating" and asked all of the third graders to sit around the outside of that team. The team she selected was the one that had been struggling.

Proud to have been selected, the team sat up a little taller and the girl who had been taking over explained the one modification she thought they should make and then asked, "What do you think we should do and why?" The two boys each shared what modification they would make and provided their reasoning. Ms. Migdol, then asked the rest of the class to comment on how that collaboration had gone well. The team being observed listened proudly, as they had demonstrated significant improvement in the essential 21st century skills of collaboration and listening.

These benefits accrue to both advanced students and struggling students. One teacher described the benefits this way:

I think the change in the gifted and talented children, it's a huge change for them because they're not used to having to work with children that are not thinkers like they are, and they have to adjust their whole mindset and change their whole attitude about how this is going to be. We do a reflection before we start, what are you looking forward to, tell me about you as a learner, and I'll get a lot of students who say, 'I don't like teamwork. I don't like listening to other people's ideas. I want to do it my way.' And in the end, when they reflect, they will say that was the hardest thing for them was to have to listen to other people's ideas and compromise to come up with a final windmill design. And it's a big process for them.

Another teacher added, "We also find that the gifted and talented students are the ones who are the most nervous to fail forward. They don't want to take that risk. They're afraid of being wrong. They don't want anyone to see that they're making a mistake if it doesn't work out that way." The STEM interactions they are having is starting to change that.

For students who might struggle with reading, these STEM experiences provide outstanding opportunities to stretch academically. Below is an illustrative observation from Amy Simon, a second grade teacher at another school in the district:

My first-grade colleague, who had just written the curriculum for first grade and was starting it for the first time, came to observe. And what she said, and this will stand out because everyone is so like, 'what is their reading level?' The parents want to know what level they're on. She said, 'this is the one place that reading level doesn't matter.' And that really stood out when she said that. And I, too, have a student who is speech and language impaired, and he goes out for services, and he will just be quiet all day long. If you looked in his notebook prior to Makerspace, he really just had letters that were, he would just

string letters together. It would just be filled up with letters, no real words. And the minute he finished Makerspace and wanted to write about it, he wrote words. There were spaces, and there were sentences. And, again, it wasn't like other kids in the class, but for himself because he needed to express and share the pride that he had for his success. So, just because he may be reading on a kindergarten level does not mean he cannot think and solve problems. And he saw that in himself, I think, for the very first time in his life.

Another teacher observed changes in the way students approach their work:

It's the way children learn and the way children think. Like, there are different things that we do within Makerspace, the wonderments, the process ticket cards [students receive cards that encourage them to process what they are discovering]. All of a sudden, you see kids coming back and they're like, 'oh I wonder.' They start to use the language, and then they start to think like a maker while you're doing other things within your day. It could just simply be center time in class. We start to hear them talking amongst themselves, realizing that they just communicated and collaborated with their partner.

These observations extend beyond STEM subject areas according to teachers:

Keep in mind that the learning happening in STEM is being applied to other subject areas, which I think is the most powerful thing, that self-efficacy of our students to say, 'Here is a challenge. Let me acquire the materials and resources I need. Let me work with my team collaboratively, and then let me solve this problem in a way that's also connected to the real world.'

These outcomes are obvious when students are working together. As we observed second graders in their Makerspace, makers were regularly announcing things like, "we just made a new discovery" and "I'm just like my grandpa. He's an inventor too." Additionally, when students were finishing they were asking questions like, "Where do we process what we drew?" Student were looking for places to write up their thinking so that it could be transparent for others.

Barriers to Exemplary STEM

While Boardman has overcome many barriers, they are still areas to improve, particularly as they relate to scheduling, resources, and mindsets. Scheduling continues to be a challenge. One primary teacher shared, "Sometimes there are scheduling conflicts where the children have Spanish, and that has to be bumped or tweaked or skipped. It's such a structured schedule. Snow days, when they come into play, kind of throw everything off balance. But you have to be flexible." Space can also be a problem when there is not a designated classroom. The previous school year, there was not room for a Makerspace classroom, so it was located in the library which made it more challenging to use effectively.

Teachers also highlighted the need for changes in thinking. One teacher shared,

I also think the shift in mindset from educators, you know, that this experience transcends some of the "check-the-box," "I have to get all this done every day, kind of mentality." So, like kind of conveying that this is a worthwhile experience, that it's not your math lesson for that day, but it's something that they are benefitting. And I think that as people experience it more

and more, they're seeing the bigger picture of what the value it brings them.

Another teacher added,

I agree with Amanda in a sense that just that mindset also of some educators who say, "well there's no way my students can do this. There's no way they're gonna be able to do this. It's too difficult. They struggle. They won't be able to maintain the duration of how long they have to understand what's going on or sit for this amount of time or work in this group." And I think, across the board, we all feel that our students who struggle academically in a traditional classroom, this is really where they do thrive. And having that freedom to really kind of just express their thoughts, and again chiming lends to that also where they're just able to communicate their thoughts and everyone gets a chance, and it just has so many other skills that are just integrated and built in that come out naturally and organically that it's really kind of that shift that they can do it. And actually, those are the kids that you're going to see probably make the most strides because of the level of comfortability that the environment really provides.

Collective Leadership for Exemplary STEM

When asked the following questions teachers' and administrators' responses were different but both groups emphasized the importance of teachers.

1. **On a scale of 0-10, how much of the exemplary STEM work has been led by teachers (10 being total control, 0 being no control)?**
2. **On a scale of 0-10, how much of the exemplary STEM work has been led by administrators (10 being total control, 0 being no control)?**

The responses from teachers and administrators for the first question ranged from 7-10 and 3-7 for the question about administrators. Teachers were more likely to believe that they were the primary drivers of STEM leadership. Administrators saw their role in developing schedules, roles, and finding

resources for materials as being a form of leadership. Both teachers and administrators appreciated the roles that others played in the STEM work.

What is occurring at Boardman would not have occurred without collective leadership. While the work has been well-supported by administrators, the real impetus and expertise behind the expansion of STEM has been Donna Migdol who was described as a "force of nature" by multiple people. Through co-teaching, co-developing, and co-leading professional learning, Ms. Migdol and her colleagues have fundamentally changed teaching and learning in their school through gradual release of responsibilities. They have built capacity, trust, and curriculum. However, without the expertise and support of administrators, there would not have been time, space, materials, or opportunity

East Syracuse Elementary

East Syracuse, New York

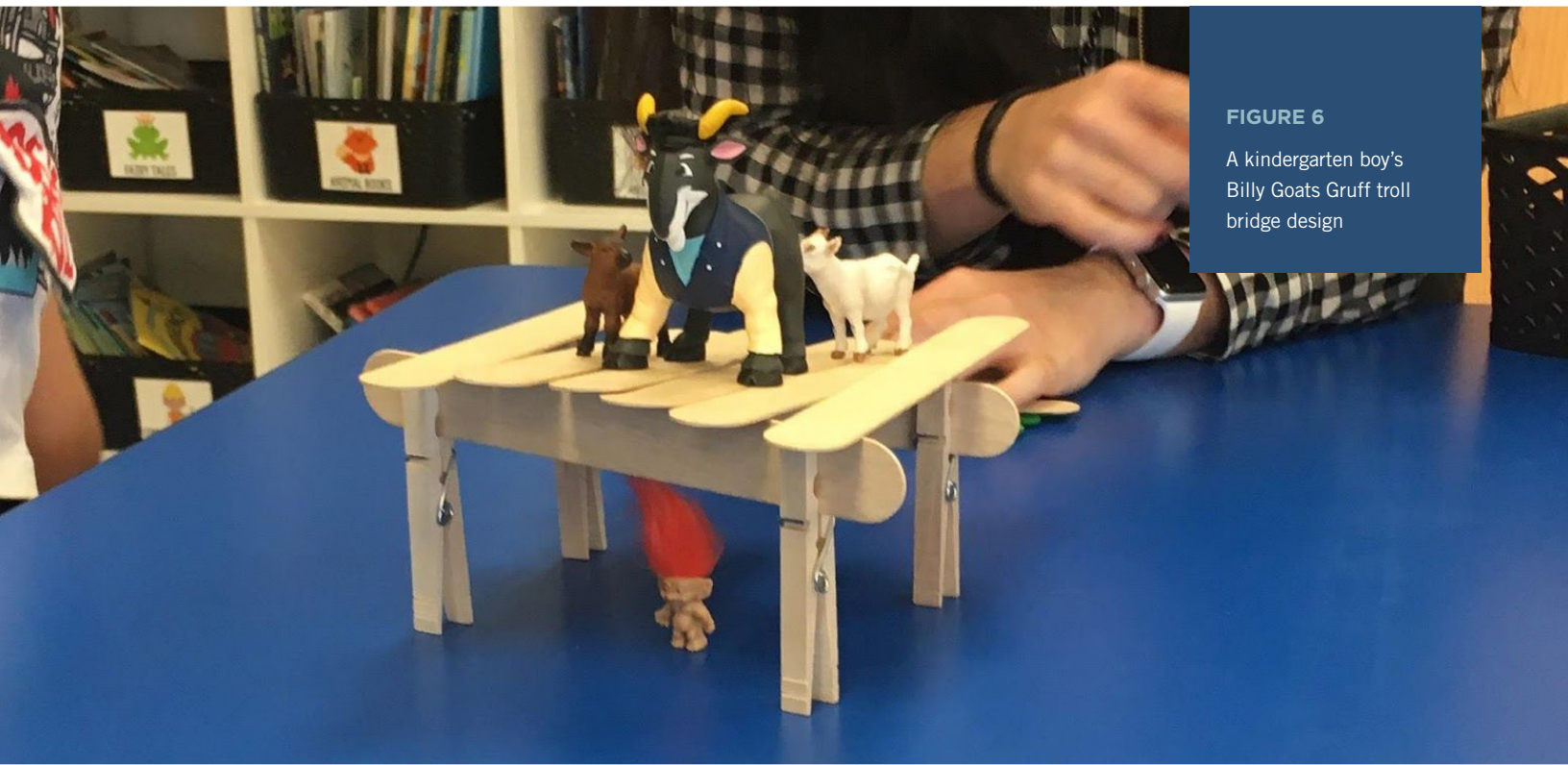|	
RELEVANT DATA	• #192 of 675 Best School Districts in New York (Niche) • 1 of 68 STEM Learning Ecosystems across the U.S. (STEM Ecosystems)
STEM EMPHASIS	• Makerspace • STEM Problem Based Learning • Dot and Dash Team • STEM Lunches
COURSE OFFERINGS	• Makerspace offered during lunch period for 3rd-5th grade students • K-5th Integrated STEM units (Pre-K STEM offered through the district)
ACHIEVEMENT	• Percentage of 4th graders proficient or advanced in ELA: 13% (NY average: 47%) • Percentage of 4th graders proficient or advanced in Math: 29% (NY average: 48%) • Percentage of 4th graders proficient or advanced in Science: 94% (NY average: 88%)
COLLECTIVE LEADERSHIP WORK STRUCTURES	• Hybrid roles, common planning time, co-teaching, and peer observation
PRINCIPAL	Ron Perry
STEM FELLOW	Molly McGarry

FIGURE 6

A kindergarten boy's Billy Goats Gruff troll bridge design

Background

"I am going to be an engineer when I grow up."

KINDERGARTEN BOY, EAST SYRACUSE ELEMENTARY SCHOOL, ANNOUNCED AFTER COMPLETING A DESIGN CHALLENGE TO BUILD A BRIDGE OVER A TROLL FOR THE THREE BILLY GOATS GRUFF.

The Superintendent of East Syracuse Minoa Central School District, Donna DeSiato, has had a vision for 21st century learners for many years. In 2007, the district strategic plan described 21st century graduates. To develop these graduates, the district was part of the first cohort of STEM Learning Ecosystems, a national initiative to improve STEM. According to their entry on the Learning Ecosystem website, their Learning Ecosystem focus is on:

Inquiry-based and trans-disciplinary learning through real-life problems that will prepare our students to develop the skills and decision-making for their futures. Our schools embrace innovative, inter-disciplinary STEM (science, technology, engineering and math) learning opportunities that focus on problem-based learning to foster curiosity, questioning, creativity, and innovation for college, career and citizenship readiness.

Much of their work is contingent upon partnerships with business, higher education, and community organizations that create cross-sector opportunities for teaching and applied problem solving.

The ecosystem extends to the elementary school level, where East Syracuse Elementary is leading the way in laying the foundation for STEM teaching and learning. Ron Perry, the principal, has a long working relationship with Superintendent DeSiato and decided to fill in as principal even after he had retired because he believes so much in her vision. Both have had long careers and are focused on student outcomes that move beyond test scores and standards. They see STEM as an ideal avenue for connecting students to real world challenges. One teacher emphasized the priority that STEM is for Principal Perry. She said, "He wants to turn every classroom into a STEM lab."

Conditions that Support Exemplary STEM

VISION AND STRATEGY

In district, there is a cohesive vision for the 21st century learner. Michelle Coolbeth, the library media specialist describes that vision: "I can't remember the last time I was at any kind of district meeting or get together where we didn't begin by talking about the 21st century learner. Our administrators always have the eye on that goal and that seems to really drive everything that we do."

In the district, there is definitely a fine line between a cohesive vision for 21st century learning and top-down visions. Ms. McGarry described the change in the district:

Leslie mentioned the "Engineering is Elementary" (EIE) program. That was brought in six years ago. That was definitely

given to teachers as not optional. So that was before we really got into STEM, and there was a little push back because of time. My job at that point was to learn all of the kits and to train the teachers. They trained us and brought in all these kits, and you're going to be training all the teachers with this. At first, I was really nervous but it is what it is. And some teachers were like, "Let's do it. Let's have some fun." Some teachers were like, "This is a pain. I don't have time." And once we got going, it seemed like there was a lot more enthusiasm, and teachers started to change it to what they wanted. It was really turnkey for getting STEM in the classroom. So that was definitely top down.

The vision and strategy for STEM at East Syracuse Elementary has saturated administrators, teachers, and students—even down to kindergarten. In a focus group session, kindergarten

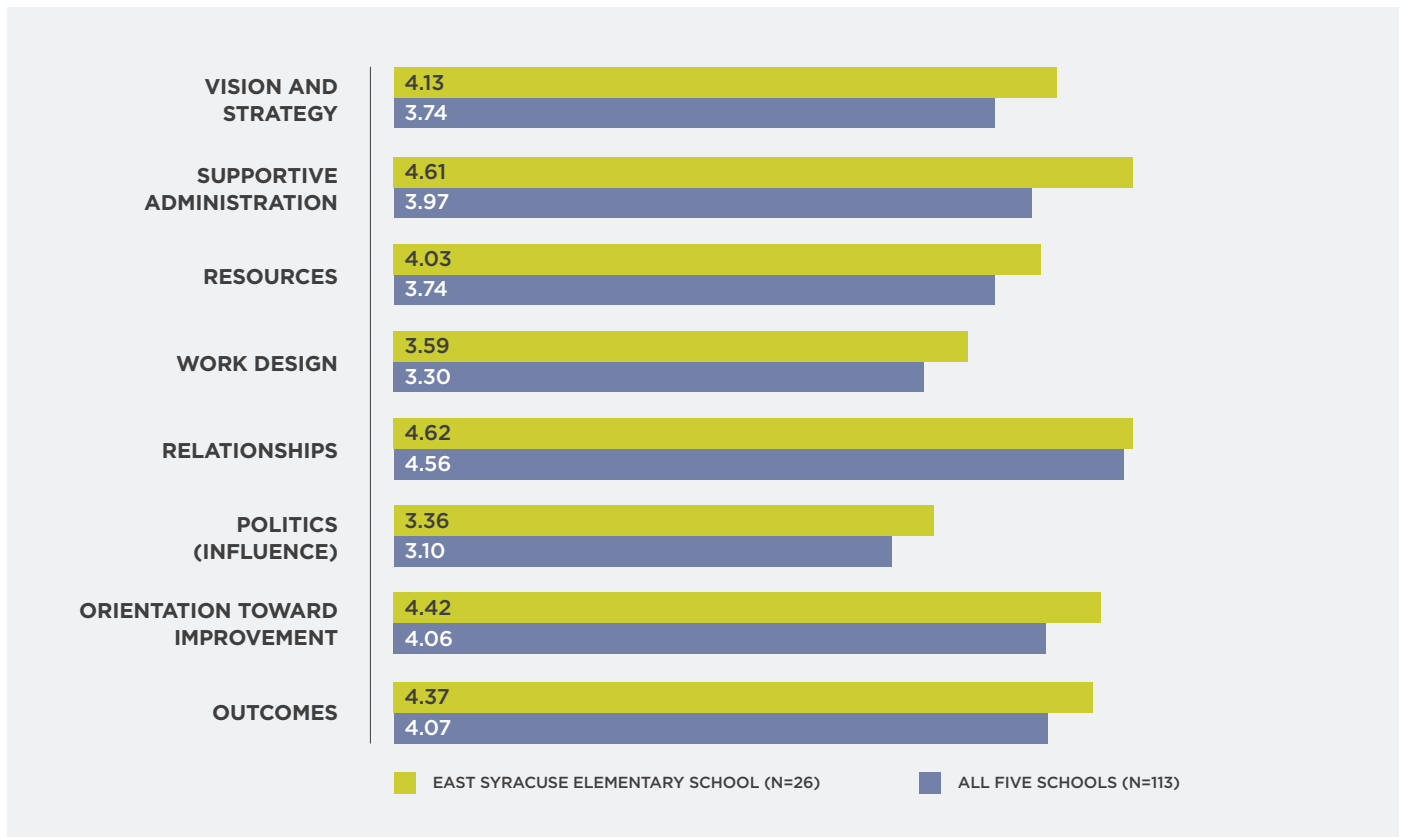|	East Syracuse Elementary School (N=26)	All Five Schools (N=113)
VISION AND STRATEGY	4.13	3.74
SUPPORTIVE ADMINISTRATION	4.61	3.97
RESOURCES	4.03	3.74
WORK DESIGN	3.59	3.30
RELATIONSHIPS	4.62	4.56
POLITICS (INFLUENCE)	3.36	3.10
ORIENTATION TOWARD IMPROVEMENT	4.42	4.06
OUTCOMES	4.37	4.07

FIGURE 8   Conditions and Outcomes for Collective STEM Leadership * significantly greater (<.05) than other schools based on one-way ANOVA (5-point scale ranging from "strongly disagree" to "strongly agree")

teacher Krystina Race off-handedly shared, "Yeah, my kindergarten students can tell you what the engineering process is." The quotation at the beginning of this section is from a student in her class who plans to be an engineer, not because a parent is one, but because of what he does at school. This is important for building a coherent scope and sequence for STEM across three schools in a district. Ms. Race continued,

That's something that I was going to say for exemplary STEM, it starts at a young age so that we can build on it so that when they get to high school, it's not this new concept that they never experienced before they don't know what the engineering process is, and so it starts at a young age so that they do learn that design process and continue to build on it and do higher level STEM activities and experiments as they get older.

Kim Liedka, a fifth grade teacher, emphasized the way this STEM culture builds momentum for 21st century skills. "It is a collaboration and it's a team project so they are working together. You can have somebody who is a very high level thinker and someone who struggles a little bit are able to work together and one doesn't take over, and they really do learn how to work together and to communicate." Because there is a coherent vision for STEM education across grade levels, Ms. Liedka continued, "when I started last year and I thought I don't know if they are going to be able to do this, they had already been doing it for 4 or 5 years. So, you give them a task and they just ran with it, and they knew exactly what to do. I was able to just step back and observe. Let it be student-led rather than us coming up and giving them the ideas. It was them taking off with it."

Another fifth grade teacher, Robin Locke added, "Knowing they're going to be applying what they're learning in their curriculum to a STEM project has that motivation to know having something as an outcome rather than learning a math problem in isolation."

SUPPORTIVE ADMINISTRATION

Teachers like Molly McGarry consistently cited supportive administration as key to their STEM success:

We are fortunate in that it really starts with our Superintendent. She's very, very supportive of the STEM model which in turn the principals are. They are free to embrace it and in turn the principals support the teachers. I think it really starts at the top because if the superintendent didn't support it, then it could be squelched. I really feel like it has to start from the top. Teachers could do it in isolation, but, Mr. Perry, he feels very strongly about STEM, and so he's enthusiastic and he's, he encourages it within the building, and then Dr. Desiato supports Mr. Perry, and I think it kind of works like that, in my mind.

That support comes in tangible forms. "As a teacher, knowing that you have the full support of your administration to take a block of your day and actually do some kind of STEM activity is powerful."

Ms. Race added, "Our administration is extremely supportive but I don't necessarily as a classroom teacher feel anyone telling me what to do in terms of STEM." Teachers reported feeling supported, but not micro-managed. She gave an extended example of the support she felt from her principal as a kindergarten teacher.

I was in a higher grade level and switched to kindergarten the first year that Ron was with us and sitting down and talking to him about what I wanted for a lesson when he came to observe, and I told him I wanted to do a STEM lesson. I think I was a little bit nervous that it wasn't going to go well, and I think he didn't tell me until afterwards, but I think he was a little nervous it wasn't going to go well. It's complicated for kindergarten, and I think that was a big moment for both of us to see how successful and engaged they were because they had done STEM lessons in 5th grade and moving to kindergarten I wanted to see could this work, what would this look like, what would I need. And I think that was a good starting point for me as a kindergarten teacher and to have that support from Ron to say, "Yeah, absolutely, this is something we see the benefit in from this age level." And that's not always common in kindergarten. I think there is an element of they're little, they can't do this it's too complicated, but we're seeing all the time that that's not true, and Ron supports us having the time and the ability to come up with things we want to try, and it's not a scripted program. It's not something we've been given from someone else saying, "here do this lesson." I do feel like we have a lot of autonomy in what we choose to do with them in STEM and how we integrate it with other things as well.

Principal Perry commented, "So true. I now know not to ever underestimate a kindergartener."

RESOURCES

Teachers and administrators feel well-supported for both materials and professional development. There are district

assets in the form of human capital and actual materials that are available but not mandated. Mary Albanese, second grade teacher, said, "Other than the EIE kits, nothing has been forced upon us. Other than that, we have been pretty much free to do whatever we like."

Ms. Liedka provided a unique "outsider" perspective:

If I talked about my own personal experience. I was new to the school last year, I came from a different school district. We never did the STEM. It was never talked about. Coming here was like opening up my teaching world…. If I didn't have the materials I needed, I could go to a teammate, or I could go to Molly. It was just such an eye-opening experience to come in here and see how it works so flawlessly, and I was able to jump into that.

To support implementation of innovative ideas, the district has

three technology specialists who are available to help implement and support technology. Ms. Coolbeth shared:

I've also found in the library, I think we have three instructional technology specialists from the district that you can email and say, "in two weeks, I would like to try this, can you come in?" And they will either teach you how to do it and if they don't know how to do it, they'll learn in the interim, or they will teach the first lesson with the students and model it for you."

Others teachers described the instructional technology specialists as "always available" and "wonderful."

East Syracuse Elementary also has solid support from their parent community as well as district colleagues. One teacher shared, "The PTO [Parent Teacher Organization] is very supportive as well. We wanted a rocket club, we asked for money and they said 'absolutely'. They supported it, so it's

FIGURE 9
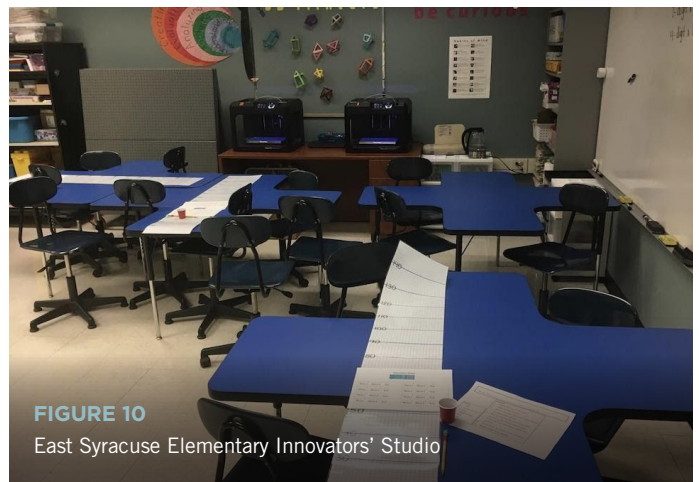East Syracuse Elementary Innovators' Studio

FIGURE 10
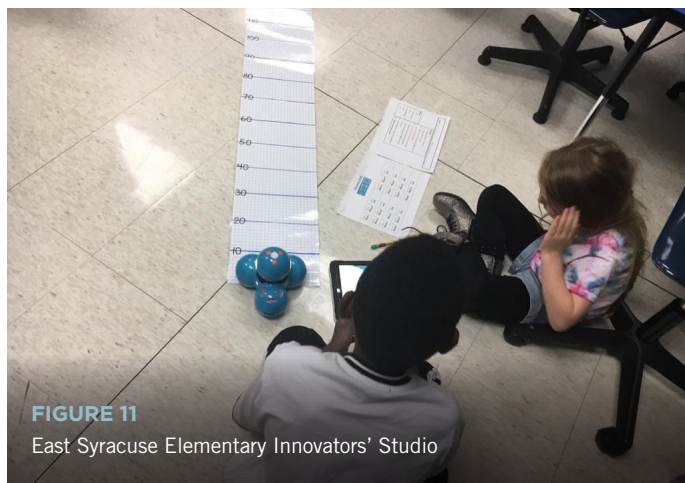East Syracuse Elementary Innovators' Studio

FIGURE 11
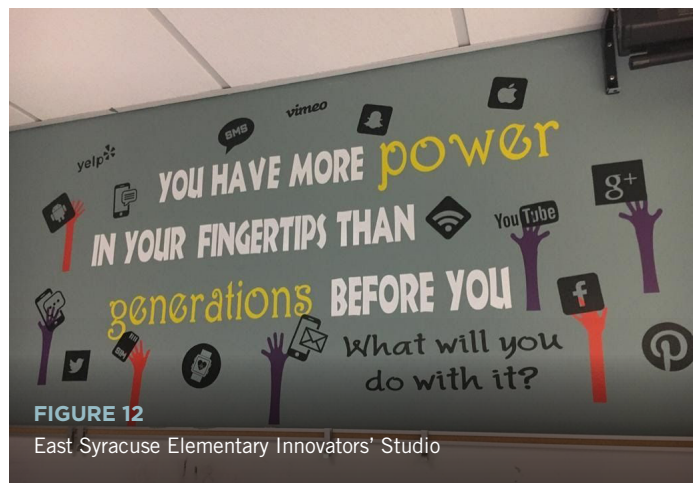East Syracuse Elementary Innovators' Studio

FIGURE 12
East Syracuse Elementary Innovators' Studio

across the whole district with everybody." Where resources or formal professional development have not been available, some of the learning has been "self taught" according to Ms. McGarry. Through the resourcefulness of teachers like Ms. McGarry, as well as the support of the PTO and the district, the school has most of what it needs to move forward.

McGarry has developed an Innovation Lab complete with collaborative furniture and a number of STEM tools that she uses in order to connect the physical space of the Innovators' Studio where she works with classes (See Figures 9 through 12). Students can also sign up for additional time to work in the studio over lunch. In order to increase the flexible use of the study, Ms. McGarry and Ms. Coolbeth plan to put a hole in the wall between the library and the Innovators' Studio so that a door will allow students to flow between the spaces. To get the materials they need, McGarry has written grants for a local education foundation, a New York state grant for a set of robots, and even gotten money from a local orthodontist for graph paper. Their ability to seek out these resources speaks to the innovative problem solving needed to build an Innovators' Studio.

WORK DESIGN

The work design at East Syracuse Elementary is fairly similar to most other New York elementary schools. Finding time for collaborative planning is challenging when more than just a grade-level team is involved. Molly McGarry and Michelle Coolbeth do most of the work promoting STEM and supporting teachers, and they have to do this work creatively. Ms. Coolbeth shared a common challenge, "It is difficult for me as the librarian to meet with a team because I may have a class for another grade level when they're meeting." A classroom teacher elaborated, "We do have common planning time at the end of the day, but because of that that's generally when we have a lot of meetings like RTI and other things, so there's not always everybody available at one set time."

However, even with these challenges, teachers find time informally during and after the school day to collaborate. The flexibility of Ms. McGarry and Ms. Coolbeth is appreciated. Kindergarten teacher, Krys Race shared:

I will say you hear Molly [McGarry] talk about her schedule, and it is very busy, but I have never heard her tell me or anyone else "no." If you come to her with an idea or if you say, "I want to do this or I have this plan" there's never been a "no." It's always been, maybe she can't be available at that time just because of

the way her schedule works but she asks, "What resources could I find for you, what do you need from me, how can I help you to set up for this or plan for this or figure out what you need?" And that's huge.

Like Donna Migdol at Boardman Elementary, Ms. McGarry is credited with much of the success of the STEM initiative at East Syracuse Elementary. Her ability to lead and influence others is facilitated by her hybrid role. She serves third through fifth graders as a half-time math support teacher who pushes into classrooms to provide tiered student support. Until last year, she served kindergarten through fifth grade in this role, but this year the district hired a half-time teacher to manage primary grades. This has allowed Ms. McGarry to use the remainder of her time to manage the Innovators' Studio. In order to make this hybrid role work, she has gotten creative. When she is delivering intervention support to students, she has "community volunteers who come in to my lab and I set up the Makerspace for the students during lunch and my community volunteers supervise and run Makerspace while I am working with students who need math help." Additionally, fifth grade students volunteer their time during certain parts of the day to help younger students in the Innovators' Lab.

Like Ms. McGarry, Ms. Coolbeth works extensively with teachers to support STEM. Students do coding in the library in scaffolded projects that become increasingly complex as they move through grade levels. These lessons are co-planned during collaborative planning time and co-taught during classes library time. While Ms. Coolbeth does not serve in a hybrid role, her role as a library media specialist affords her some flexibility to work with teachers and students in collaborative ways.

One other strength that teachers observed is the autonomy they have in the classroom. Unlike many elementary schools where the curricular focus is almost exclusively math and reading, teachers felt like they had time to teach STEM lessons. One fifth grade teacher shared, "It was amazing to come here and know that I could do all of these STEM projects. There was nobody telling me I had to do it. There was nobody telling me what I had to do. I just had free rein to do whatever I wanted and to know that I have the support of the administration to take a chunk of time every Wednesday morning to do a STEM project."

SUPPORTIVE SOCIAL NORMS AND WORKING RELATIONSHIPS

Building on the strong administrative support that teachers feel and the work that they are able to do together, teachers

described a strong network of professional relationships. Most of them spoke of the healthy culture that exists in the school and in the district more broadly. This is an illustrative comment from a teacher:

The benefit that we have here is that we have good interpersonal relationships between teachers. And between Molly [McGarry] and between Ron [the principal] we have that network to kind of say, "I am thinking about doing a STEM lesson around some broad concept," and then bounce ideas off each other and kind of find resources for things we think would work well for that concept or lesson and go from there, and there is that trust and understanding that if it doesn't work it's not a failure.

These norms feed a strong culture that can facilitate improvement. When coupled with high leadership capacity and necessary resources, schools can make significant progress. One teacher described the type of tangible support she felt from her school and district. "This is my second building in the district, and I can't remember a single instance with either a teacher or an administrator where I came up with an idea and someone said 'no.' Everyone's always been like, 'Okay, let's try it. Let's see what happens.'" This perspective on trying new things with others is most likely to occur where there are high levels of relational trust.

SHARED INFLUENCE

Due to those high levels of relational trust that seem to exist districtwide, influence flows between teachers and other teachers as well as between teachers and administrators. Molly McGarry explained,

Well, we are fortunate in that it really starts with our Superintendent. She's very, very supportive of the STEM model which in turn the principals are, they are free to embrace it, and in turn, the principals support the teachers. I think it really starts at the top because if the superintendent didn't support it, then it could be squelched."

Teachers feel that ideas in the district do bubble up from the classroom, but feel that administrators maintain a cohesive focus on 21st century learners while supporting teacher-led initiatives. To illustrate, a teacher said, "Our administrators always have the eye on that goal [21st century learner] and that seems to really drive everything that we do, and it trickles downs into the decision making."

Teachers have wide latitude for what occurs in the classroom and share ideas between classrooms and schools. Administrators provide as much formal and informal support as possible as long as the initiatives build toward the districtwide vision of the 21st century learner.

ORIENTATION TOWARD IMPROVEMENT

In a school culture with strong relationship and constructive politics, a positive orientation toward improvement typically persists. Principal Perry shared, "We had to create an environment where the culture that was already in place could flourish with the concept of STEM. If it wasn't for our teachers being professionals who do take learning risks and encourage their kids to take learning risks, our STEM program would not be where it is today."

Similar to the other schools in this study, the culture of risk-taking and "failing fast and forward" that are part of the engineering process contributed to a pervasive STEM culture where failing is not only tolerated, but expected as a part of the improvement process. One teacher said that the school culture is about "understanding that if it doesn't work, it's not a failure. As teachers, we see that students didn't fail, it's just how can we improve it next time and what can I learn from that and where do we go from there."

This orientation toward improvement extends to the entire district and beyond teachers and administrators. There is a districtwide college and career committee that connects the district to community partners. Two teachers described the committee and a recent meeting:

We also have high school students who are on that committee as well as community members and business owners, and that's something that we are constantly talking about is partnerships with them and how they can help out with programs and career options and internships and things like that and STEM is very much a part of the conversation that we have at those meetings as well.

A second teacher added,

It's a really good point about the students meeting because we were just at a technology meeting last week, and there were two high school students on the committee. I think they spoke more than any adult. They were just a wealth of information and seeing how far along they are by the time they are seniors is really a push for us to say, "Okay, yeah we have to start at kindergarten" if we're going to get to that point.

OUTCOMES

This orientation toward improvement leads to better outcomes for students because tracking their progress is a central focus of evidence collection. Krystina Race described what she saw happening in her kindergarteners:

They start to ingrain those things into their lives, and it is so rewarding when you hear one of them. You are not really paying attention and all of a sudden you hear this little nugget from the table say, "Hey guys, we have to work as a team. It is okay that that thing didn't work. We are just going to try again." Just that attitude shift is what I see being the true outcome of STEM in my classroom at least.

She added that she has noticed a change in "perseverance level." They have learned that "the only true failure is when you quit." She added that she has started to "hear the kids sometimes talking about that."

From kindergarten to fifth grade, teachers are describing evidence of improved outcomes from robotics clubs after school who compete nationally, to students choosing to spend their lunches in the Innovators' Lab. STEM is integrated into reading through literacy events that use "breakout boxes" to teach problem solving, arts enhancement where they are imagining students on the international space station, and the drama club that is using green screen technology for plays. Perhaps the most significant evidence is in what the teachers are hearing students say. As the class was coring on storage devices for the international space station to build on the 3-D printer, a fifth grader said, "I've always loved engineering. You get to use your creativity for what does and does not work."

Teachers see STEM benefitting all students. Ms. Liedka described what she is seeing in her students:

I had some students last year, because I was also in the inclusion room, so I had students at a much lower reading level, math level, and I also had a student that was a behavior problem. I let them at the end of the year choose the group that they wanted to work with, and these three boys chose to work together, and I thought, "Oh, this is going to be interesting." Off the top of my head, I don't remember what the task was. They had to build some type of tower, and I had some very high-level thinkers in my room last year, and the only group that completed the task was the group I was hesitant to let work together. They were able to work together. They were able to figure it out. That was eye opening for

me because I was hesitant to let them work together. It was amazing. My TA kind of stood there and our jaws hit the floor, and we were like, "Look what is happening."

With an increasing population of students coming from homes with limited financial resources, STEM has been extremely important. One teacher shared, "I think that for kids who may lack resources at home, this opens up a whole world of possibility to them, and that is something that we talk about at the school's college and career day." Another teacher added, "I hear more and more parents say to me, especially at the fifth-grade level, that their child is now talking that they want to be engineers, and I didn't hear that a few years ago."

East Syracuse Elementary sees their work as foundational to the work that district middle and high schools will do. Robyn Locke, fifth grade teacher, shared, "Also, if you look across the district to see the things they are putting into place for our current 9th grade class and then the new paths they can go into like aviation and the STEM team at Pine Grove. It doesn't just end here."

Barriers to Exemplary STEM

Although a number of key elements are present, teachers and administrators still see barriers to STEM. Finances remain a constraining factor. Principal Perry said,

I think finances is a barrier. And we had that right at the beginning, we overcame that rapidly by way of some grants, but it's still, there are things that IDS that Ms. McGarry and the school, classroom teachers and members of the committee are coming up with and some of them require finances. Professional development is one of those where the desire for professional development greatly exceeds the budget for professional development. So finance, I think, even though we are well on the way, I think as the program grows, that's still going to be a challenge we have to look at.

This also limits what the school can do to extend opportunities beyond the school day. Perry continued,

We are able to extend the school day with enriching activities, and we believe strongly that it has a direct impact on student achievement. That also gets back to a challenge. We do offer the enrichment after school, but I think we could reach more children if we had the finances to offer transportation because we have a lot of children who will not be able to get home without bus transportation.

As is the case at other schools, time is limited. One teacher described the limited time for integration.

I think part of that is what we are talking about with integrating it with other subject areas. A lesson we did recently in my classroom was tied to an ELA topic that we're talking about, so we used the book that we modeled for interactive read-aloud and tied that to our STEM lesson for that day, and then tied that to an actual STEM activity later on. I think that's one way around some of the time constraints because some of it is just during the day where do you find time for this, you have to kind of be creative about how you integrate it with other things.

Time for collaboration with key STEM leaders is also limited. Ms. McGarry is engaged in math support much of the day, and Ms. Coolbeth has other library responsibilities. As is typical in many schools, Ms. Coolbeth explained, "It is difficult for me as the librarian to meet with a team because I may have a class for another grade-level when they're meeting." McGarry also feels the challenge of finding time to meet. She said, "Often times if we are working together and we are doing a multi-grade type situation, or if Michelle and I are doing something with a grade. It has to be usually outside the time of the school day."

Even when teachers do have time to collaborate, the tyranny of the urgent can dominate the time. One teacher said, "We do have common planning time at the end of the day, but that's generally when we have a lot of meetings like RTI and other things, so there's not always everybody available at one set time."

Other than these barriers, curriculum, resources, and dispositions related to STEM are definite assets in the district. The fact that there is support from the library media specialist and a half-time STEM position are assets relative to other schools.

Collective Leadership for Exemplary STEM

Teachers and administrators at East Syracuse Elementary were most positive about the influence of teachers.

When asked, "On a scale of 0-10, how much of the exemplary STEM work has been led by teachers (10 being total control, 0 being no control)?"

Teachers responded: So, anything we do in kindergarten we do have to come up with, in the past. I know our new science kits have some STEM lessons in them. I haven't investigated really what those consist of yet. Prior to this anything done in kindergarten would have to be teacher created, teacher sought. So, 10.

Ron Perry agreed,

You guys [the teachers] have to give kids the opportunity. So,
I credit you. I say teacher directed would have to be pretty
close to a 10 when it comes to teacher responsibility and
leadership here. I say that because we kind of built into our
STEM two different structures. One was Makerspace. The
other is innovative studio. And the evidence for me that it
is teacher directed is that Miss McGarry will put a sign up
outside innovative studio and before you know it all the slots for
innovative studio are filled up. That's another thing too; choice.
We stress giving kids choice. Staff needs choice as well. I think
that is a big part of the success of the program.

Pine Grove Middle School

East Syracuse, New York

RELEVANT RANKINGS	• #192 of 675 Best School Districts in New York (Niche) • 1 of 68 STEM Learning Ecosystems across the U.S. (STEM Ecosystems)
STEM EMPHASIS	• Building design based on STEM culture • Flexible teaming • Makerspace • Integrated Problem Based Learning • Co-teaching
ACHIEVEMENT	• Percentage of 8th graders proficient or advanced in ELA: 13% (NY average: 47%) • Percentage of 8th graders proficient or advanced in Math: 32% (NY average: 48%) • Percentage of 8th graders proficient or advanced in Science: 98% (NY average: 89%)
COLLECTIVE LEADERSHIP WORK STRUCTURES	• Common planning time, flexible scheduling, co-teaching, and peer observation
PRINCIPAL	Doug Mohorter
STEM FELLOW	Jason Fahy

Background

"Let us present our aquarium proposal to you."

TWO EIGHTH GRADE GIRLS, PINE GROVE MIDDLE SCHOOL, PRESENTING THEIR PROPOSAL TO INSTALL AN AQUARIUM IN THE SCHOOL'S LOBBY TO THE PRINCIPAL.

The STEM story of Pine Grove Middle School really begins with the eighth grade Orange Team. The Orange Team consists of 96 students. Over the last decade, the team has developed a strong reputation for collaboration and STEM. Jason Fahy is the eighth grade science teacher and teams with an English, math, and social studies teacher to integrate STEM into all aspects of student work. They have partnered with NASA, the Allyn Foundation, and other local organizations to develop innovative curriculum, STEM projects, and programs that extend learning beyond the school day and school year. They have transformed the way students and teachers collaborate across eighth grade and the entire school. Each year, students participate in a Mission to Mars project where they develop Mars rover prototypes. Projects like this become interdisciplinary endeavors that have become a marker of the Orange Team and Pine Grove Middle School as the team's approach to STEM and collaboration has spread.

In fact, the collaborative philosophy of the Orange Team is reflected in the re-designed building that re-opened in 2016-2017. Each team exists in a four-classroom pod with collaborative space between the rooms. The teams have control of their schedule for most of the days, in a bell-free environment where they can combine the whole team into one class of 96, two classes of 48, or four classes of 24. This type of flexible grouping facilitates interdisciplinary inquiry where teachers can co-teach as students engage real-world problems from multiple perspectives. The entire building now reflects the flexible use of spaces, the lack of a bell schedule, and the ability to access outside resources that teams have adopted after learning how the Orange Team was using their time, space, and resources. As Principal Doug Mohorter said, "Teams just needed to know that they had the flexibility and resources to do what they wanted to do. They can take risks because I can take risks because Donna [the superintendent] lets me take risks."
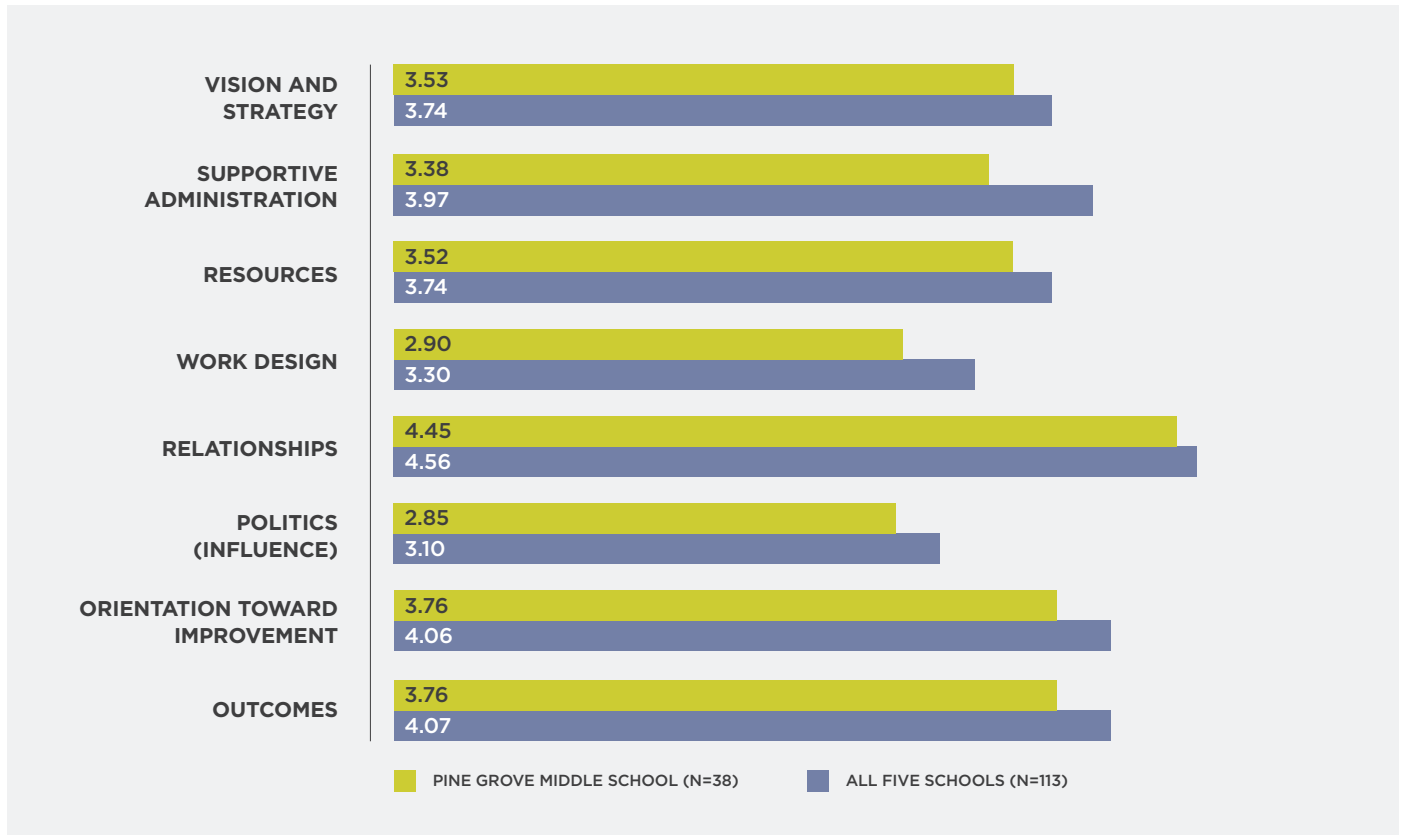
Conditions that Support Exemplary STEM

FIGURE 14   Conditions and Outcomes for Collective STEM Leadership * significantly greater (<.05) than other schools based on one-way ANOVA (5-point scale ranging from "strongly disagree" to "strongly agree")

VISION AND STRATEGY

Vision and strategy for exemplary STEM learning and collective leadership go hand in hand at Pine Grove Middle. According to administrators, teachers, and students, leadership and learning work well when they are "authentic" around "real life examples" and allow students and adults to "answer their own questions as much as possible." Sue Kowalski, the librarian, emphasized the process that leadership for exemplary STEM learning requires:

I would say when I think exemplary, any kind of student project, I think of it as rich with student voice and leadership. There are resources and a framework, but the path and process are as valued as much as the final product whether or not there is one intended but the process is rich with authentic experiences,

chances to try and fail, chances to redirect, that it's not necessarily "at the end you will produce this," but "this is the process and what do we get out of that."

This vision and strategy for STEM learning requires a particular type of collective leadership. Roles are defined and differentiated at Pine Grove, but this kind of clarity provides freedom for leaders to perform the requisite leadership work. Jason Fahy said,

Administration helps to communicate district goals and building goals for the directions we should be taking, but it's really up to the teachers and the teams of teachers and staff that work with teachers to come up with what those lesson plans look like and what the student experiences are rather than having the

administration attempt to dictate what the experiences should be and then letting that trickle down. Again, I think it's the clear leadership through goals and then allowing teachers to be able to meet those goals in a variety of ways that make it [STEM learning] strong.

SUPPORTIVE ADMINISTRATION

The clear vision and strategy are directly related to the support that administrators provide. A seventh-grade science teacher, felt that teachers "have been given permission to be creative and pursue a variety of projects, topics." Other teachers agreed with these sentiments and believed that most of the time, "the ugly process was celebrated, endorsed, accepted, and encouraged." One teacher shared that in his 25 years of experience in the district, he had never been "shot down" for any idea. If the idea has been developed and there is an implementation plan, the idea has "truly been encouraged." Other teachers agreed that this was also their sense of the way ideas bubbled up in the district.

Not only do they feel support for their ideas, teachers cite administrators' ability to help overcome specific constraints. For example, when the eighth grade Orange Team wanted to consider how they could share students across teachers and periods, administrators helped them figure out ways to make this happen. Moving beyond just flexible scheduling and finding ways to allow teachers and students to collaborate, the superintendent and school board have communicated an emphasis on holistic education of all students. As Fahy stated, "It's been communicated to us as a group, as a whole, that there are more ways to measure a student than standardized test scores, and that's something that we've all heard. We've heard it from our superintendent directly, and we've heard it from the school board." Teachers find this message to be "very empowering" especially for "teachers who are trying to be creative."

RESOURCES

Pine Grove has attempted to meet many of their needs by creatively using existing resources. For example, adjusting the schedule to allow for a bell-free schedule with flexible grouping across four different core classes, did not pose any additional costs. Certainly, the building renovation was influenced by the desire for teacher and student collaboration, but additional space and expense were not added to allow for this increased

connectivity. Building on the STEM problem-solving culture that is evident in all five of the schools in this study, Pine Grove leaders identified and solved issues that arose. Sara Hughes, a social studies teacher, described this approach, "So I think we just figured out how you're doing team meetings and spaces and the hallways and everything from facilities to content to shared staff. I just feel like we solved all our own problems." She felt that administrators would "help you find the resources." She said, administrators would literally and figuratively, "tear down walls for you and take you other places to see how people are doing these things."

Of the five schools studied, Pine Grove certainly had the best facilities overall due to their recent renovation. However, much of the reason for these outstanding facilities that included many collaborative spaces, quality lab designs, and Makerspaces, was due to the manner in which teams of teachers and administrators designed the building together. While teachers and administrators were dispersed across other buildings in the district during the renovation, they met regularly to discuss plans for how to allocate resources and what design priorities should be. These kinds of conversations had not always been easy at Pine Grove with some teams of teachers believing that resources were only available to particular teams. When Doug Mohorter assumed the role of principal, he made it clear to teams that they could all access resources for innovative ideas. While this idea took some time to permeate the culture, nearly every team at Pine Grove is attempting some type of innovation with the resources they need.

WORK DESIGN

The design of the Pine Grove building very much represents the design of teacher and student work. Glass is everywhere because work is shared and transparent. Collaborative space for teachers and students made conversations about improvement feel natural and pervasive. Most importantly, teachers have time to work with one another as they have 40 minutes every day with their teams—time that they control.

Nicole Petranchuk, an English teacher, shared, "I feel like we've been given time within our day to be able to do that [collaborate]. So, we have our team literacy time, which the focus is literacy, but obviously you can hit that through science and social studies." She added that reading and writing are "not just the English teacher's responsibility anymore and during our team literacy time, a lot of teams use that time to pursue some different STEM activities in addition to other literacy

initiatives." Another social studies teacher added that the best aspect of Pine Grove's work design is "flexibility in general. We are able to take our block of time with our students and use that without the constraints of a schedule." By working in teams with flexible scheduling, these teachers have tapped the flexibility of the typical elementary school day while taking advantage of the additional expertise provided by multiple content and pedagogy experts working with the same students in multiple configurations.

Additionally, teachers can take advantage of paid curriculum development time over the summer to pursue something new. According to teachers, the summer work was "led by people on the team who get a great idea." They continued, "We have not been turned down for hours, and we've asked for upwards of forty when we first started." The summer teams are comprised of "whoever can make it so anybody in the district who wants summer curriculum time just fills out an application and gathers whoever you know is relevant to whatever project." The project "has to tie into district goals, so you have to show how you're meeting district goals. But even then, I think there's permission to think out of the box and encouragement." For example, "We did a media literacy so you know media literacy and nobody said, but how does that tie into traditional literacy, so it was supported and encouraged." She added, "You know the planning time and compensation for it—that was huge."

SUPPORTIVE SOCIAL NORMS AND WORKING RELATIONSHIPS

The working relationships at Pine Grove have shifted over the past decade. Teachers described several strong teams at the middle school in the past, but there was a lack of cohesion and even some jealousy at times. Some teams felt that other teams "had it made and they got everything." Some of the more innovative teams could be judgmental of others at times. As one teacher shared,

I think we have shifted to acknowledging that this is hard for some people instead of accusing them of being apathetic. I think there's a shift in attitude that this is really hard for them. And then there's others of us and I think in this crowd we all happen to be people are like "Yeah, let's try it," but I personally, I mean I can speak for myself I would judge people who were not willing to try new things.

Nicole Petranchuk, English teacher, described the change as a "grassroots" movement.

I feel like for the most part, we are, the building is, we are problem solvers, and we are risk takers. Sometimes we forget that there is a small pocket of people that just aren't naturally, so I do feel sometimes they may need a little more support than maybe they get. So, you know, that's always something we need to keep in mind. Because I think we take it for granted here that that's just what we do, it's in our nature to make things happen, but some people just need a little extra support.

In order to build that support, teachers move well outside of the traditional STEM fields. They try to incorporate the library, English teachers, and social studies to extend inquiry and problem solving into new areas. Sara Hughes, a social studies teacher, said, "we started working together as a team trying to do interdisciplinary, transdisciplinary STEM. I think for us, those kind of go together, but I think it's kind of cool that it's showed up in the social studies inquiries that are relatively new on that last step of taking informed action." For example, the eighth-grade social studies teacher was observed doing an inquiry-based lesson on the Maine explosion in Cuba in 1898. She set the stage for the inquiry lesson by giving students just enough information in clues located within envelopes to determine who might have been responsible for the U.S. battleship's explosion in Havana Harbor. This historic incident was particularly appropriate for inquiry-based thinking because the U.S. blamed Spain for the explosion, and it became the precipitating event of the Spanish-American War. However, in 1976 a team of American naval investigators found that the explosion was probably due to a fire that ignited the Maine's supply of ammunition and that Spain was not responsible. Because of the exposure to inquiry-based teaching and the support she had received from the rest of the team, the teacher was comfortable providing students with clues to what had occurred that led to the explosion as they worked to determine causes and effects. An eighth-grade student shared that she really appreciated this approach to social studies because it "gives more choices of how to learn." As teachers have been welcomed into changes, students have also embraced those changes in ways that increase the social capital of both teachers and students.

SHARED INFLUENCE

Due to the nature of the Pine Grove's organizational structure, teachers within the same team have a great deal of influence on one another. Additionally, teams influence one another as they see what other teams are doing with their students. In fact, the school's physical structure as well as integration across

disciplines is largely due to the influence of the 8th grade orange team. In this way, influence and leadership seem to be generated from the grassroots. Sara Hughes said,

I cannot think of any literal asking for leadership. I feel like everything has been bubbling up—like PBIS [Positive Behavior Intervention Supports] initiatives, that's teacher-led, like the different stations and the share fair, that's teacher-led. Whenever we have an idea, we can ask, and it can happen, and that's a pretty powerful tool. I think that's maybe stronger than if we were told directly to focus and to grow.

Another teacher added, "And I think the projects that have become or taken on a life of their own or have become more sustainable are the ones that are teacher or student led. I just think, nothing against administration, but I think if it is a top-down project only, it loses its steam."

Administration does fulfill an important role according to teachers.

School administration communicates district and building goals for the direction we should be taking, but it's really up to the teachers and the teams of teachers and staff that work with teachers to come up with what those lesson plans look like and what the student experiences are rather than having the administration attempt to dictate what the experiences should be and then letting that trickle down. Again, I think it's the clear leadership through goals and then the allowing teachers to be able to meet those goals in a variety of ways that makes it strong.

The culture of shared influence has grown over time. Some people were initially frustrated that administration was not telling them what to do. "In any building, the third of people who are you know, not into what the district, you know just kind of dragging their heels a little bit, and I remember those conversations of 'they're not even telling us what they want us to do, tell us what they want us to do.'" The teacher leader responded, "Well, if they tell you what to do, you'll hate that too, so this time you get to pick what you want to do and make it your own." The teacher leader reflected, "I think that now after a couple years it's finally starting to work itself out. So maybe that is a way that teachers have been forced to lead, like, 'Here's your time. You figure out how to do it.'" Early adopters were very influential. One teacher shared, "They [the early adopters] are allowed to keep pushing and pushing and innovate without being diluted." He added, "It seems like the administrative approach was to let it [what the early adopters were doing] really smolder and catch fire and allow certain groups of people to just keep pushing and pushing and develop it further and further, and let other people come on board as they see fit."

ORIENTATION TOWARD IMPROVEMENT

Pine Grove is a STEM culture. Design thinking, problem solving, prototyping, and testing permeate the culture. "Our go to statement is 'be a problem-solver, I don't know' and you let them [students] go." This is true for students, teachers, and administrators. The principal feels that he can take risks because his Superintendent expects risk taking. A teacher shared a similar sentiment about Pine Grove's administration, "I think they [administrators] encourage us to take risks too, so, we are then able to encourage the students to take risks." Jason Fahy added,

I think that is key though it is not a product. It is a process. It's not the schedules. It's not the teams. It's not the building. It's the fact that we solve our own problems, and we're never even going to like get to the end. It's not like we'll go, "Oh, we got to the end and are a transformed school." We are constantly going to be transforming and there's no end in sight because it's always a new context, always a new problem.

Sue Kowalski elaborated, "There is no end. That's what they're always saying, we're preparing the kids for things that haven't even been created or discovered yet so there is no end." Some teachers shared that this process can be "scary business' for particular teacher because they want "everything to be laid out." However, they are also afraid of "feeling left out" so they will eventually engage.

Students have helped teachers change their orientations toward improvement. As the librarian, Sue Kowalski used to have students come in and make tutorials for other students, but now the students say other students are just going "to have to start figuring stuff out." Jason Fahy added, "And to tell you the truth, that's what we're modeling in our teams. We're given chunks of time and groups of kids and saying, 'Yep, let's figure it out,' and I think that modeling that instruction is what evokes more of that for kids because we are making it safe for them to think that way."

OUTCOMES

These changes that teachers and students attribute to the STEM culture in their school are outcomes in and of themselves.

During an interview with the principal, two eighth grade girls entered his office. They had put together slides and a proposal for why the lobby needed an aquarium. They gave a three-minute pitch that included research on the stress reduction associated with an aquarium, cost, and a care plan for the aquarium. They were confident, polished, and succinct. A year later, there is an aquarium in the lobby.

Students cannot learn if they are not present. The STEM culture has resulted in improved attendance according to teachers. One teacher shared, "Remember year one energy project? We had 100% attendance the first time [for all of the students on the team]. We had a student that up to this point was a major attendance issue, and she would come to school during the project. She would come when she knew we were working on the project." Students are coming to school because they are engaged. Jason Fahy recalled one of the first years of a Mars rover project that they had instituted.

We were doing the Mars rover project the first time. We had an absolute mess—robots driving everywhere, and it's back when we had bells, and the bell rang, and it was the end of the day, and I think we had 35 kids in the classroom because we extended out into the hall, and the bell rang, and nobody moved, and it was the end of the day, and they all just sat there and kept working. And then finally, after a minute or so, a student asked, "Do we go home now?" And that engagement of not looking at the clock and not thinking about going home or going to sports but to be thinking about the task I'm trying to solve—that's a big deal.

Student learning should extend beyond the classroom and beyond the time students spend in particular classrooms. Pine Grove teachers repeatedly cited evidence of impactful, lasting learning. The learning experiences have had long-term residual benefits. Sue Verbeck, a seventh grade science teacher, recalled,

Kids bring things up well after the fact. They're already in high school, and we used to do a big project around at Onandaga Lake, and somebody came back, and they did the whole reminiscing thing, "Remember when we did this and this," and they said, "And they [the community partners] took all of our ideas." The kids were planning for the improvement of Onandaga Lake and a lot of the ideas the kids came up with keep showing up in the news—whether it's the path around the lake, or a shuttle, or a boat shuttle from Destiny across the lake, and it's kids who are long gone keep kind of showing up and doing the 'remember when' which is fun, and it's real. And they

presented in front of real people. They had scientists. They had district people. They had parents, and they didn't hesitate to get up and have quality conversations on real authentic problems in our area, and they nailed it.

Learning outcomes extend far beyond what students do in STEM classes when the school becomes a "STEM environment." Students "have no fear of stepping up to lead to take charge to try something." Sue Kowalski needed a student to lead a club, so she put "an advertisement out and just said, 'I need five students who want to take the lead on that,' I didn't even give a specific, and within two hours, I think I had 13 kids who came. Now they run the class, and every day they have ideas." They are consistently asking questions such as, "How about we try this? What could we do? And next time, we should probably start thinking about?" Kowalski summarized what she had observed. "It's a bigger conversation than just thinking about a task…. And I have to think with all the other things they are involved with, the kids that go to high school from us, they just keep doing it."

Pine Grove is being recognized beyond their local area and state. In 2019, the U.S. Department of Education highlighted the exemplary collaborative assessment practices at Pine Grove in this video. The video highlights students' and teachers' real-time digital feedback on food chain problems. Pine Grove was one of ten schools in country that was highlighted for leveraging digital technology to support STEM learning.

Barriers to Exemplary STEM

Pine Grove has overcome many of the barriers to exemplary STEM that exist for most schools. For example, time for effective collaboration, co-teaching, and peer observation are all evident because of the way the day is structured for teams. Starting in 2014, every team received common planning time. In the renovated school design, glass and collaborative spaces make teaching and learning more transparent across classes and subjects. Because teams combine students, there are multiple opportunities each week to co-teach and observe one another.

Teachers also have remarkable autonomy in the cross-disciplinary projects that they will undertake in order to teach standards. Many times, this will take the form of STEM projects like the Mars Rover or Onandaga Lake. However, these curricular decisions can extend to individual lessons like an inquiry investigation in social studies into the causes of the U.S.S. Maine explosion in Havana. Teachers all cited autonomy in developing and testing relevant curriculum for their students.

Because of their status as a STEM Ecosystem as a school district and the support they receive from Superintendent Donna DeSiato, there is strong alignment of resources and vision for STEM learning. This results in a positive environment for experimentation and data collection. However, this has not always been the perception of everyone at Pine Grove. Sometimes, teachers had viewed resources as being allocated based on popularity. One teacher described some ill will that had been more prevalent in the past:

I think we struggled a little bit with a feeling of haves and have nots. For those teams who were being very proactive and really making decisions to pursue STEM and other creative ways of looking at education and others who didn't. It came off looking like we had more, or we had different things or better things, or we were given those things when in fact we were just taking them. We were being more proactive and pursuing the things we wanted, and if we needed something, we asked for it and worked to get it. And I think over time, we have all got those things, and I think it's just taken us a little while to have a level playing field. There were labels, and I'm not sure how some of us and I mean the different teams or individuals got labels as a result but I think that was probably our biggest hurdle. I don't know if we've totally jumped them yet, but all we're getting there. I think it's a lot better now.

Because the STEM culture is now more pervasive and trust seems to have increase, these sentiments are less prevalent.

Collective Leadership for Exemplary STEM

Teachers and administrators at Pine Grove were most positive about the influence of teachers were asked:

"On a scale of 0-10, how much of the exemplary STEM work has been led by teachers (10 being total control, 0 being no control)?"

The average teacher response was 9 for their roles in the work. On average, they saw administrators as a 5. Teachers feel the support of administrators, but they feel the work is up to them to do what students need for effective STEM learning. They also feel that the ideas bubble up from classrooms and not delegated by a supervisor. One teacher summed up here experience at Pine Grove:

I'm trying to think of a single example and I can't think of anyone, I don't mean this to be rude in any way, but I cannot think of anyone asking for leadership. I feel like everything has been bubbling up. Whenever we have an idea, we can ask, and it can happen, and that's pretty powerful. I think that's maybe stronger than if we were told directly to focus and to grow.

Central High School

East Syracuse, New York

RANKINGS	#192 of 675 Best School Districts in New York (Niche) 1 of 68 STEM Learning Ecosystems across the U.S. (STEM Ecosystems) Newsweek named Central High School to its 2020 list of the top STEM high schools in the country
STEM EMPHASIS	Global Environment (Clean water Educational Research Facility Partnership) Pharmaceuticals (Bristol Myers-Squibb partnership) Broadcast journalism Makerspace 3-D modeling (Rochester Institute of Technology credit available) Autonomous guided vehicles Information technology (Cisco Networking partnership) STEM and STEAM nights for parents
ACHIEVEMENT	Completers with Regents Diploma: 93% Completers with Advanced Regents Diploma: 48%
COLLECTIVE LEADERSHIP WORK STRUCTURES	Collaborative Educator Summits, Summer Leadership Week, hybrid roles, common planning time, co-teaching, and peer observation
PRINCIPAL	Greg Avellino
STEM FELLOW	John Herrington

Background

"It is kind of a figure-it-out-yourself class… Every week you have a new problem to solve."

SOPHOMORE GIRL, CENTRAL HIGH SCHOOL, REFERRING TO A CLEAN WATER FIELD RESEARCH CLASS.

Walking through the Cleanwater Educational Research Facility (CERF) and into the DeSiato-Donovan Greenhouse provides a glimpse of why East Syracuse Minoa Central is successful as a district, and how Central High School is leading the way with capstone research experiences for students. The greenhouse itself is a physical manifestation of the partnership Superintendent DeSiato forged with Mayor Richard Donovan through a grant from the National Oceanic Atmospheric Administration (NOAA) and the East Syracuse Minoa Education Foundation. The greenhouse has become the site of innovative student research like the work pictured above (See Figure 15). State University of New York's College of Environmental Science and Forestry (SUNY ESF) wanted to partner with Central High to offer a class for college credit. The work is led by John and Pamela Herrington, two dynamic Central High science

teachers, who partner with research biologists at CERF. Over the last decade, students have experimented with clean water reclamation, aquaponics, pollination, and even ways to heat the greenhouse with renewable energy during cold New York winters. Through a process of experimentation with mulch, wood chips, and leaves—all of which were provided by the village of Minoa at no cost as a function of village services—the students tested which materials produced the most heat as they decomposed. They found that they could raise the temperature of water moving through PVC pipes under decomposing leaves that generate heat reaching 140-degrees Fahrenheit. This heats the water in the pipes to 100-110 degrees Fahrenheit, and the pipes enter the greenhouse and radiate heat. Within two years, the leaves become rich soil that the village can use. With two classes of nine student each, they work one day each week at

the CERF, and two to three days per week at school analyzing data and designing new experiments for the greenhouse. One student summed up what she liked about the class. "You are not working alone. Your team can present ideas to the teachers. When things fail, we go from there." This kind of confidence is not groundless hubris. A CERF research biologist, shared something he often hears the Herringtons tell students, "Competence builds confidence."

While the CERF project is just one component of what Central High offered, this represented much of what sets it apart as a vibrant STEM ecosystem. Community and business partnerships have been integral to the success of Central High's students, as are innovative administrators, teachers, and students who fully embrace an engineering mindset where failure is just another data point on the way to a solution. The school truly represents a "figure-it-out" culture which permeates its leadership, learning, social, and community fabric.

Conditions that Support Exemplary STEM

Central High School respondents were not significantly different from any of the other schools on any of the seven constructs or outcomes. This means that they were relatively positive about collective leadership. Perhaps this should not be surprising given that Central High builds on the work of elementary and middle school feeders (East Syracuse Elementary and Pine Grove Middle) also in the study. However, this consistency with other sites is interesting and is indicative of the importance of these constructs for successful STEM cultures (See Figure 16).

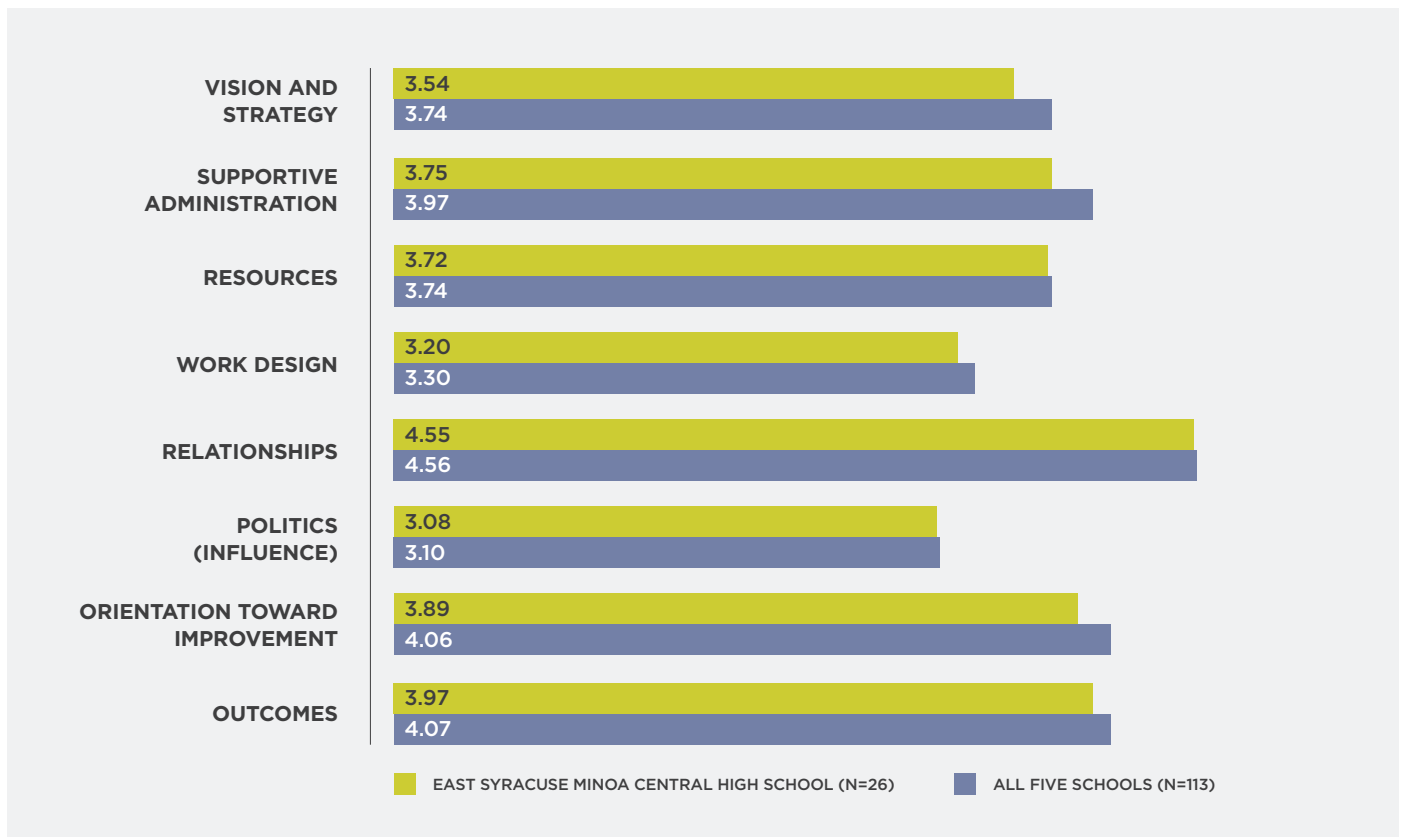|	EAST SYRACUSE MINOA CENTRAL HIGH SCHOOL (N=26)	ALL FIVE SCHOOLS (N=113)
VISION AND STRATEGY	3.54	3.74
SUPPORTIVE ADMINISTRATION	3.75	3.97
RESOURCES	3.72	3.74
WORK DESIGN	3.20	3.30
RELATIONSHIPS	4.55	4.56
POLITICS (INFLUENCE)	3.08	3.10
ORIENTATION TOWARD IMPROVEMENT	3.89	4.06
OUTCOMES	3.97	4.07

FIGURE 16 Conditions and Outcomes for Collective STEM Leadership * significantly greater (<.05) than other schools based on one-way ANOVA (5-point scale ranging from "strongly disagree" to "strongly agree")

VISION AND STRATEGY

"The East Syracuse Minoa Central School District will be an exemplary 21st Century learning community whose graduates are prepared to excel in a complex, interconnected, changing world." This is the vision statement in the 2018-2023 district strategic plan. The shared district vision and strategy for STEM is particularly evident at Central High School. In a focus group with building and district administrators, they expressed this shared vision. Adam Shatraw, Coordinator for Early College Spartan Academy, said, "We are about real world application and exposure to what is really happening." Randi Ludwig, the Coordinator for College and Career Readiness, added, "STEAM is inclusive for all students and is infused in all classes…. It is not siloed."

The vision and strategy for collective leadership and STEM extended far beyond STEM subject areas. DeSiato summarized,

I'd also say, for us, it's a way of thinking and learning. It's a way of approaching learning and that while science, technology, engineering, and mathematics may be the nucleus where we initially began to explore this area, it really applies to all areas of learning for us when we apply the engineering design process, when we look at problem solving as a way to both engage the learners and to allow them to apply their thinking in innovative ways to look at multiple solutions to solve a problem. They [students] are going to collaborate with their peers. And they're going to look at applying their knowledge with the risk they may actually fail, and then reflect and reapply another set of solutions and learn from those attempts until they actually have a deeper understanding and learning, so it is a way of thinking and learning and it shifts from a very, what we see as a factory model of sideline subjects and a "sit and get" model to an engagement model.

The vision and strategy permeate the culture of Central High through regular articulation via the district strategic plan, weekly newsletters, and numerous school publications. More importantly, the vision and strategy are perpetuated through the work teachers and students are doing together. English teachers are collaborating with STEM teachers on research projects, and students are partnering with teachers and community members to solve real world issues in environmental sustainability, pharmaceuticals, and broadcasting journalism. Unlike many schools, a vision statement did not need to be memorized and repeated; instead, the vision is enacted and embodied.

SUPPORTIVE ADMINISTRATION

Repeatedly, teachers and administrators cited the support of Executive Principal Greg Avellino and Superintendent DeSiato. Multiple teachers shared, "Greg has never said 'no' to me." Avellino attributes his ability to say "yes," to a supportive central office. "We are given a lot of permission to innovate." This support extends to teachers and students in the classroom. Assistant Principal Tokinma Killins added, "Teachers have a lot of autonomy in trying new things. In addition, we are all supported through PD (professional development) and conference opportunities. Our district goal is for staff and students to use technology in a way that transforms the learning experience. We want everyone to be able to look at the ways we are currently using technology and take it to the next level."

Darlene Baker and Wendy Davis, who lead a pharmaceutical partnership program with Bristol Myers-Squibb, described DeSiato's support that initiated the project. "Dr. DeSiato heard about it, passed it along to us. We checked it out and went to the training. Her networking was key." Cindy Brazill who is in charge of Central High's Makerspace, said that the funding for their Makerspace came from the support of a state senator and assemblyman who helped them advocate for a grant. She said, "Dr. DeSiato goes to all of these legislator breakfasts and her connections make a difference." Tim Keough, a science teacher, citing the steady leadership of DeSiato and Avellino said, "Stable leadership has allowed us to do a lot of things." Superintendent DeSiato attributes some of her ability to provide support to where she is at in her career.

I am not looking for my next contract. I think we all have one common thread. When we get up in the morning, we know why we are coming here. It is about how we can make a difference for kids. I see my role as giving permission, support, and protection. The permission is to take risks. We are bright enough to get back on course. To give support for professional learning, we will engage in the support to do this work. Einstein's theory is that you can't solve the problem at the same level. There needs to be some predictability here so that teachers can focus on their creativity. Protection – some of the critics can be their own colleagues. Protection – unless you have walked in their shoes for some period of time, we ask that you not critique someone else.

Supportive administration does not always mean saying "yes" or being an indiscriminate cheerleader. Avellino said,

There is a high level of trust. They [teachers] know that they can come in here, and we can speak honestly. There was a teacher

to whom I had refused to give tenure in another district. When I was first introduced as the principal, she reached out to see if we could talk. It was a good conversation. When she was at [the other school district], she was not child-centered and was not a happy person. When we talked, she said, "Do you remember what you told me? You told me, 'You have to get happy!'" She is still here and is still teaching. She has gotten better, and it is a different environment.

Adam Shatraw, the Coordinator for Early College Spartan Academy, provided a succinct explanation of how far the support for collective leadership and STEM extends. "The ability and encouragement to innovate goes beyond our STEM programs and into our humanities programs, so the innovation is really systemic."

RESOURCES AND CAPACITY

Most of the extensive resources at Central High were gathered by creative, high capacity teachers and administrators. Adam Shatraw described the work of teachers and administrators:

You see a lot of searching out new opportunity for us to try from the faculty and the students. We are trying to find ways for them to do it. The program I am coordinating is a partnership with Onandaga Community College. It was a competitive grant that our district office applied for. This was something new innovative and different.

These kinds of partnerships and creative ways of accessing resources is common at Central. While not nearly as advanced as Staten Island Tech's studio, Central has a broadcasting studio that started when a group of students and a teacher were awarded $15,000 through a contest nine years ago. With the support of Central technology teacher Michael Ferris, students arrive early each morning to produce "The Morning Show." The morning show is co-produced by an English teacher and Ferris is also seeking to add a social studies teacher. Students were in the process of building a new set and re-organizing the studio. The only constraint Ferris could see were the limitations that exist with their current facility. He and his students were attempting to engineer the best space possible. Additionally, Ferris and Central alumni have strong ties to Syracuse University's Newhouse School, a top-ranked broadcasting school, which provides significant opportunities for students through learning experiences and accessible expertise.

One Project Lead the Way teacher, has a degree in math and electrical engineering. His students use a 3-D modeling program as well as build autonomous guided vehicles. He explained, "Most of the work my students are doing is work that I did not do until college." At the end of his course, students can take an exam that gives them credit through the Rochester Institute of Technology.

Wendy Davis and Darlene Baker are part of a partnership with Bristol Myers-Squibb where students develop a target drug for a chemical trial to address a fictional High School Syndrome (HSS). Wendy Davis, who had been a chemist in the pharmaceutical industry, has the deep professional knowledge to support this work. Students simulate taking the drug to market, create a poster and a commercial, and present it to Bristol Myers-Squibb officials. Each week, 12-13 juniors and seniors come before school to work on the project. The project is partially funded by Bristol-Myers Squibb, the Science Olympiad, and a small contribution from the district. Through this work, teachers are co-teaching across disciplines that include biology, chemistry, business, and marketing.

Chrystal Corbett, a business teacher, is passionate about the work she is doing with students who are using Cisco Networking curriculum. She is particularly passionate about bringing girls into information technology and takes every opportunity to discuss the opportunities with prospective students. She said, "other schools are struggling with their business courses. We are not." She attributes this to the fact that for the last three years students have earned Cisco certificates and see the benefit of their work. She is always in need of additional computers, but she said, "When I ask for assistance, Greg [Avellino] will add to our budget."

Avellino does not limit his support to STEM initiatives. He said,

There are a lot of things here that are not STEM, and I do not want the other things to feel less important. If a social studies teacher comes with an idea, I want to support that as well. Andy Reid is heading up the Model UN [United Nations] program. He needed some books, and I got them for him. Equitable is making money available for opportunities. If the money is not there, we will try to see what we can get.

Obviously, the district does not have unlimited resources. Superintendent DeSiato explained,

We have worked hard to shift the resources to what we need. Teachers are coming together as teams of teachers to purchase things they need. Quite often, districts will ask how much

we added to the budget, so we continually shift [reallocate resources]. We have been fortunate to get money from legislators and grants mainly because we have a track record that they will see it used in our classrooms. We are able to give that information back to them for how it has been used. Our ESM Education Foundation [community funding organization] has been so supportive of ideas that teachers or teams of teachers have had. These folks in this room come up with ideas are on the cutting edge. Sometimes we can't do it this year, but we will the next budget year. The one area we did not retreat on was professional learning even when budgets were tight. Professional learning is key – particularly learning tours [teams of administrators and teachers travel to other schools and district to observe innovative ideas]. Not so much to replicate other work, but to be inspired. We invite them to come and visit us as well.

WORK DESIGN

Central High School is expanding these learning tours, Collaborative Educator Summits, co-teaching, flexible work schedules, cross-disciplinary planning, as well as training on the engineering design process and professional learning communities (PLCs). These expanding opportunities are indicative of the flexible way in which Central High approaches the way they design the work of teachers and administrators. School leaders are looking for ways to expand opportunities for teachers to innovate within and across districts. According to DeSiato, "Our Collaborative Educator Summit brings hundreds of people within and around New York State who are actually sharing practices and where they are. From that, we have also had STEM and STEAM learning tours. We give teachers inside and outside our district opportunities to see teachers implementing STEM learning. Some of that is very organic. It is from the very practitioners who are actually working on it."

In addition to this organic professional learning, Central hosts STEM nights for parents where they can be exposed to the work that their students were doing. This builds on the work that elementary and middle school parents have already experienced through STEM and STEAM nights such that these nights are considered part of the culture.

Teachers like Chrystal Corbett are working as .8 full-time equivalent teachers (FTE). This allows for hiring flexibility for administrators and work/life flexibility for teachers. Corbett has students in her lab working over lunch because she has flexibility through the freedom she feels. She said, "I want to be here for these kids, but I can also be home for my own kids."

The training in the engineering design process has allowed the STEM culture in the school to spread into different disciplines. To support this cross-disciplinary integration, each summer, the district supports administrators with a Summer Leadership Week that provides professional learning around teaching and learning and technology and learning. STEM integration is also happening organically. Cyndee Brazill who is in charge of Central's Makerspace is working with teachers from all different disciplines to support their work in whatever ways the Makerspace could fit within their curriculum. For example, while students were reading dystopian novels in their English classrooms, they were creating enhanced body parts with the 3-D printer. Students come to the Makerspace over an hour before school starts to work on their own. Brazill has the flexibility to support this work and teachers see the need for engaging students, treating engagement as something of an engineering challenge.

SUPPORTIVE SOCIAL NORMS AND WORKING RELATIONSHIPS

District and school leadership are not hierarchical. Administrators see themselves as undergirding supports for student and teacher vision. Given the support of district and school administration, perhaps it should not be surprising that Central teachers and administrators have strong working relationships. Avellino attributes some of this to the length of the relationships in the district. For example, he has known DeSiato for 35 years. Additionally, Avellino was a constant presence in the hallways and classrooms. For multiple hours a week, Avellino sits at a small desk near the front entry of the building in the hallway so that he is visible and available to teachers and students. This visibility supports teachers' and students' views that he is accessible and increases his awareness of what is occurring in the school.

Trust has grown over time. Teachers believe that administrators support them in tangible and intangible ways in their work. Students have agency to "just figure it out" when they are confronted with challenges. Returning to the CERF project, the previous ten years of the project exemplify supportive social norms. A married couple, John and Pamela Herrington, lead the work alongside research biologists, through a NOAA grant that was supported by the superintendent and mayor. Far from a source of jealousy among other staff, teachers speak of the CERF project with pride. Students feel enough ownership to demonstrate constant problem solving. For example, several of the plants in the greenhouse needed temperatures warmer than

the 50-60 degrees—the temperature to which the greenhouse drops in the winter. Therefore, students built a greenhouse within the greenhouse to increase the temperature of that space by 10 to 15 degrees. John Herrington consistently reiterates that students identify the problems and then test their own solutions. When asked by a student what he thought would happen in one pollination experiment, he answered honestly, "I do not know." This was not a cagey teacher trying to get a student to think for herself. He confided that he really did not know. This kind of support is prevalent across the building from students to teachers to administrators.

John Herrington gives credit to his science department chair, Sean McGlynn, Principal Avellino, Superintendent DeSiato, and his teaching partner and wife. McGlynn and Avellino provide the tangible support needed for the program, Pamela Herrington is a thought partner and essential communicator with the school and district, and DeSiato supports with resources and her presence at student presentations. However, challenges remain. For effective STEM teaching, this kind of support is particularly important. Assistant Principal Tokinma Killins shared, "We just need time. Whenever you are doing something with STEM, you have to be sure that people feel comfortable with what is being taught. When the IT (instructional technology) team presents, we become students. They teach and encourage us to experiment while providing support. They become our partners as we implement the newest technology into our day to day work." Kieran O'Connor, Executive Director of Planning, Development, and Technology added, "We have people out constantly in schools. We try to track who has been seen and who hasn't." In this way, everyone receives needed, systematic support.

SHARED INFLUENCE

A remarkable amount of the shared influence present at Central High School comes from engagement with business and community partners. Randi Ludwig, Coordinator for College and Career Readiness said, "Real engagement with partners—multiple connections on multiple levels—means actually listening to each other—genuine listening to each other and responsiveness to the outside community whether STEM community or business community." One administrator added,

Our partnerships are strong. They are who we are. We go and form partnerships with common shared goals working on things that benefit both groups. We have many partners with business, community organizations, and higher ed. They provide another

lens into a world outside of school. Their resources go beyond any kind of monetary resources.

Assistant Principal Killins said that the established partnerships with various organizations, especially those that are rapidly growing has "really been helpful in our work of preparing students for the ever changing, interconnected, global world they will engage in upon graduation. It also helps close that gap that exists in ensuring students are college and career ready."

Additionally, Central High School invites other schools into their school. In doing this, they spread their influence but also have the opportunity to learn from others. DeSiato highlighted this:

We have had hundreds of learning tours over the last seven years. We have had them from four countries and five states. What we see is that people want to come back to see what has the teachers so excited about what they are doing on that team. I think it resonates inside of them because they got into the profession and they want it back. We need to rediscover teacher voice and student voice.

Randi Ludwig added, "I think it is the voices. Our student panels are always mind-blowing. They are always talking about what they learned. The way they view failure. The way they speak about their experiences here. Teachers have told them, 'You figure it out.'" While some students might hear "figure it out" as something less than supportive, the confidence that Central teachers have in their students is a strong sign of encouragement and confidence in the ability of their students.

ORIENTATION TOWARD IMPROVEMENT

Central High School, and in fact the district as a whole, has a strong orientation toward improvement that starts at the top and permeates all levels of the district. Many of the partnerships and projects that were occurring at Central are due to this orientation toward continual improvement. Tokinma Killins described the school and district:

[Students] are to be inquisitive—ask lots of questions. These skills are taught in the elementary school, built upon in the middle school, and they are ready to experiment and push beyond their comfort zones in high school. Students become visionary as they think through, design and create products. Education needs visionaries and ESM has a great one in Dr. DeSiato. She thinks so far ahead, watches, listens and is in tune with what's happening globally. Therefore, she is able to identify many of the technologies and or experiences our

students need to be prepared for success after graduation. When students know the Superintendent is invested there is no ceiling to what they can do. They become game changers, as well as educational experience drivers for those coming behind them.

At every level, there appears to be support for the development of personal vision within the context of the larger district vision. Executive Principal Greg Avellino believes that growth occurs even when people do not actually change positions. He said, "I have a firm belief that some assistants want to stay assistants. Every year, we re-organize and look for areas where APs [assistant principals] have no experience so that they can continue to grow." Avellino applies this growth to his own work with parents and students. "For several years, I used the same basic PowerPoint for incoming freshmen, and we heard from parents that they needed different feedback. We turned the information into an online parent handbook and we made the presentation different. This has resulted in better communication with parents."

This type of humility, embodied by an engineering mindset that requires change and data collection was clearly evident in the district strategic plan. The plan includes annual iterations of 90-day plan-do-study-act cycles (PDSAs) building on improvement science popularized by the Carnegie Foundation (Bryk, Gomez, Grunow, & LeMahieu, 2015). The strategic plan is the district's "framework for success." They used Stephen Covey's habits of highly effective people (Covey, 2004, 2005) which undergirded an emphasis on growth and improvement. The habits with several examples related to improvement included:

- Be proactive: involving students, staff, and community in planning, implementing, and monitoring
- Begin with the end in mind: continual reflection on and evaluation of existing programs, team and individual actions, and next steps for improvement based upon the district strategic plan
- Put first things first: align school and department improvement plans and personal growth plans with the strategic plan
- Think win-win: approach all partnerships with students, parents, families, staff, and community with mutual respect to meet common goals
- Seek first to understand, then be understood: expanding and strengthening collaborative partnerships
- Synergize: combine strengths of students, staff, and

community through collaboration to achieve greater results than could be achieved independently
- Sharpen the saw: celebrate success, balance and renew resources, and focus on service
- Find your voice and inspire others to find theirs: emphasize students' voices, aspirations, and ideas in continually shaping the district strategic plan

OUTCOMES

The partnerships with corporations such as Bristol Myers-Squibb, Siemens, and higher education institutions, community projects like CERF, and recognition that Central High School and the district have received as a STEM Ecosystem and top STEM school are indicators of their success. Central High students have realized increased numbers of awards and scholarships. Students present their research to groups during learning tours and at an Environmental Summit each June at SUNY ESF. However, the outcomes that teachers and administrators focus on are much more student specific.

A technology teacher described what is occurring at Central:

I was able to visit when they built robots where they had to carry an item. The next year, they had to carry an item and keep it in a straight line. You see that a lot. Kids are being challenged to move further and further ahead. I think there is a lot of teacher leadership in the high school. When teachers feel like they have the freedom to take risks, they tend to do so. You will see teachers and students learning together.

This work was supporting all students, and particularly girls. Greg Avellino said, "By exposing as many students as we can to new opportunities, their eyes are opened—they may not know what they do not know." He added, "For example, we had a student who was not going anywhere academically until she got exposed to opportunities in STEM. She is now finishing her PhD. In the Rx class [in partnership with Bristol Myers-Squibb], we are seeing more girls going through this." He went on to describe multiple children from challenging backgrounds who are going to elite universities to study in STEM areas because of the opportunities Central had afforded them.

These opportunities for students are also benefitting the community. The CERF project is just one example of this. Students, who are passionate about finding ways to turn sewage into clean water for re-use are using village waste to heat a greenhouse where they can find environmentally

friendly solutions alongside research biologists and teachers. While not entirely quantifiable, students' perspectives on the world and their own self-efficacy are being transformed. John Herrington explained that, "In developing real world research projects students often have to deal with failure—things go wrong. Pumps break, things leak, plants die, etc. This might be the second most important things students learn at CERF. You can't quit and have to keep solving problems that arise." The most important thing they learn is that students "are the drivers of their own learning." He described it this way:

Often times students ask me "How do I fix that" or "How do we solve that problem" and they hate my response, "I don't know" or "I think you can figure that out." After the initial shock of not getting it spoon fed to them, I then guide them in the direction to help solve the problem. Ownership in their learning takes some getting used to by some students. They want the immediate fix. But I feel these behaviors of finding ways to solve their own problems will benefit them not only in college, but in the real world.

Barriers to Exemplary STEM

Even with all of the work that has been done and the partnerships that have been established, teachers and administrators would still like to see more opportunities to expand and deepen STEM learning. The CERF project is an excellent example of both barriers that remain and barriers that have been overcome. Because of the unique learning environment, time is always at a premium. Teachers in these types of courses need time for more grant writing and time to prep for projects and assessing student learning. As John Herrington observed, "There are no multiple-choice tests at CERF to assess research projects." Additionally, not all teachers, counselors, and students understand what CERF is about which makes attracting the right students a challenge. All students, even struggling students, are welcome to take the class, but it is a college level class with challenging content. However, Herrington has seen students who struggle with the content excel with their research projects. In order grow as an educator, Herrington would like relevant professional development opportunities which are hard to find given the nature of his course. One barrier that has been overcome has been transportation to the site. Because there is district support for this kind of STEM learning the transportation department has addressed the hurdles that had to be overcome to move students during the day.

As in almost any school, resources, facilities, time, and opportunities to collaborate are limited, but Central is making progress. What gets funded is determined by priorities and the strategic plan. Even in 2008-2010, when budgets were being cut for everyone in the district, professional learning remained a priority. The Collaborative Education Summit and Summer Leadership Institute area are prioritized. To control cost and maximize impact, the district sends teams of teachers and administrators to STEM national conferences, to other schools for learning tours, and has sent teams to Carnegie Summits where they apply improvement science to their school. These teams then return with and share the information through their school teams and professional learning communities.

Superintendent DeSiato described how they were addressing some of the barriers related to resources:

We've worked hard to shift the resources to what matters and what we believe we will need rather than to spend the resources on what we no longer really need. We've got more than enough construction paper in enough closets to last a lifetime because that's typically what we've been trying is people got their budgets and they spent them predominantly on the same things every year making sure they had stockpiled those things in the event you got to a year when somebody was going to tell you that you do not have the money. I think through building that trust that the resources will be there for you, because we first and foremost put them in our classrooms, that people began to say well this is what I really need and then they also come together as teams of teachers and say "Gee, we couldn't buy this if it was just my budget but if it was our budget as in a grade-level or department then we could purchase these things." And we saw that happening consistently more often and more often and now those folks who share that with their colleagues that's pretty much become the pattern. So it's quite

often that other school districts will ask how much more money did we add to our budget and the truth of the matter is we have a tax cap in New York, so it's not like we have the ability to add millions of dollars. We don't, so we continually shift. I will say we have been very fortunate to receive funding from our legislators, funding from various grants. and other grants.

Desiato believes that they continue to get additional funding because of how they demonstrate the use of those resources in classrooms with students. In order to find additional resources, the district has found some success with local fundraising and the way ideas spread. Both district and school administrators cite the ESM Education Foundation as a catalyst for innovative ideas that have spread from classroom to classroom. Once individuals or teams of teachers were funded, the ideas "spread like wildfire once the people saw it work and other people took that on." However, not everything in the district gets funded immediately, but whenever possible, DeSiato attempted to "add it in the next budget cycle."

Central High's Coordinator for College and Career Readiness, Randi Ludwig, cited the limitations of their facility as compared to Pine Grove:

When they [Pine Grove] redesigned the middle school, it was designed for project-based learning collaborative thinking as the elementary objective. We can't move walls, but we have Greg who knows every inch of this building. When we needed more space for computers, you know, it's like we move to shift space because we can't get a new building. We'll change the space and where can you walk now, so you have to be a bit of a pit bull.

Ludwig also described how collaboration and teaching effectiveness are enhanced efficiently through good hiring practices and partnerships. "I just had to hire a counselor, and one of her advantages was she worked at [a partner organization]. We already knew her and what she had to offer. So looking at people when they're new and what are they bringing to the school allows us to utilize a different perspective or one of their strengths or focus. You know that person's going to be on board with our philosophy." This type of hiring practice does not cost Central any more money, but it maximizes the investment in the employee and the school.

Collective Leadership for Exemplary STEM

Teachers and administrators at Central High were extremely positive about the role collective leadership played in STEM teaching and learning:

"On a scale of 0-10, how much of the exemplary STEM work has been led by teachers (10 being total control, 0 being no control)?"

The average teacher response was an 8 for their roles in the work. On average, they also saw administrators as an 8. Administrators' responses were nearly identical. Teachers feel the support of building administrators, but they feel also feel the support of community partners and district administrators. Teachers also see students as primary partners in the work. As one teacher shared, "To sum it up I guess, opportunities lead to passion because that's what we've seen every kid has a story and the way those names we just mentioned they're all opportunities that just lead to develop passion and I think the kids get to see the staff's passion as well, and it's very effective."

Assistant Principal Tokinma Killins added what she thought was essential for the school's success:

The only thing that I would add is on a really basic level, relationships. The relationships developed between teachers, administrators or staff in general that encourage students to question, research, present and defend beyond their comfort zone create innovative thinkers and risk takers. They won't be afraid to ask questions or try new things. Again, these skills must start early. Students who have these types of experiences have a stronger sense of self and are excited about education, learning, and will push to shape their learning experience. It is so exciting to see them push because that push will take them and us to the next level.

These strong relationships between administrators, teachers, students, and community partners appear to be the driving force of much of Central's success.

Theoretical Framework and Methodology

The theoretical framework undergirding the initiative is an analytic model for collective leadership development (Eckert, 2018; Eckert, 2019). Collective leadership encompasses the practices through which teachers and administrators influence colleagues, policymakers, and others to improve student outcomes (Eckert, 2018). This framework is based on the literature on work redesign (e.g., Campion, Mumford, Morgeson, & Nahrgang, 2005; Hackman & Oldham, 1980; Humphrey, Nahrgang, & Morgeson, 2007), leadership development across organizational type and sector (e.g., Avolio, 2010; Conger, 1992; Day, Zaccaro, & Halpin, 2004; Van Velsor, McCauley, & Ruderman, 2010; Yukl, 2013) and teacher leadership (e.g., Berg, 2018; Lieberman & Miller, 2004; Mangin & Stoelinga, 2008; Murphy, 2005; Wenner & Campbell, 2017; York-Barr & Duke, 2004). The focus of the model is on leadership, not the leader, just as focusing on teaching instead of the teacher is beneficial (Hiebert & Stigler, 2017). This theory views leadership functionally (Firestone, 1996), as redesigned work to be performed rather than as a particular role to be assumed (Mayrowetz, Murphy, Louis, & Smylie, 2007; Smylie, 1994). The theory frames collective leadership as a blending of the work of teachers and administrators to identify and advance shared goals that will benefit students.

Systematic development of collective leadership that can promote school improvement and affect student outcomes, is dependent on seven conditions that comprise the elements on the left side of the model (see Figure 1). Of the seven constructs, we argue that first four—vision and strategy, supportive administration, resources, and work design—are antecedent to the other—three, supportive social norms and working relationships, constructive organizational politics, and orientation toward improvement—acknowledging the systemic interactive relationships among all seven (Bass, 1990; Firestone, 1996; Smylie, 2010; Yukl, 2013).

To understand collective leadership in support of STEM learning, required a definition of exemplary STEM and a deeper understanding across contexts. Exemplary STEM learning includes content and context integration in the application of design thinking through the use of science, technology, engineering, and mathematics knowledge. (Hansen, 2014; Johnson, Peters-Burton, & Moore, 2016; Lynch, Peters-Burton, & Ford, 2015; Peters-Burton et al., 2014; Tofel-Grehl & Callahan, 2014). Across schools where exemplary STEM learning is occurring, there is a sense of independent student learning, inclusion, and an emphasis on research and inquiry (Tofel-Grehl & Callahan, 2014). For the purposes of this paper, exemplary STEM is a multi-disciplinary integrated approach that addresses global and local challenges through the development of critical thinking, problem solving, teamwork, communication, and empathy.

DATA SOURCES

We identified an initial list of over 30 schools across New York after consulting with Regents, the State Department of Education, State Teachers of the Year, and reviewing state STEM achievement data (e.g., graduation rates, math and science testing data in grades 3-8 and Regents exams). To narrow the list of possible schools, we identified schools with above average state STEM achievement data, conducted videoconferences with school leaders of recommended schools, and ensured that we had at least one elementary, middle, and high school from different parts of the state. Additionally, we identified one district with an elementary, middle, and high school in order to see STEM learning develop P-12. We selected Staten Island Technical High School, Boardman Elementary, and three schools from East Syracuse-Minoa Central School District. This district is a STEM Learning Ecosystem, a national initiative to improve STEM (STEM Ecosystems, 2019). The three schools in the district were East Syracuse Elementary, Pine Grove Middle School, and Central High School (see Table 1).

In partnership with NNSTOY, we selected 15 Fellows from across New York who applied to partner in this work. The application required potential participants to provide evidence of their accomplishments as STEM teacher leaders and were evaluated accordingly. After selecting Fellows from a

competitive applicant pool, through monthly videoconferences, they provided feedback by confirming and disconfirming initial findings and providing evidence from their own schools. Five additional accomplished STEM teacher researchers were also selected to help develop interview protocols, survey items, and to review initial drafts and findings. These 20 STEM teacher leaders increased the generalizability of the five case studies.

METHODS

Over the course of two years, we collected data in all five high schools. We used survey data of school and district STEM leaders (n=113) and semi-structured responsive interviewing (Rubin & Rubin, 2005) with teachers (n=52) and administrators (n=18). The administrators included superintendents, central office administrators, principals, assistant principals. Teacher leaders voluntarily signed up for individual or focus group time slots during planning periods, before, or after school. Interviews and focus groups were 30-90 minutes in length. We conducted classroom observations, and observed leadership meetings, staff meetings, and professional learning communities through site visits to all five schools. We conducted document analyses of school STEM surveys, school climate surveys, student data, program planning documents, committee work products, student achievement data, and school improvement plans to facilitate triangulation (Patton, 2002) in a multiple-case study design (Yin, 2014).

Interview transcripts and field notes were transcribed, organized, and coded using Dedoose. The data were coded into categories that comprised the analytic model of collective leadership development (See Figure 1). Two researchers blind-coded the data concurrently. To ensure inter-rater reliability, through testing and regular collaboration to reconcile discrepancies, the researchers' pooled Cohen's kappa was .86. This pooled kappa value indicates excellent agreement even by the most conservative estimates (Cicchetti, 1994; Fleiss, 1971; Landis & Koch, 1977; Miles & Huberman, 1994). When there were discrepancies, we used memos to reconcile coding differences across school sites. Through memo writing, we were able to better understand model constructs as they manifested themselves in different contexts.

Using the analytic model to determine the potential for improved collective leadership practice in support of student outcomes (Funnell & Rogers, 2011), we employed cross-case synthesis (Yin, 2014). By matching observed events to the analytic model and then comparing them across cases we were able to organize findings and check for disconfirming evidence. The complexity of the analytic model required a robust analysis of all data as the model itself is comprehensive. Moreover, document analysis including school level data on climate and culture triangulated similarities and differences across schools.

Demographics

	Total Enrollment	Economically Disadvantaged	White	Asian/ Pacific Islander	Black	Hispanic	Multiracial	Native American
BOARDMAN ELEMENTARY	318	7%	83%	4%	1%	10%	3%	--
CENTRAL HIGH SCHOOL	1033	41%	88%	2%	5%	2%	2%	1%
EAST SYRACUSE ELEMENTARY	305	72%	82%	2%	10%	4%	3%	--
PINE GROVE MIDDLE	729	46%	87%	2%	4%	3%	3%	1%
STATEN ISLAND TECHNICAL HIGH	1313	39%	48%	47%	1%	4%	--	--

Demographic and achievement data retrieved https://data.nysed.gov/profile.php?instId=800000041734

REFERENCES

Avolio, B. J. (2010). Full range leadership development (2nd ed.). Thousand Oaks, CA: Sage.

Bass, B. M. (1990). Handbook of leadership: Theory, research, and managerial applications (3rd ed.). New York, NY: Free Press.

Berg, J. H. (2018). Leading in sync: Teacher leaders and principals working together for student learning. Alexandria, VA: ASCD.

Bryk, A. S., Gomez, L. M., Grunow, A., & LeMahieu, P. G. (2015). Learning to improve: How America's schools can get better at getting better. Cambridge, MA: Harvard Education Press.

Bryk, A., & Schneider, B. (2002). Trust in schools: A core resource for improvement. New York, NY: Russell Sage Foundation.

Campion, M. A., Mumford, T. V., Morgeson, F. P., & Nahrgang, J. D. (2005). Work redesign: Eight obstacles and opportunities. Human Resource Management, 44(4), 367–390.

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normal and standardized assessment instruments in psychology. Psychological Assessment, 6, 284–290.

Committee on STEM education. (2018). Creating a course for success: America's strategy for STEM education. Retrieved from The White House website: https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf

Conger, J. (1992). Learning to lead: The art of transforming managers into leaders. San Francisco, CA: Jossey-Bass.

Covey, S. R. (2004). 7 habits of highly effective people: Restoring the character ethic. New York City, NY: Free Press.

Covey, S. R. (2005). The 8th habit: From effectiveness to greatness. New York, NY: Free Press.

Darling-Hammond, L., & Bransford, J. (2005). Preparing teachers for a changing world: What teachers should learn and be able to do. San Francisco, CA: Jossey-Bass.

Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). Professional learning in the learning profession: A status report on teacher development in the United States and abroad. Retrieved from National Staff Development Council website: http://www.learningforward.org/docs/pdf/nsdcstudy2009.pdf

Day, D. V., Zaccaro, S. J., & Halpin, S. M. (2004). Leadership development for transforming organizations: Growing leaders for tomorrow. New York, NY: Psychology Press.

Eckert, J. (2018). Leading together: Teachers and administrators improving student outcomes. Thousand Oaks, CA: Corwin Press.

Eckert, J. (2019). Collective leadership development: Emerging themes from urban, suburban, and rural high schools. Educational Administration Quarterly, 55(3), 477–509. https://doi.org/10.1177/0013161X18799435

Eckert, J., Ulmer, J., Khatchatryan, E., & Ledesma, P. (2016). Career pathways of teacher leaders: Adding and path-finding new professional roles. Professional Development in Education, 42(5), 687–709.

Ericsson, K. A., Krampe, R. T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. Psychological Review, 100(3), 363–406.

Firestone, W. A. (1996). Leadership: Roles or functions? In K. Leithwood, J. Chapman, D. Corson, P. Hallinger, & A. Hart (Eds.), International handbook of educational leadership and administration, Part I (pp. 395–418). Boston, MA: Kluwer.

Fleiss, J. L. (1971). Measuring nominal scale agreement among many raters. Psychological Bulletin, 76(5), 378–382.

Funnell, S. C., & Rogers, P. J. (2011). Purposeful program theory: Effective use of theories of change and logic models. San Francisco, CA: Jossey-Bass.

Hackman, J. R., & Oldham, G. R. (1980). Work redesign. Reading, MA: Addison-Wesley.

Hansen, M. (2014). Characteristics of schools successful in STEM: Evidence from two states' longitudinal data. Journal of Educational Research, 107(5), 374–391. https://doi.org/10.1080/00220671.2013.823364

Hattie, J. (2015). What works best in education: The politics of collaborative expertise. Retrieved from Pearson website: https://www.pearson.com/content/dam/corporate/global/pearson-dot-com/files/hattie/150526_ExpertiseWEB_V1.pdf

Heath, C., & Heath, D. (2017). The power of moments. New York, NY: Simon & Schuster.

Hiebert, J., & Stigler, J. W. (2017). Teaching Versus Teachers as a Lever for Change: Comparing a Japanese and a U.S. Perspective on Improving Instruction. Educational Researcher, 46(4), 169–176. https://doi.org/10.3102/0013189X17711899

Humphrey, S. E., Nahrgang, J. D., & Morgeson, F. P. (2007). Integrating motivational, social, and contextual work design features: A meta-analytic summary and theoretical extension of the work design literature. Journal of Applied Psychology, 92(5), 1332–1356.

Jackson, C. K., & Bruegmann, E. (2009). Teaching students and teaching each other: The importance of peer learning for teachers. American Economic Journal: Applied Economics, 1(4), 85–108.

Jensen, B., Roberts-Hull, K., Magee, J., & Ginnivan, L. (2016). Not so elementary: Primary school teacher quality in high-performing systems. Retrieved from National Center on Education and the Economy website: http://ncee.org/wp-content/uploads/2016/05/169726_Not_So_Elementary_Report_FINAL.pdf

Jensen, B., Sonnemann, J., Roberts-Hull, K., & Hunter, A. (2016). Beyond PD: Teacher professional learning in high-performing systems. Retrieved from National Center on Education and the Economy website: http://www.ncee.org/wp-content/uploads/2015/08/BeyondPDWeb.pdf

Johnson, C. C., Peters-Burton, E., & Moore, T. J. (2016). The need for a STEM road map. New York, NY: Routledge.

Kraft, M. A., & Papay, J. P. (2016). Developing workplaces where teachers stay, improve, and succeed. Retrieved from The

Albert Shanker Institute website: http://distributedleadership.org/assets/asi-(2016).pdf

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. Biometrics, 33(1), 159–174.

Lieberman, A., & Miller, L. (2004). Teacher leadership. San Francisco, CA: Jossey-Bass.

Lynch, S. J., Peters-Burton, E., & Ford, M. (2015). Building STEM opportunities for all. Educational Leadership, 72(4), 54–60.

Mangin, M. M., & Stoelinga, S. R. (2008). Effective teacher leadership: Using research to inform and reform. New York, NY: Teachers College Press.

Mayrowetz, D., Murphy, J., Louis, K. S., & Smylie, M. A. (2007). Distributed leadership as work redesign: Retrofitting the job characteristics model. Leadership and Policy in Schools, 6, 69–101.

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis. Thousand Oaks, CA: Sage.

Murphy, J. (2005). Connecting teacher leadership and school improvement. Thousand Oaks, CA: Corwin Press.

Murphy, J., Smylie, M. A., Mayrowetz, D., & Louis, K. S. (2009). The role of the principal in fostering the development of distributed leadership. School Leadership and Management, 29, 181–214.

Patton, M. (2002). Qualitative research and evaluation methods. Thousand Oaks, CA: Sage.

Peters-Burton, E., Kaminsky, S. E., Lynch, S., Behrend, T., Han, E., Ross, K., & House, A. (2014). Wayne School of Engineering: Case study of a rural inclusive STEM focused high school. School Science and Mathematics, 114(6), 280–290. https://doi.org/10.1111/ssm.12080

Ronfeldt, M., Farmer, S. O., McQueen, K., & Grissom, J. A. (2015). Teacher collaboration in instructional teams and student achievement. American Educational Research Journal, 52(3), 475–514.

Rubin, H. J., & Rubin, I. S. (2005). Qualitative interviewing: The art of hearing data. Thousand Oaks, CA: Sage.

Smylie, M. (2010). Continuous school improvement. Corwin Press.

Smylie, M. A. (1994). Redesigning teachers' work: Connections to the classroom. In L. Darling-Hammond (Ed.), Review in Research in Education (Vol. 20, pp. 129–177). Washington, D.C.: American Educational Research Association.

Smylie, M. A., & Brownlee-Conyers, J. (1992). Teacher leaders and their principals: Exploring the development of new working relationships. Educational Administration Quarterly, 28, 150–184.

Smylie, M. A., & Eckert, J. (2018). Beyond superheroes and advocacy: The pathway of teacher leadership development. Educational Management Administration & Leadership, 46(4), 556–577. https://doi.org/10.1177/1741143217684893

STEM Ecosystems. (2019). East Syracuse Minoa Central School District STEM learning ecosystem. Retrieved from East Syracuse Minoa Central School District STEM Learning Ecosystem

Tofel-Grehl, C., & Callahan, C. M. (2014). STEM high school communities: Common and differing features. Journal of Advanced Academics, 25(3), 237–271. https://doi.org/10.1177/1932202X14539156

Van Velsor, E., McCauley, C. D., & Ruderman, M. N. (Eds.). (2010). The center for creative leadership handbook of leadership development (3rd ed.). San Francisco, CA: Jossey-Bass.

Wenner, J. A., & Campbell, T. (2017). The theoretical and empirical basis of teacher leadership: A review of the literature. Review of Educational Research, 87(1), 134–171. https://doi.org/10.3102/0034654316653478

Yin, R. (2014). Case study research: Design and method (5th ed.). Los Angeles, CA: Sage.

York-Barr, J., & Duke, D. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. Review of Educational Research, 74(3), 255–316.

Yukl, G. (2013). Leadership in organizations (8th ed.). Boston, MA: Pearson.