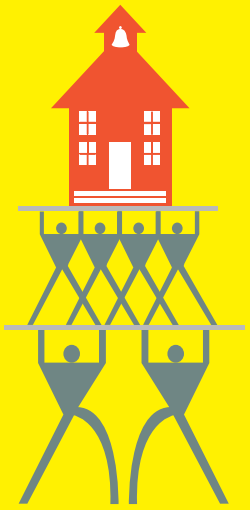

SUPPORT COLLABORATE **RETAIN**

STRATEGIES FOR IMPROVING THE STEM TEACHING CRISIS

by: MEGHAN GROOME, JULIA RANKIN *and* JENNIFER WHEARY

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THE STEM PIPELINE

Our nation's ability to develop workers and citizens with skills in science, technology, engineering and math (known as the STEM subjects) is an issue of equity, economic vitality, and educational necessity.

On an individual level, access to STEM education is now an essential component of financial security. STEM skills have become increasingly important not just in STEM occupations but also in general employment as well. The Center on Education and the Workforce at Georgetown University has pointed out that the "increasing demand for workers holding STEM certificates, certifications, and degrees is a proxy for the demand for underlying competencies." Critical thinking; active learning; and mathematical, inductive and deductive reasoning – skills valuable in work and in life generally – are just a few of these competencies.[1]

The National Governors Association estimates that 70 percent of all jobs– not just those in technical fields– created in the next few years will require at least some STEM competency. There is real danger that individuals without STEM skills will be shut out of many employment opportunities, and in many cases relegated to low-wage, low-skill jobs instead.[2]

"...Access to STEM education is poised to amplify already existing socioeconomic inequities by limiting individual access to higher quality jobs."

In this way, access to STEM education is poised to amplify already existing socioeconomic inequities by limiting individual access to higher quality jobs. Systematic problems continue to limit the access of specific demographic groups, particularly those coming from lower-income families, to quality STEM education. Recently released scores from the U.S. Department of Education's National Assessment of Educational Progress (NAEP) show a growing gap between the STEM proficiencies of urban and suburban school students. The dividing line between these two groups falls not necessarily along an urban versus suburban setting per se, but rather along socioeconomic lines, and how factors such as funding per student can affect these schools.

Because cultivating workers with solid STEM skills is indispensible to fostering international competitiveness and ongoing innovation, increasing the number of people completing postsecondary credentials in STEM subjects has become a much talked about goal. Yet focusing only on postsecondary STEM education falls short of what is needed.

The STEM pipeline, in its most complete sense, begins with early childhood and elementary education and proceeds through high school and college. Sophisticated STEM skills do not just magically emerge at the postsecondary level. Instead these skills must be nurtured much earlier. The ability to reason scientifically and the background knowledge of science and mathematical concepts one learns starting in elementary school is an essential foundation for later learning. This ability and knowledge is valuable in and of its own right. It also becomes the scaffolding on which more advanced STEM skills can be

built. Gaining this knowledge in the K-12 years is equally essential for those students who move on to formally study STEM subjects in college and those who do not.

Beyond employment, STEM skills such as critical thinking are essential in our daily lives. A person who can understand and use the process of scientific inquiry is better able to solve problems than someone who cannot. The reasoning skills that we learn by studying STEM subjects are useful any time we evaluate evidence or make a decision that affects our personal lives or society at large. As career scientist and educator Cecily Selby has asked: "Is not the ability to distinguish between different kinds of evidence essential for active citizenry in a democratic society?" To illustrate this point, Dr. Selby quotes Rampele Manphele, former chancellor of the University of South Africa: "With its emphasis on evidence and honesty, science enables us to call the bluff of those who would lie to us."[3]

When the numbers are added up, many feel our educational system is producing enough qualified individuals to fill the ranks of most PhD-level positions. The larger issue is that we fail to provide basic science and math literacy skills to the majority of American school children.[4] Troubling statistics show that even after 25 years of rhetoric around the vital nature of STEM education, the average number of hours an elementary school student spends studying science continues to decline.[5]

New York City provides one example of how the STEM pipeline is broken. New York City is home to nine major science research institutions, approximately 475,000 working scientists, and 25 National Medal of Science recipients–the most in the United States.[6] Yet there is a great chasm between the city's abundant scientific resources and its public school children, most of whom still struggle in the sciences. The 2005 Trial Urban District Assessment from the National Assessment of Educational Progress showed that the city's fourth and eighth-grade students fall 20 or more percentage points below the national average in scientific achievement.[7] In 2008 New York City fourth graders scored 6 percentage points behind students in the rest of the state in their math proficiency rates, and 17 percentage points behind in their science proficiency. Eighth grade students in New York City scored 15 percentage points lower than eighth graders elsewhere in the state in their math proficiency, and 30 percentage points lower in science.[8]

Additionally, according to the New York City Department of Education, African American and Hispanic students–the two minority groups who comprise the majority of the student body–continually perform lower than white and Asian/Pacific Islander students on New York State assessments at the high school level. In 2009 the achievement gap between white and African American high school students was 22 percentage points.[9]

The trends visible in New York City are visible throughout the country. There is no shortage of evidence of the STEM skills crisis in the K-12 grades. Fortunately there is also no denial of the importance of addressing it. Many organizations have focused on how to change the tide. A tremendous amount of thinking, policy efforts, funding, and education reform has focused on improving STEM education, and results have been positive in individual cases. But more can be done.

WHY STEM TEACHER RETENTION IS VITAL

In January 2011 a group of seasoned and well-respected educators and policymakers participated in a panel discussion at the New York Academy of Sciences on strategies for improving STEM education. The audience, which included scientists, teachers, and teacher educators, reacted very strongly against the solutions proposed by the panelists. Audience members' main objection was a perceived lack of connection between the policies proposed by panelists and the day-to-day working reality of math and science classrooms. Issues such as pay, working conditions, and the tension between standardized testing and inquiry-based learning quickly surfaced as reasons why top teachers were leaving the field and why many of the audience members who were working teachers were frustrated with their careers.[10]

"In the minds of working STEM educators and those who train them, current efforts to improve STEM education are limited by schools' ability to retain good teachers."

In the minds of working STEM educators and those who train them, current efforts to improve STEM education are limited by schools' ability to retain good teachers. Those working in the field believe that efforts to recruit the best and brightest teachers, to train them well, and to improve curricula or pedagogical practices will be severely limited if schools cannot keep the teachers in whom they have invested.[11]

While retention of teachers across all subjects is a problem, retaining STEM teachers poses an additional challenge. As more states require STEM teachers to earn degrees in specific scientific disciplines, these teachers have a wider array of job opportunities available to them. Someone with a physics or math degree, for example, has the capacity to pursue jobs in industry that use their skills, pay much more than teaching, and have other attractive attributes. Math and science teachers are in fact the most likely to leave the teaching profession altogether due to job dissatisfaction. Studies of teacher turnover show that math and science teacher turnover has increased by 33 percent over the past two decades.[12]

Looking across all subjects, about a third of new teachers leave the field within the first three years, and one half leave after five years.[13] A conservative national estimate of the annual cost of replacing them is nearly $3 billion.[14] In addition to the financial costs of having to replace teachers, high teacher turnover is associated with lower student achievement.[15]

Teacher retention is an issue that cuts across subject areas. However, it has an important connection to STEM education. One of the most often-cited reasons for the STEM achievement gap is a lack of skilled and trained teachers in these subject areas.[16] The greatest percentage of under-qualified teachers at the K-12 level is found in STEM disciplines. Forty percent of high school math teachers and 20 percent of science teachers in high needs areas lack a higher education degree in the subject they instruct.[17]

To change this course, President Obama has called on all stakeholders to recruit one million new teachers to American classrooms. However, teacher recruitment is only half of the battle. Teachers with

math and science backgrounds are difficult to keep in the classroom, especially in schools in underserved areas.[18] The Carnegie Corporation and other organizations are already examining the process of recruiting new math and science teachers. However, few organizations are currently examining how to keep those new teachers in the classroom.

Solving the teacher retention crisis is a multifaceted, complex agenda that requires action on multiple fronts. Important work has been done to think broadly about ways our society, the scientific community, and the educational system at large can shift focus and enhance science teaching as a profession. Efforts at this broader level are essential, as are efforts at the district and individual school level. (See the section on "Science Teaching as a Profession.")

Our goal in this paper is to identify some promising practices for schools who wish to retain their STEM teaching talent. Many of these practices can be loosely categorized under the umbrella of school culture. Broadly speaking, they include workplace conditions and the quality of the relationships that teachers have with administrators, students, and each other.

When researchers study what makes teachers leave the profession and what makes them stay, a range of factors come to light. Some are external factors such as relocation and childrearing. But many teachers seem to describe the same combination of factors that frustrate them: a mismatch between good teaching practice and accountability measures; too much chaos and too little stability, too many responsibilities for the amount of time in the work day; and too little pay to make a middle class lifestyle feasible.

Teachers who stick with the profession acknowledge these challenges but describe employing a range of strategies to cope with them. These strategies include: building a network of like-minded colleagues, establishing positive professional relationships in and outside of their schools, feeling supported by their school leadership, and seeking pathways for professional growth.

SCIENCE TEACHING AS A PROFESSION, AN INTERVIEW WITH SHEILA TOBIAS

In *Science Teaching as a Profession: Why It Isn't. How It Could Be,* (NSTA Press, 2010) co-authors Sheila Tobias and Anne Baffert represent the voices of teachers as powerful insight into what is needed to retain STEM teaching talent in our schools. In a personal interview with us, Tobias explained that the book offers a "window into the minds and feelings of secondary science teachers," something that is much needed because in many educational debates "No one seems to care about the quality of teachers' work lives."

For the book, Tobias, her co-author and a range of collaborators talked to science teachers about topics such as working conditions, salaries, public and administrative support, curriculum, assessment, teacher evaluation, and job satisfaction.

These teachers largely experienced a lack of control and respect in their workday. Whether it was teaching assignments, hiring decisions, classroom materials, budgets, or other decision-making, teachers felt unable to influence matters that greatly impacted their ability to be successful and to offer students the best learning opportunity.

"What we found is diminishing influence over policies within schools, within school districts and within the state," Tobias told us. "A recurring complaint we heard is how very little time [teachers] have to do their jobs because of 'administrivia'."

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The intention of this paper is to illustrate the importance of these factors and their role in teacher retention and to provide some basic ideas about ways in which schools may begin to address them. Our goal is to further the discussion about the impact of interventions in these areas by highlighting the issues these interventions are meant to address and sharing the perspectives and experiences of educators.

Through this, we hope to offer ideas and inspiration to those looking for solutions to the retention crisis. We do not seek to provide an exhaustive and definitive evaluation of each practice mentioned. Broadly stated, many of these practices are aimed at positively influencing school culture and creating an atmosphere of collaboration and cooperation. These types of interventions show great promise. Researchers have found that in many cases schools that have improved the knowledge and support of their teachers 1) have successfully narrowed the STEM learning gap during the middle school years, and 2) tend to have lower teacher attrition rates.[19]

"Teachers want more autonomy over how and what they teach. They are disturbed by a loss of control, especially over student assessment," Tobias told us. Teachers want to be "appreciated for their expertise, trusted for their judgment, and valued by their administrators and society in general."

Science Teaching as a Profession offers several concrete recommendations for increasing the professionalization of teaching. One is making a concerted effort to involve science teachers in school and district governance. One mechanism for achieving this is to establish science teaching councils to contribute to decisions currently completely under the purview of principals and administrators. The creation of alliances within the scientific community to support teachers' ongoing development is also a potentially powerful change.

In our work and in the Tobias-Baffert findings, powerful and positive things happen when science teachers visit labs, attend workshops, or are otherwise engaged with working scientists in professional development opportunities or other projects. "If teachers are experiencing less control, when you link them with scientists and focus on improving their efficacy, and give them nurturing and support they are not getting elsewhere, classroom teaching is enhanced," Tobias explained to us.

Tobias told us that these types of interactions impact the political environment in which decisions about education are made. "When the science community is involved, people with more political clout than teachers get to understand what conditions are like in the schools. That is a secondary but no less valuable effect of teacher-scientist connections. Their support begins with an understanding of the conditions under which teachers work. And until people outside the school hierarchy get into the classroom or interact with teachers they cannot know it."

CAREER LADDERS AND CAREER LOOPS: THE TEACHING TRAJECTORY

Many different careers offer "career ladders" which provide clear paths to advancement within the profession. Teaching has been criticized for not having a strong career ladder system. The opportunities that do exist encourage teachers to move out of the classroom, into a support role such as a coach and then into an administrative role. The career ladder metaphor is problematic for teaching. It implies that the goal of advancement is to move up and out of the classroom and ignores the idea that teachers can find advancement and challenge by shifting content areas, grades, school types, and job titles.

For both of those reasons, we propose rebranding the teacher "career ladder" as a "career loop." The career loop metaphor suggests that teachers can find ways to stay intellectually engaged in the classroom while moving in multiple directions–laterally within content areas or curriculum

choices; vertically among grade levels; horizontally by choosing different sizes and types of schools; and finally amongst different jobs such as classroom teacher, principal, coach, and central administrator. The focus of career loops is to keep good teachers engaged in their own professional journey and serving their school districts and regions in a variety of capacities.

The personal stories of teachers with whom one of the authors (Rankin) has worked illustrate the importance of career loops for talented teachers. Both teachers profiled participated in the California Science Project Teacher Retention Initiative (CSP-TRI). (See the section on "Building Communities That Support Teachers" for details of this program.)

ANNE STEPHENS

Anne was an award winning secondary science teacher with 19 years of service in her school district. Throughout her career, she stayed involved in professional development programs for science teachers, both as a participant and leader. At several points in her career, she co-wrote watershed education grants and was granted a .2 or. 4-time leave of absence to act as a project manager, job sharing her position with another science teacher.

In 2005, Anne was offered the opportunity to teach science methods at the university level and serve as co-director of a CSP-TRI grant working with teachers from her school district. She was granted a one-year professional leave from her classroom position to pursue this opportunity. When her year was up, she transferred into a position at the local high school where she was told she would be itinerate for several months until a portable science classroom arrived. A few months turned into several years of pushing a cart from room to room, and the stress of teaching college prep chemistry and biology labs under such conditions became too much. When Anne was finally assigned to a classroom, it had no water or lab equipment. At this point, without a science classroom in which to teach, Anne applied for a PhD program at UC Davis, and took a visiting educator position with the California Department of Education, all within the guidelines of a professional leave of absence as written in her contract.

Six months after starting this new position, Anne's school district told her to either return to her classroom teaching position after the winter break, or resign from the school district. After 19 years, she resigned from her teaching position with the district. Today, Anne is continuing

her PhD work in science education research. She is working with another high school in the Sacramento area as part of her graduate research, but misses teaching. She feels that education in general would benefit greatly if teachers could periodically cycle out of their teaching duties to pursue professional development opportunities. Although these opportunities are made available for those entering administration, research shows that this is not the case for science educators.[20]

BAMA MEDLEY

Bama Medley has been working in the Santa Maria Bonita School district for 18 years. She began as a math and science teacher at the middle school level and worked in that position for 13 years. The district then received a California Math Science Partnership (CaMSP) grant and hired Bama as the program coordinator, serving teachers in her community for three years.

In her second year as the CaMSP coordinator, Bama was invited to chair the Science Committee of the Curriculum Commission for the California State Board of Education, a volunteer position. There she honed her skills working on state frameworks, curriculum adoption and materials approval. She began to examine science content for the English Language Arts (ELA) core curriculum for publishers.

Administrators were impressed by Bama's skills as a staff developer and her work with ELA on the commission. When the CaMSP grant was finished, they asked to her to continue her work at the district level. Although not in the classroom, Bama continues to support science and math teachers through volunteer activities in her district. She has been invited to assist the California State Superintendent of Schools in the development of the Next Generation of Science Standards.

Bama credits her administration for seeing the value in what she does and supporting her work. She says, "It keeps me in education. I like bringing my work back to the teachers and serving my district."

SCHOOL CULTURE AND WORKNG CONDITIONS

Many studies have found that teachers, particularly those with stronger academic backgrounds, prefer to teach in schools with higher achieving students. When teachers switch schools, they are likely to move to schools with higher percentages of higher- achieving students and relatively fewer minority and poor students.[21] Contrary to popular belief, teachers gradually move to classrooms higher up the socioeconomic ladder not because of a desire to stop teaching economically disadvantaged students. They move because teachers see higher achieving schools as having other positive attributes, such as better facilities, more preparation time, and greater resources in general.[22]

Teaching in high poverty urban schools is more challenging to an individual teacher. Physical facilities, instructional materials and technology infrastructure can often be much worse in high poverty schools than those found in well-resourced, suburban schools. One of the authors (Groome) is a former classroom science teacher who continues to work with urban educators on a daily basis. She has visited many school buildings that are older and in need of repair. While most of the schools are generally clean, many lack basics like toilet paper, hand soap, and access to a safe place to leave personal belongings—a situation that is unimaginable to most professionals. In public schools facing these conditions, the only way around this lack of basics is for staff and students to provide their own supplies. A lack of basic resources is particularly frustrating for teachers trying to offer science lab experiences.

COMPENSATION

While the research and policy ideas discussed here suggest that changes can be made in areas such as school culture and workplace conditions, we do not want to give the impression that compensation does not play a role in teacher retention. As with any occupation, teachers are sensitive to wage issues. Salary levels can affect whether someone chooses to become a teacher, what district they choose, and when they start.

Higher new teacher salaries have been linked to increases in commitment to the teaching profession,[30] and they are also associated with lower teacher attrition.[31] Despite the known benefits of increasing teacher salaries, United States teacher salaries have held steady over 15 years.[32]

Our point here is that salaries are only one aspect of teacher preferences. Research suggests that working conditions are as important as wages in determining where a teacher decides to teach. Such non-wage attributes are a particularly pertinent factor in large urban districts where salaries are typically the same across the board but school characteristics differ widely. These include characteristics of students, class size, school culture, facilities, leadership, and safety.[33]

While physical working conditions, access to basic resources, and student demographics create major challenges for teachers, research shows that school culture plays a large role in teacher retention and student achievement as well. One recent study looking specifically at the turnover rates among 50,000 math and science teachers found that teachers who experienced greater levels of autonomy, respect and administrative support were much *less* likely to leave than teachers who did not experience these things.

Math teachers, for example, who felt a higher degree of classroom autonomy were 70 percent less likely to leave their schools than their cohorts who did not feel the same level of autonomy.[23]

Other studies echo that factors like the quality of relationships between staff and school leadership and the support teachers feel in the classroom have been shown to impact job retention and to improve student achievement across all subjects.[24] In fact one study found that administrative support, along with school facilities and class size, are more important than salary and student demographics in teacher retention and student achievement.[25] Surveys of beginning teachers in New York City show that working conditions and specifically school administration are the most important determinant of teachers' career decisions.[26]

When surveying teachers in Massachusetts, researchers found that teachers who described their work environments as unsupportive were about five times more likely to leave their schools before the following year.[27] In the same study, teachers in supportive environments were not only more likely to stay at their schools, students in these schools also had higher math and science achievement scores. The specific characteristics that researchers found as being linked to these positive outcomes are tied to the social relationships found within the school, that is, the interactions and atmosphere found between teachers, administration and students.

School culture is a somewhat fuzzy concept. But researchers Susan Moore Johnson, Matthew Kraft, and John Papay have offered a helpful working definition of positive school culture. This includes:

- the extent to which teachers report having productive working relationships with their colleagues;
- the extent to which teachers report that their school leaders are supportive and create school environments conducive to learning; and,
- the extent to which school environments are characterized by mutual trust, respect, openness, and commitment to student achievement.[28]

Moore et al sum up an important part of their findings in the following way:

"It is surely important to have safe facilities, adequate resources, and sufficient time for preparation, but if teachers are to achieve success with their students—particularly low-income and high-minority students who rely most on the school for their learning—they also must be able to *count on* their colleagues, their principal, and the organizational culture of the school to make success possible."[29]

Focusing on these characteristics provides a clear direction for policymakers and school administrators, one that is often more actionable than addressing the issues of the crumbling infrastructure of American schools, the current structure by which we pay teachers, and persistent achievement gaps determined by zip code.

COUNTING ON EACH OTHER: WHY IT'S IMPORTANT AND WHAT IT MEANS

In a school environment that retains teachers and motivates them to stay, the quality of relationships–between teachers, administrators, building staff, and colleagues at other schools–matters a great deal. Relationships are dynamic. They must be cultivated and can be influenced by specific policies and practices.

SCHOOL LEVEL SUPPORT

Teachers, particularly those who are early in their careers, view face-to-face interactions with administrators as essential to their success.[34] Researchers have found that new teachers who identify their administration as "supportive" feel encouraged, believe they will continually improve in their career, want to remain at their current school, and are content with their decision to do so. In contrast, new teachers who experience inconsistent, unsupportive, abusive, or neglectful principals are more likely to leave their schools either to pursue another career or to teach elsewhere.[35]

Researchers Kathleen Brown and Susan Wynn of Duke University interviewed principals and found that those who retain teachers at a rate higher than that of their peers:

- have a keen awareness of issues affecting new teachers;
- take a proactive versus reactive approach in supporting new teachers; and
- commit to professional growth and excellence for themselves, their students, and their teachers (new and veteran alike).[36]

A SUPPORTIVE ADMINISTRATION BY JULIA RANKIN

M. Leon McKinley, my principal when I taught junior high in the Bloomfield Public School system in Connecticut, truly listened to and respected his teachers. He was student focused and very positive. He worked within the confines of his position to support those who would help bring his vision to fruition. He could not provide more money to his valued teachers, but he could give them better classrooms, access to more technology, permission to attend professional conferences and institutes, and an open schedule. He did anything within his power to better his students, his teachers, and his school.

I remember being at a meeting with Leon and four or five others in which he shared his new plan for the school. I sat and listened but could not offer my support. It just didn't seem to be a good program

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When principals and teachers are asked to define what support means, the ideas and practices they offer converge around creating a safe environment for teachers and schools to acknowledge their strengths and weaknesses, to air issues, and to grow. This does not always mean that every conflict or problem gets resolved, but rather that there is an opportunity and a forum to have open, frank and productive discussions within a school.

Quotes from principals illustrate this:

> *"Support means a lot of different things... discipline, organization, affirmation, resources, parents, teachers, curriculum, instruction.... Everything you do, I think, falls under the umbrella of support."* [37]

> *"I think we lose [teachers] because they become overwhelmed by it. I think it really depends on whether they have the support in the first couple of years to help them say, "This gets better. It does not always feel like this. Experience will make a huge difference. I know your heart is totally broken right now because that parent just yelled at you, but you're still doing good things. There are many parents that will like you, and you will have some others that will yell at you down the road, but it won't always feel like this when it happens because you're going to feel more confidence in yourself." There has to be that kind of real dialogue happening for them to know that they're not just star struck: 'Oh, my God. What did I get myself into? This is not what I thought it was going to be."* [38]

In our own interviews and discussions with teachers and principals, the theme of supportive school environments continually emerged. One elementary school teacher with five years of experience explained that a supportive principal serves as a good example and encourages teachers to support each other. "If your principal is listening to teachers, valuing their opinions in staff meetings and treating them like professionals, you are more likely to treat your peers the same way," she explained.

Another elementary school principal explained that supporting and retaining teachers goes hand in hand with an overall realistic attitude that teachers choose to be in a school, and may not always be there. Remembering this motivates this principal to create an atmosphere of respect and challenges her to meet each person's needs in a way that is appropriate for that person. She told us:

> *"We have to remember that what feels like support to some people can feel overbearing to others. We*

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for the school. I can't remember what the program was at this point, but I do remember clearly how Leon reacted when I went back to his office later that day and told him my concerns. My peers thought I was crazy. He already had it planned and was excited about it. But I knew he wanted the best approach for the school.

I met with him, gave him my opinion and then watched incredulously as he looked straight at me, the wheels turning in his head. I was not sure what he would say but knew he was thinking about what I had told him. "OK, Let's think about it," he responded. "How do you see it happening?" he then asked.

I had worked with several principals prior to Leon and was amazed and relieved. He wanted to be a success and knew that he had to respect his lead teachers to get the change he wanted. He knew the power of empowerment and shared leadership. The planning team later reconvened and devised a new plan. I will never forget that encounter or the respect I had for him after that.

Equally important was the opportunity he offered his staff to design their own professional development for the year. I was just reaching four or five years in the profession—the time when a lot of teachers decide to leave. Having the opportunity to think about and pursue my own career development was something I very much welcomed and appreciated. I went to Bloomfield with the intention of teaching for two years while working on my PhD dissertation. I ended up staying for 13 years, long after I had my PhD.

try to do day-to-day spontaneous observations of classrooms to provide a different perspective for teachers. Some teachers see that as support, while others are unnerved by it. For every teacher, we try to encourage an open and honest dialogue about what they find challenging. I enjoy those dialogues, whether or not I agree with a teacher's perspective or approach. In our school, we have a philosophy and consider it part of our job responsibility as administrators to grow these individuals. We try to give teachers an environment where they also continue to learn themselves. As teachers acquire new knowledge, they share it. We find that for our teachers, an awareness of themselves as learners makes them better teachers. I don't think you can expect someone to be happy for very long if they aren't growing themselves."

"Creating opportunities for teachers to interact and collaborate with their peers at their home schools as well as other locations is one of the main tools that principals can use to help teachers grow."

Creating opportunities for teachers to interact and collaborate with their peers at their home schools as well as other locations is one of the main tools that principals can use to help teachers grow. While this takes time and planning, it is well worth the investment. The extent to which teachers interact and collaborate with each other and with more experienced colleagues influences student classroom success and teacher retention rates.[39]

TEACHER-TO-TEACHER COLLABORATION

Research shows that beginning teachers who are able to collaborate with other teachers and attend new teacher seminars are less likely to change schools or leave the profession than teachers who do not begin their careers with these types of support at hand. One study compared new teachers who had access to collaborative relationships and new teacher seminars to those who did not. About one in five (21 percent) of those who lacked access to these experiences left the profession after one year and 18 percent changed schools. Among their counterparts who engaged in collaborative groups and seminars, 15 percent left the profession, and only 12 percent changed schools.[40]

Collaboration and interaction between new and veteran teachers can take a variety of forms. The form does not seem to be as important as the opportunity to engage and share information with teachers who have faced similar experiences, and to do so in a non-judgmental, low-pressure environment.

New teachers feel more satisfied and competent and perform better when they regularly interact with other teachers in this type of environment. Researchers have found that supportive environments help teachers recognize their interdependence, develop high work standards, and promote continuous learning by all. In contrast, in environments when teachers feel isolated and have weak professional communities, teachers are left to fend for themselves and find themselves competing rather than collaborating with colleagues.[41]

Another teacher talked to us about how working in an environment with few resources can be both a challenge to collaboration as well as a way to enhance it.

"When you don't have a lot of materials, you have two choices. You can become competitive with your colleagues, keeping what you have close to the vest–keeping any books, materials, curricula or knowledge you have a secret. Or you can decide to share it. The cues you get from your principal matter a lot in this regard. But if colleagues are able and have a great desire to share what they have, everyone benefits. The whole 'We are all in this together' attitude goes a long way."

One suburban physics teacher talked about the collaboration that results from his having to share his lab with other teachers.

"Our science department philosophy is that all of the courses should be taught in the same room. So all classes share the same lab space. That way we know we are consistent. We don't have to buy three sets of equipment. Another teacher and I can set up the labs together. We share our equipment. We share the effort. We share our lesson plans. The situation forces us to collaborate. There is less competition and much less isolation."

Despite the positive impact of having access to supportive peers, many beginning teachers find themselves starting out in isolated circumstances that provide little structure or opportunity to interact with colleagues.[42] For example, more than a quarter (28 percent) of school districts in North Carolina provide early career teachers with regular opportunities to collaborate with colleagues.[43]

"Teachers and schools can pursue collaborative opportunities in a variety of ways, formal and informal, on-site and virtual."

Teachers and schools can pursue collaborative opportunities in a variety of ways, formal and informal, on-site and virtual. Creativity in working within the structure of a given school and the reality of the school day are important. Teachers can participate in teacher workshops, ongoing small group discussions or instructional planning meetings with others. The research shows that even teachers who participate in these types of things intermittently feel they have a larger impact on students and are more likely to stay in their current positions. Networking of any sort, whether it be face-to-face or electronic, is extremely beneficial to teachers and is linked to increased retention.[44]

This is an area where the creative cooperation of individuals and institutions can achieve impressive results in developing formal and informal opportunities for teachers to gain support and professional development within and outside of their schools. A wide range of partners—among them schools, districts, members of industry, working scientists, universities, non-profits and cultural institutions—can work together in this capacity. Two of us, Meghan Groome and Julia Rankin, have considerable experience fostering these types of connections. Rankin in particular has been creating professional communities of practice, also known as professional learning communities, to enhance science teaching.

BUILDING COMMUNITIES THAT SUPPORT TEACHERS

For three years (2008-2011) Rankin coordinated the California Science Project Teacher Retention Initiative (CSP-TRI). The project focused on creating opportunities for collaboration and ongoing professional growth among science teachers as a way to reduce high attrition rates among California secondary science teachers.

CSP-TRI connected middle and high school science teachers from a wide variety of schools with working scientists, professors, and graduate students in professional learning communities (PLCs). Nine different colleges and universities participated in the project, offering intensive, content-focused professional development experiences.[i]

PLCs can be either school-based, or extended into the larger community.[45] The CSP-TRI project used the extended PLC model. The program created PLCs of varying types to match the attributes of the region and resources available. Participating teachers and university science professors collaboratively determined the year's agenda. All participating universities held summer institutes for PLC members and hosted on-campus retreats and special events. Some brought teachers together regularly to share and critique lesson plans and other course materials.

As teachers and scientists began to form collaborative communities with a shared vision and common goals, teachers began to feel empowered and professors began to understand what teachers needed and how to better assist them. At the same time, teachers shared their expertise in developing effective lessons and instructional strategies that could be applied to teaching their college courses. At many sites, more team teaching at the college level was encouraged. As the level of trust and respect increased within groups, professors began to change the way the professional development was organized and conducted based on teacher influence.

The Center for Teacher Quality (CTQ) conducted a longitudinal study of the program. They gathered data using three surveys over four years of 316 CSP-TRI PLC participants. They also did case studies at three of the nine sites to determine the effect of participation on retention and classroom skills. In studying CSP-TRI PLC participants, the Center for Teacher Quality found that "Relevance of professional development, perceived classroom effectiveness, and identifying as part of a CSP-TRI professional learning community" were all predictors of classroom retention.[46] Some of CTQ's specific findings include:

- Overall, teachers who participated in PLCs felt more confident about their teaching abilities, especially with regard to assessing student learning.
- In the study, teachers' confidence in their ability to assess student learning in science was associated with anticipated length of stay in teaching. The more confident teachers felt, the longer they anticipated staying in the profession.
- PLCs provided the most effective learning experiences and were viewed most positively by participants when they had the flexibility to pursue teachers' needs and to evolve their goals, practices and priorities accordingly.

i. The nine CSP-TRI PLC sites were: California Polytechnic at San Luis Obispo (Cal Poly SLO), the California State Universities of Chico (CSU Chico), Fresno (CSU Fresno), Humboldt State University (HSU) and Northridge (CSUN) and the Universities of California at Irvine (UC Irvine), Los Angeles (UCLA), Riverside (UC Riverside) and San Diego (UCSD).

- Teachers particularly enjoyed and benefitted from participating in shared decision-making, setting their own goals, and being respected as professionals. (See the section on "Science Teaching as a Profession" for perspective on the importance of these characteristics.)

- PLC participants were likely to work collaboratively with other teachers in their schools. CTQ found that beginning teachers highly valued the support they received through their PLC. Teachers benefitted from sharing strategies for how to meet the challenges of the classroom, organize their curriculum, plan lessons, and develop lab activities.[ii]

Developing relationships with working scientists was another important aspect of the CSP-TRI project. These interactions not only enriched classrooms, they kept teachers engaged and allowed them to further develop their skills. As the PLCs gained in strength at the various sites, several of the professors began to develop joint activities. Teachers and science faculty enjoyed joining colleagues from other PLCs and felt the experiences were enriching.

To reach the required number of participants, teachers of all levels were invited to join PLCs. This turned out to have a very positive impact on all involved. Less-experienced teachers valued the expertise of their seasoned peers. More experienced teachers enjoyed sharing their craft and learning new techniques and methodologies from younger colleagues. A similar effect occurred from bringing teachers together who had experience teaching at different grade levels.

The experience of the CSP-TRI project shows that PLCs can be a powerful support system to help retain teachers. But they only work if they are sensitive to the people within the group and are open to change as members fluctuate. To be effective, flexibility is key. PLCs must be responsive to the needs of the current members, and maintain a focus on improving teaching skills and student learning outcomes. They also need to draw on resources available within the surrounding community—such as scientists at nearby research facilities, professors at local colleges, support staff from cultural institutions or practitioners in the field.

As important as administrative support is within schools, it does not always happen. Some would say it rarely happens. Teachers can still find support outside of the school in a collaborative community that enriches their teaching experience. PLCs, if properly established and maintained, can have tremendous impact on teacher effectiveness, teacher retention and student learning.

ii. Research on elementary teachers shows that having even one teacher formally seek out a professional learning community or other network may benefit other teachers at their school. See Clement Jackson and Ellis Breugmann, "Teaching Students and Teaching Each Other: The Importance of Peer Learning for Teacher" (Cornell University School of Industrial and Labor Relations, Working, 2009) for a study of how students see larger gains in math and reading achievement when their teacher has more effective colleagues.

CONCLUSION AND RECOMMENDATIONS

Part of the solution to retaining STEM teachers involves influencing factors at the school and district level that affect workplace culture and create more supportive environments and extended networks with better collaboration and communication. Academic research and the feedback of individual teachers suggest that these "softer skills" have the potential to have significant impact on even the hard realities faced by teachers working in challenging situations.

When we propose focusing on workplace culture as a way to retain teachers and to develop their resilience and their talent, we do not mean it is appropriate to ignore other issues–such as crumbling infrastructures or drastic shortfalls in funding. These issues are real, but they are also not going away any time soon. In the meantime, schools and communities are places where individuals can work together, quite literally, to make important improvements.

" Part of the solution to retaining STEM teachers involves influencing factors at the school and district level that affect workplace culture and create more supportive environments and extended networks with better collaboration and communication. "

RECOMMENDATIONS

We chose the area of teacher retention and school culture as one where we could provide actionable policy recommendations for a set of stakeholders who include individual teachers, teacher educators, school leaders, and policymakers at all levels. Ideally, these recommendations could be enacted systematically. We believe incentives could be created to encourage a district to review their own policies and enact them in concert.

TEACHERS

- Where possible, STEM teachers should include school culture as an important factor when deciding to teach at a certain school. While many new teachers do not always have a choice in where they are posted (In fact, some teachers never get a choice in their posting), teachers can investigate school culture during the interview process so they are prepared for the conditions under which they will work. In the best case scenarios, principals and other teachers can emphasize school culture in their recruitment materials.

- If teachers are not finding the support they need, they can take steps to build a network of peers who can provide the support that is lacking in their schools. While many teachers may be isolated or not have peers in their schools or geographic areas, many professional organizations offer both in-person and virtual support options.[iii]

iii. The "Resources" section of the K-12 Education Program at the New York Academy of Sciences, found at http://education.nyas.org/teacher-resources/, is one place where teachers can go for information on these types of support options. Another example is the WISE Women in Science Education group at the Association of Science Teacher Educators (ASTE). See http://theaste.org/memberresources/.

- Teachers should look for opportunities to refresh and update their own understanding of STEM subjects, both within and outside of their area of expertise. These opportunities might include engaging in summer internships, participating in workshops, and pursuing links or collaborative projects with the scientific community.

- Teachers should understand the professional and personal rewards and risks associated with taking new positions outside of their current roles and work closely, if possible, with their administration to ensure a fluid transition between positions and organizations.

TEACHER EDUCATORS

- Teacher educators can make teacher networking and networks part of their teacher education programming. Incoming teachers should be taught about the value of a teacher network, learn how to activate and take advantage of their own network, and be encouraged to provide support for incoming new members of the network. Teachers should leave their preparation programs with an existing network that has been actively cultivated and used during the course of study.

- Teacher educators can also build virtual platforms using existing technology (i.e. LinkedIn, Facebook, etc.) that will link current students to alumni and endure through time and as teachers move geographically.

- Teacher educators can also incorporate longitudinal research components into their programs to understand who stays in teaching and to better link preparation and retention.

SCHOOL LEADERS

- It is difficult to provide the support teachers need when there is little support structure in how schools and districts are set up. At a time when we are trying to build STEM networks and opportunities, districts are reducing or eliminating science departments and support staff or combining them with other departments. Currently there is no dedicated director of science in New York City, Los Angeles and other major U.S. cities, a little known fact. New York City, for example, has not had a person solely designated as a leader of science since one of the authors (Rankin) left that position in 2007. Districts can reverse this trend by bringing in dedicated science leadership.

- School leaders can create structural changes that allow for teacher collaboration and incorporate elements of shared planning time, interdisciplinary study teams, and interdisciplinary project-based learning environments.

- Leaders should also regularly survey the level of satisfaction with the school and the professional development needs of the staff at the school

- In addition to the professional development opportunities presented to teachers, school leaders can provide opportunities for teachers to design or choose their own in collaboration with their peers at the school or within their network.

- School leaders can also choose or encourage professional development options that allow teachers to pursue topics that they are passionate about and will connect them more deeply into

their content area. School leaders can encourage and support teachers to find opportunities for experiences in science labs, summer research institutes, and other projects that connect them with scientists and professionals in their field.

- School leaders should also identify areas where they would like to receive professional development and build their own professional networks. One example of such a network is Urban Science Education Leaders (USEL), a group organized under the National Science Teachers Association.[iv]

POLICYMAKERS

- Policymakers can create evaluations and tests that incentivize excellent teaching, encourage teachers to think creatively about their practice and create porous borders between classrooms and STEM professionals and organizations.

- Policymakers can add the measurement of teacher retention to school accountability measures and offer incentives for districts and schools to focus on improvement in those areas.

- They can also continue to pursue policies that encourage high quality teachers to choose and stay at schools that need them the most.

- Policymakers can also seek opportunities to work with teachers, parents and other stakeholders to develop policies and practices to retain teachers.

EXTERNAL PARTNERS AND ADVOCATES

- These groups can continue to draw awareness to the importance of teacher retention among policymakers, parents, and the general public. In these lean economic times, emphasizing the costs associated with teacher turnover and the return on investment for teacher retention interventions makes a strong case for focusing on teacher retention.

- Universities, businesses, government agencies, and scientific and cultural institutions should encourage their faculty, staff and students to get involved with local teachers and to provide training and programs to help facilitate this. Examples include providing course credit for outreach, requiring community service hours for graduation, and adding outreach work as a factor in tenure and hiring decisions.

iv. Rankin initiated USEL in 2005 while Director of Science for New York City Schools with then Director of Science for Chicago, Michael Lach and past NSTA Presidents, Anne Tweed and Mike Padilla.

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