STEM Teachers in Professional Learning Communities:

From Good Teachers to Great Teaching

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NATIONAL COMMISSION ON
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The National Commission on Teaching and America's Future (NCTAF) empowers educators to transform their schools from teaching organizations into learning organizations that prepare today's students for 21st century college, careers, and civic engagement. With a network of state coalitions, and partnerships with school districts and professional education organizations across the county, NCTAF has been a leading voice for over a decade on what matters most for student learning: quality teaching in schools organized for success. For more information, visit: www.nctaf.org.

The research synthesis discussed in this executive summary is based on an NSF-funded project, *STEM Teachers in Professional Learning Communities: A Knowledge Synthesis* (grant DRL 0822013), conducted by NCTAF and WestEd. The opinions and recommendations presented here are those of the National Commission on Teaching and America's Future and do not necessarily reflect the position of the National Science Foundation.

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INTRODUCTION

STEM teaching is more effective and student achievement increases when teachers join forces to develop strong professional learning communities in their schools. This finding is supported by a two-year National Science Foundation funded study, *STEM Teachers in Professional Learning Communities: A Knowledge Synthesis* ("Knowledge Synthesis"), conducted by the National Commission on Teaching and America's Future (NCTAF) and WestEd, based on an analysis of nearly two hundred STEM education research articles and reports.[1] The finding further supports an earlier NCTAF report, released in 2010 with Pearson Foundation funding, that synthesizes research papers and projects documenting teacher learning team initiatives across all school subjects (See Box 1: *Team Up for 21st Century Teaching*).

These two studies place a capstone on a decade of teacher effectiveness research. We now have compelling evidence that when teachers team up with their colleagues they are able to create a culture of success in schools, leading to teaching improvements and student learning gains. The clear policy and practice implication is that great teaching is a team sport. Performance appraisal, compensation, and incentive systems that focus on individual teacher efforts at the expense of collaborative professional capacity building could seriously undermine our ability to prepare today's students for 21st century college and career success. Every school needs good teachers—but a school does not become a great place to learn until those teachers have the leadership and support to create a learning culture that is more powerful than even the best of them can sustain on their own.

These findings have significant implications for America's competitiveness in a global innovation economy. Student mastery in science, technology, engineering, and mathematics (STEM) is essential to our economic growth. But America's twenty-year decline in international science and mathematics standings tells us that we have serious challenges to overcome. Countries that persistently rank at the top of international measures of science and mathematics achievement do things differently. A growing number of reports indicates that one of their biggest advantages is in the clear, consistent, and coherent support systems they provide for teachers from preparation through induction to accomplished practice.[2]

Learning is no longer preparation for the job; it *is* the job. Today's students are preparing for a future in which they will invent and reinvent their work, team up to solve problems, develop new knowledge, and continuously acquire new skills. They need teachers who know how to create schools that look like the learning organizations they will work in for the rest of their lives.

Box 1

Team Up for 21st Century Teaching and Learning

The findings of the NSF Knowledge Synthesis confirm the findings of a previous NCTAF analysis released in 2010 with Pearson Foundation funding: *Team Up for 21st Century Teaching and Learning: What Research and Practice Reveal about Professional Learning.* (Key excerpts are found at http://www.nctaf.org/TeamUp.htm.) For the *Team Up* study, NCTAF examined lessons learned about learning teams across all levels and subjects of schooling. After reviewing hundreds of studies and research reports, we were able to identify six principles that make a learning community effective:

- **Shared values & goals**
- **Collective responsibility**
- **Authentic assessment**
- **Self-directed reflection**
- **Stable settings**
- **Strong leadership support**

The research section of the *Team Up* report contains articles that address learning teams through several lenses—the impact on personal practice, the factors present in successful Professional Learning Communities (PLCs) that last over time, and student outcomes on standardized tests. The five articles included in the research section of the *Team Up* study provide a strong evidence-based argument for the power of collaborative communities to improve teaching and learning.

Team Up also includes three case studies, written by practitioners that were selected by an advisory panel of experts. These cases put a face on learning teams of teachers working together not only to deepen their understanding of their students' learning, but also to find ways in which this learning can be enhanced.

That the findings of the *Team Up* study are corroborated by the NSF Knowledge Synthesis creates a powerful argument for the implementation of learning teams in education more broadly. (The complete tables of contents for both reports are located at the end of this report.)

To meet the needs of today's learners, the tradition of artisan teaching in solo-practice classrooms will have to give way to a school culture in which teachers continuously develop their content knowledge and pedagogical skills through collaborative practice that is embedded in the daily fabric of their work. Teacher collaboration supports student learning, and the good news is that teachers who work in strong learning communities are more satisfied with their careers and are more likely to remain in teaching long enough to become accomplished educators.[3] This report takes us one step further, summarizing the impacts of learning teams, particularly in STEM content areas, on teacher practice.[4]

OVERVIEW OF NSF KNOWLEDGE SYNTHESIS STUDY

HOW THE NSF STUDY WAS CONDUCTED

Completed in the fall of 2010, *STEM Teachers in Professional Learning Communities: A Knowledge Synthesis* was a two-year analysis funded by the National Science Foundation (NSF). For this study, NCTAF partnered with researchers in the STEM Program at WestEd to critically examine knowledge about learning teams of teachers in STEM subjects. The full NSF report is available on NCTAF's website: http://www.nctaf.org/documents/STEMTeachersinProfessionalLearningCommunities.AKnowledgeSynthesis.pdf.

Box 2

Methodology of the NSF Knowledge Synthesis

***Set criteria for inclusion and appropriate search terms*:** We searched over two dozen variants of "professional learning community" using Boolean logic to require that every obtained entry included terms related to STEM teachers.

***Included five types of research in our synthesis*:**

1. **Empirical research studies** published since 1995, mostly articles in peer-reviewed journals for primary research, or dissertations (Note: We conducted Standards of Evidence reviews of the methodological rigor of twenty-five of these empirical research studies.[5]);
2. **Other research, i.e., non-empirical research** (e.g., theory building), research-based articles in other than peer-reviewed journals, including recent conference presentations;
3. **Published expert knowledge and advice** in periodicals, professional development trade books, and advice about PLCs on Web pages;
4. **Published descriptions of models** of STEM teaching in PLCs, sometimes with "lessons learned" but without formal research; and
5. **Panel of practitioner experts** engaged in three rounds of questions posed in online surveys, with each round of written responses followed by online discussion sessions.

Our charge was to review and evaluate existing knowledge about STEM teachers in professional learning communities (PLCs), including both prospective teachers and classroom teachers across grades K-12. Our study's definition of "professional learning community" was inclusive, only requiring that the enterprise involve three or more teachers and be a sustained effort over time, rather than a one-time event. Learning communities can take many forms, are inspired by varied purposes, and function in different ways. However, they all share the general aim of focusing teachers on improving their practice and learning *together* about how to increase student learning.

Our guiding questions focused on the impacts of STEM teachers' participation in PLCs on:

- **Their content knowledge and pedagogical content knowledge;**
- **Their instructional practices; and**
- **Their students' achievement in STEM subjects.**

The NSF Knowledge Synthesis asked a standard research question: *What do we know?* But the study went further by also asking: *How well do we know it?* and *What else do we need to know?* As noted in Box 2, we began with a conventional literature search, but our Knowledge Synthesis then went much further. PhD-level analysts independently inspected the strength of each research study using thirty-one Standards of Evidence (SOE) that were developed by Horizon Research, Inc. through another NSF grant.[6] We also looked at published model descriptions of STEM learning teams, including research on their strengths, challenges, and "lessons learned" about designing and implementing them.

The NSF Knowledge Synthesis drew upon an unusually wide range of relevant knowledge sources: synthesis of research results, independent analysis of the research quality, published expert advice, model descriptions, advice from focus groups of experts, and STEM organizations' published policy recommendations and support statements.

The Knowledge Synthesis also included information beyond research studies. We examined published expert advice on designing and implementing STEM learning teams. In addition, we used an intensive focus group of experts to test the ideas and analyses we were developing. This allowed us to obtain up-to-the-minute advice from a group of STEM experts involved in professional development, administration, and research, all of whom had prior experience with multiple kinds of STEM learning teams. We also benefitted from the support of a group of distinguished experts who served as external advisors for the NSF grant. (See Appendix B: "List of Advisory Board Members and Expert Practitioner Panel.")

WHAT DOES THE NSF KNOWLEDGE SYNTHESIS TELL US?

STEM LEARNING TEAMS HAVE POSITIVE EFFECTS ON STEM TEACHERS AND THEIR TEACHING

Policy and STEM education organizations in recent years have put a premium on increasing individual teachers' content knowledge, e.g., *How well do mathematics teachers know their math? What evidence is there that learning teams can help teachers develop deeper subject matter knowledge?* Research studies and experts from the Knowledge Synthesis agreed that:

- **Participating in learning teams can successfully engage STEM teachers in discussions about the mathematics and science that they teach.**

Learning teams resulted in STEM teachers learning more mathematics and science and using more research-based methods for teaching them.

This seemingly basic finding is more important than it may appear. While it is considered a professional trait to continuously seek more knowledge, in reality it can actually be threatening for professionals even to acknowledge that there is something more that they should know or understand better. Teachers operating in traditional artisan isolation are often hesitant to discuss the content that they teach. PLC research, however, shows that building trust and openness in a learning team leads to a collaborative professional environment where STEM teachers can comfortably talk and learn about STEM content. Our Knowledge Synthesis further showed that STEM teachers in learning teams:

- **Understood the mathematics and science better; and**
- **Felt more prepared to teach mathematics and science.**

That is, they did not just *talk* about math and science content: they deepened their *learning* as well. Not surprisingly, teachers also indicated that they felt more prepared to teach mathematics and science. This occurred even among elementary school teachers, many of whom do not feel well prepared to teach mathematics and science.

Learning team participation can change what teachers *know*, but do teachers in STEM PLCs also go on to change what they actually *do*, i.e., *Does their instruction change?* The Knowledge Synthesis found that STEM teachers participating in learning teams improved their practice by:

- **Using more research-based methods for teaching mathematics and science (e.g., more use of student inquiry);**

- **Paying more attention to students' reasoning and understanding; and**
- **Using more diverse modes of engaging students in problem solving.**

Box 3:

Findings from the NSF Knowledge Synthesis on STEM Teaching in PLCs

STEM PLCs had the following effects on teacher knowledge, beliefs/attitudes, and focus:

- Engaged teachers in discussion about content knowledge or knowledge about how to teach it (pedagogical content knowledge), and/or enhanced their understanding of content knowledge and pedagogical strategies.
- Advanced teachers' preparedness to teach content, or attitudes toward teaching methods.
- Increased teacher focus on students' mathematics or science thinking.

STEM PLCs had the following effects on teacher instructional practice:

- Teaching practices became more "reform-oriented."
- Teacher attention to students' reasoning and understanding increased and teachers engaged students in more diverse modes of problem solving.

STEM PLCs had the following effects on students' science and mathematics achievement:

- Mathematics PLCs led to enhanced student learning or achievement in mathematics; however, there were no studies examining student outcomes in science.
- Increased science and mathematics achievement outcomes for students were reported by the expert panel based on unpublished results from PLCs they had led or independently examined.

Online tools are increasingly being used to support STEM PLCs:

- Research is limited, but promising, as to how online tools are extending the reach and resources of STEM PLCs.

Across STEM education professional organizations there was universal support for PLCs:

- Forty organizations in STEM education, professional development, or education policy had position statements and/or policy recommendations for PLCs that were universally positive.

STUDENTS OF TEACHERS PARTICIPATING IN STEM LEARNING COMMUNITIES LEARN MATH BETTER

Does increased teacher knowledge and improved instruction result in better student learning in STEM? We found the answer from published research especially promising in mathematics, and our expert panel confirmed this by drawing upon many unpublished local results.

We found six studies that were able to overcome the problematic methodological challenges for investigating links between learning teams and student achievement. All studies were of student mathematics achievement. This is likely, in part, because there are typically many more large-scale assessments in mathematics than in science. The good news is that every one of these studies showed positive effects for student learning of mathematics.

Our study's expert advisers, all of whom have designed and implemented learning teams, attested to finding increased student learning of mathematics and science in their experience and investigations. The panel strongly stated that learning teams can be an effective professional development model for all STEM teachers educating all types of students. PLCs can be particularly helpful for teachers in schools and districts that serve diverse student populations.

The published evidence about whether students learned STEM better is positive but just emerging, and only in mathematics; however, substantial local evidence likely exists of changes in students' mathematics and science learning.

It is important to emphasize that the research studies supporting these findings examined well-designed and well-implemented STEM learning teams that were created for the purposes of the research study and overseen by researchers for quality of implementation. However, "professional learning community" is a term encompassing a broad spectrum of activities, and no research claims can be made about what poorly designed or implemented learning community will accomplish. Our panel of experts certainly saw problematic learning community enterprises around the country.

Some experts noted, however, that even in "less than ideal" learning community designs and implementations, there were instances when the participants still felt there was profound value to breaking teachers' isolation by conferring, collaborating, and sharing strategies and plans for mathematics and science lessons.

ONLINE PLCs ARE A GROWING PHENOMENON

The typical model for a STEM PLC is a group of teachers working in the same school, either in grade level (in elementary schools) or curricular groups (as in high schools). Some PLCs also function across districts, with teams meeting face-to-face in afterschool, summer, or weekend workshops. However, the increased availability and flexibility of online platforms and tools make it possible to extend the work time and resources of face-to-face PLCs. Increasing numbers of STEM professionals now work together in virtual PLCs where they rarely, or never, meet in person. These online features support goals of PLCs in new and creative ways (e.g., sharing and analyzing student work through online files, observing other teachers' videotaped or live streaming lessons, and commenting in real time or through asynchronous discussion groups).

Given the rapidly evolving nature of online PLCs, the research base in this area is limited. Articles we reviewed and comments from the expert panel indicated that key components for effective online PLCs include:

- Skilled facilitators;
- Availability of collaborative online tools (e.g., interactive whiteboards, video/audio, text chat space, shared workspaces); and
- Stable and "user friendly" platforms.

UNIVERSAL SUPPORT FOR LEARNING TEAMS IN THE STEM COMMUNITY

To what extend does the STEM education community currently embrace the idea of learning teams? To answer this question, we examined policy or advice about learning teams published by over forty organizations involved in STEM education. (See Appendix D.) We sought out groups that are well-respected national nonprofit research and advocacy organizations with a specific focus on STEM, as well as those with a broader education reach that includes STEM.

In reviewing mission statements or policy positions regarding professional learning communities on the organizations' websites, we found that several organizations had created their own learning communities, many of which were online PLCs.[7] Others had published papers or books describing standards, models, and approaches for implementing learning communities.[8]

We did not find any opposition to the concept of STEM PLCs, but some cautioned against superficial notions and weak implementation of learning teams, which they suggested are less likely to yield substantial changes.

Box 4

Examples of STEM Organization Support for PLCs

Over 40 organizations were examined and 74 examples of published expert advice reviewed. Although some organizations that were searched made no statements regarding PLCs at the time of our review, those that did provide some discussion or statement about PLCs were all positive. Support for PLCs in STEM teaching took a variety of forms:

- ***Endorsement of teacher collaboration or projects focused on PLCs***
  Advocating for PLCs as a school change model, noting that PLCs positively affect teacher practice, school climate, teachers' perceptions of self-efficacy, and/or student achievement, usually based on research and/or field experiences.
- ***Statements on benefits of PLCs***
  Indicating that PLCs can encourage reflection on practice, improve pedagogy, and address content knowledge.
- ***Research and case studies about PLCs***
  Citing PLCs' positive effect teacher practice, school climate, perceptions of self-efficacy, and student achievement.
- ***Information for creating a PLC***
  How-to guides for creating PLCs, discussions of how teams should be formed to function best, and principles of effective PLCs.
- ***Instructional materials around content that PLCs could help implement***
  Suggesting that PLCs be used as a means to best support the use of these materials.
- ***Encouragement for members to participate in PLCs***
  Both the NEA and AFT encouraged members to participate in PLCs to improve pedagogical skills.
- ***Creation of PLCs for their membership and supporters***
  Most take place in an online setting.
  Common purpose for most is professional development.
  Several focus on leadership development and coaching.
- ***Advocacy for the implementation of PLCs in general***
  Although we were searching for STEM PLC advocacy, some organizations provided broad advocacy for PLCs across subject areas.

NEED FOR MORE RESEARCH, BETTER RESEARCH AND MORE VARIED RESEARCH

In depth, high quality research on PLCs and their evolution and impacts over time is needed. Given the nature of research grants, the published knowledge to date (research, advice, and models) overwhelmingly focuses on PLCs created as a part of a research study. While the in-depth Standards of Evidence analysis we conducted for our Knowledge Synthesis found the quality of individual empirical studies were generally judged as poor, similar concerns regarding methodological rigor have been found when inspecting research on other STEM education topics. The call for SOE inspections is a recent move by the field to raise the bar for appraising educational research; it is a conservative schema wherein a study's total rating becomes poor even if just one or a couple of features among the thirty-one examined standards is found to be weak. (See: *STEM Teachers in Professional Learning Communities: A Knowledge Synthesis,* Appendix D, for a detailed discussion of the SOE analysis.)

Few researchers have sought out STEM PLCs for study wherever they are found. We have not taken the pulse of the "naturally occurring PLCs" and their impacts. Many school districts likely are collecting evidence of the effects of PLCs (evaluations, if not research), and these, along with independent case studies as well as collections and analyses of such local existing evidence (for example, teacher research and published blogs), could be valuable sources of knowledge.

Because our synthesis draws upon a set of many studies, most of which were found to contain positive results on similar questions of interest, we regard their collective findings as substantial supporting evidence of the effectiveness of STEM PLCs. But there is much more work to be done.

THE IMPORTANCE OF DESIGN AND IMPLEMENTATION OF STEM LEARNING TEAMS

STEM learning teams that met high research standards for effectiveness had a number of key design and implementation principles in common. Except as noted, these principles were identified as critical in the *Team Up* study as well.

SHARED VALUES AND GOALS

Our expert panel ranked this as the most important factor and its value is affirmed by most researchers. Shared vision emerges from a collaboratively defined understanding of what constitutes worthwhile student learning, with all members of the PLC working together on problems around that common vision.

The team should clearly identify a STEM learning challenge around which the learning team can come together. As a foundation, learning teams should have a strong and steady focus on the ultimate goal of improving student learning. Teams should develop a shared vision and belief that all teachers and students can learn.

The Knowledge Synthesis suggests the design and implementation of effective STEM learning teams must address key features: shared goals and values, leadership support, issues of time and pacing, focus on student data and work products, collective responsibility for student achievement, good facilitation, and building trust.

LEADERSHIP SUPPORT

Teams need the support of principals and administrators. School leaders who give team members dedicated space and time to meet empower them to make decisions based on student needs. The leadership should foster a climate of trust while also providing appropriate catalysts to assure that teams meet and work together effectively.

TIME

Teachers need a common time to meet on a regular and sustained basis. It can take more than just a few weeks or even months to move a team that is unfamiliar with collaboration to open up in detail about deeper, substantive aspects of STEM teaching. Continuity is also important, since it takes time for the trust to be built and more time to build a common language, norms, and protocols that work for the particular PLC. Often, it is challenging to implement such scenarios in the prevailing U.S. school structure and policy culture, which places a heavy emphasis on individual teacher performance over teamwork. Additionally, the pressure for rapid outcomes too often trumps the time and trust necessary to develop effective learning teams.

USE OF STUDENT DATA AND WORK

Our panel of experts felt strongly that learning teams need to examine student data and work examples as a key focus and strategy of the team's work. As they do this work, it is important for them to adopt and use common rubrics and protocols to guide their examination of student work. The design and use of protocols, however, must be carefully considered and monitored lest the regulations become the ends instead of the means.

Learning team focus on student learning, and team members need to be comfortable working with a variety of authentic measures for gauging what students know and can do. Student work and assessment data are only pieces of the analysis. Another important way for teachers to understand what is working and why is through observing each others' teaching of specific lessons followed by reflective feedback.

COLLECTIVE RESPONSIBILITY

Team members should have shared and appropriately differentiated responsibilities. The orchestration of team member responsibilities should be based on content knowledge, pedagogical skill, and teaching experience. There should be mutual accountability for student achievement among all members of the learning team.

GOOD FACILITATION

Too often, there is a lack of recognition that facilitators have multiple roles. The research suggests that there are three important roles that facilitators need to fulfill: (1) facilitating knowledge, including helping to find relevant STEM or STEM education expertise if/as needed; (2) processing facilitation to attend to the structure and interaction of the groups; and (3) focusing facilitation to keep the group on target.[9] Facilitation—whether face-to-face, online, or a combination of the two—requires engagement, tact, careful "listening" to what is said and what is not said, as well as content and pedagogical knowledge. And it is important to remember that helping other adults (teachers) to learn is a different expertise than helping children to learn; that is, an expert teacher does not necessarily make an expert facilitator of a learning team.

TRUST

All of the above principles should work together to foster a sense of trust within the learning team, leading to members' being comfortable in reflecting on their own and others' work in an open and constructive environment. Members need to know that their school administrators support them in this honest reflection and that their team members are all working together to help each other improve student learning.

A SINGLE SCHOOL SUBJECT

This element was not addressed in the *Team Up* report, but it received considerable attention in the NSF Knowledge Synthesis. The latter study found that achieving a strong focus on the specifics of mathematics or science teaching is easiest when learning teams are comprised of teachers of one particular subject.

Although multi-subject PLCs were not as likely to delve deeply into each subject area, it is possible for teachers in cross-content teams to engage meaningfully in their subject content and pedagogy if they take additional time and adopt more complex strategies to support cross-disciplinary learning. At the elementary level, grade level teams can adopt specific school subjects as a focus of each learning team initiative. Conversely, they could also establish a learning team for a particular subject area (e.g., mathematics) that cuts across several elementary grades. At the middle and high school levels, mathematics and science departments could transform department meetings, which all-too-often are primarily administrative, into interdisciplinary learning team meetings. Larger schools may also be able to continue to support learning teams in more specific subjects, e.g., Life Science or Algebra.

Such scenarios are well established in some other countries. For example, U.S. researchers examining STEM teaching in Shanghai noted that every middle school mathematics teacher was involved in two math learning teams: one comprised of all teachers responsible for the same math subject and another comprised of mathematics teachers across all math subjects and grades in the school.[10]

MOVING FROM RESEARCH TO PRACTICE

NCTAF'S STEM LEARNING TEAMS

With these research principles in mind, NCTAF has, over the past two years, been engaged in developing "STEM learning teams" that work in "STEM learning studios."

NCTAF's STEM learning teams share the core competencies of trust, collaboration, and shared accountability for student achievement critical to all successful teams. In addition, STEM learning teams are intentionally cross-curricular. They engage science, math, and technology teachers who work together on a team to focus on ways they can enhance their STEM teaching as they build on the intersections across the content areas. Furthermore, in NCTAF learning studios, another key element has been added to the learning teams—participation by scientists and engineers from partner organizations in government, business and industry. These STEM experts work closely with teachers as together they design and implement project-based learning activities that address key student learning challenges identified by the teacher teams.

Including adjunct experts as fully participating members of the team broadens teachers' perspective, giving access to "real world" data, tools, and resources. Teachers have the opportunity to discuss projects with STEM volunteers prior to implementation, and the industry and government volunteers often work alongside the teachers when the projects are implemented in the classrooms. This goes far beyond the limits of the typical "drop-in" expert, who presents a lecture to an auditorium full of students and then leaves.

NCTAF has found that STEM business and government professionals want to apply their expertise and experience in structured and productive skill-based volunteering programs. Furthermore, with large numbers of STEM professionals nearing retirement and looking beyond their current jobs in government and industry, the learning studio model provides an opportunity for "hands-on" work with teacher teams and students that will become a pathway into possible encore education careers that will make a difference for today's youth.[11]

NCTAF launched its first STEM learning teams in 2009 with a NASA grant, in partnership with the NASA Goddard Space Flight Center and high schools in several Maryland school districts. As of Spring 2011, there are eight high schools in three school districts in Maryland, with several new high school and middle school teams under development. Activities typically begin in late spring with the selection of teams of approximately five teachers (e.g., math, science, and technology) in each of the participating schools. Learning teams composed of teachers in these schools identify learning challenges they will focus on with their students. STEM industry and government agency volunteers are then recruited as team members based on the expertise they can contribute to the topics and learning challenges identified by the teachers.

Learning team program implementation launches with a three-day summer workshop for all team participants, focused on building each team's skills in project-based learning and teamwork. This workshop also allows for initial planning of four inquiry-based project modules that address specific teaching and learning challenges the teachers identify within their core curriculum. The STEM volunteers work with the teacher teams during these studio design sessions in the summer as well as during quarterly design sessions during the school year. Typically, one module is taught per quarter though they vary in scope and length. Some teams choose to have one theme that carries across the entire school year, with all modules building on that theme, while others select different topics to address in each module.

An independent evaluation completed at the end of the first full year showed an almost immediate positive impact on both teachers and students.[12] Students reported substantially more opportunities to work collaboratively, across disciplines, and on projects that were more challenging and engaging; approximately three-quarters of students said that what they had learned in class helped them better understand the world around them. Teachers indicated similarly high degrees of satisfaction, reporting significant and positive changes in their own STEM content knowledge as well as in their ability to deploy project-based learning and work collaboratively on cross-disciplinary teams. Teachers gave high marks to the opportunities to interact with scientists and work in teams to plan activities. Building on these successes, NCTAF is expanding STEM learning studios with additional industry partners and districts.

OTHER MODELS

It addition to the above NCTAF initiative, there are a wide range of additional PLC models for STEM teachers currently in place throughout the STEM education community. The full report from our NSF study elaborates some of them in the section "Discussion of Models."[13] That discussion draws upon twenty-two articles, many of which describe research that offers insightful "lessons learned" about the design and implementation of one or more STEM PLC model in the U.S. or abroad. Most of the research reviewed in the Knowledge Synthesis describes relatively small projects that worked with a particular model in just a few PLCs, such as Matt Ellinger's research about a mathematics PLC for elementary teachers.[14] In contrast, Mayumi Shinohara and Kirsten Daehler describe one of the more widespread science PLC models, "Understanding Science," which has engaged 1,000 teachers in twenty states.[15] Finally, a book edited by one of our NSF Knowledge Synthesis advisors provides one of the most recent and extensive looks at a range of STEM PLC models.[16]

Further, a current Horizon Research, Inc. project, which previously provided the SOE analysis method for our project's analysis of empirical research studies, is now building upon our Knowledge Synthesis report to delve into specific questions about the design and implementation of various STEM PLC models. Researchers at Horizon and Education Development Center are exploring in depth the "wisdom of practice" held by experts who have deep experience with STEM PLCs, drawn particularly from the large community of researchers involved in NSF's program for Mathematics and Science Partnerships all across the U.S.[17]

IMPLICATIONS FOR FUTURE POLICY

The results of the NSF-funded Knowledge Synthesis, taken together with the Pearson-funded *Team Up*, make it clear that teachers working and learning together in teams are able to build the collective capacity that is necessary to create a culture of success that improves school performance and student achievement. This has significant implications for today's education policy debate, which focuses on individual teacher professional development, performance appraisal, compensation, and incentive systems at the expense of the collaborative professional teamwork that is necessary to meet the needs of today's learners. The media has us "waiting for superman"—the iconic teacher hero who can singlehandedly "stand and deliver" a better education for every child.[18] But ensuring that every child is well prepared for college, career, and life in a complex world is a challenge that goes far beyond the capacity of stand-alone teachers working in self-contained classrooms. To meet this challenge school leaders, teachers, and experts from industry and government need to join forces to create learning organizations that support more effective teaching, deeper student learning, and higher impact community engagement than any of them can achieve alone.

Professional development, performance appraisal, compensation, and incentive systems today focus on the individual teacher's effort at the expense of collaborative professional capacity building.

We have a once-in-a-generation opportunity to create an education system that will develop the innovators, entrepreneurs, and leaders our nation needs to thrive in a global community. To meet this goal, we need:

1. **School staffing policies that promote PLCs and the power of learning teams.**

    - Providing structured, stable **time and space** for teacher teamwork is essential to the success of a PLC. If teacher collaboration is to become the norm, rather than the exception, the design structure of the school day and the deployment of school staff needs to change.

    - Providing **embedded professional development** for PLC work**,** using outcomes of the PLC work as the basis for decisions regarding further staff development needs.

We have a once-in-a-generation opportunity to create an education system that will develop the innovators, entrepreneurs, and leaders our nation needs to thrive in a global community.

    - Creating **incentives** that recognize the **contributions of members of PLCs** to signal that the work of PLCs is a highly valued professional activity.

    - Creating **new roles for teachers** as trained PLC facilitators can provide leadership opportunities for current teachers, or part-time positions for effective teachers who might otherwise leave the classroom due to retirement, childcare responsibilities, or other personal priorities.

2. **Policies that engage principals and other school leaders in PLCs so that they become knowledgeable and effective learning team members themselves, and therefore effective leaders of PLC initiatives in their schools.**

3. **Policies that promote and support the use of online professional networking tools to strengthen and expand PLC work.**

    - Using **social networking** and **mobile technologies** to blend face-to-face and virtual learning teams in order to extend the time and resources for teachers to support and learn from one another.[19]

4. **Deeper research on PLCs to provide a more fine-grained analysis of the collaborative practices that improve teaching effectiveness and student learning.**

   - In-depth research, with tools like those deployed in the Standard of Evidence reviews, will help practitioners and policymakers build a case for the long-term impacts of professional learning communities on STEM teaching and learning.
   - At the same time, collecting and analyzing local data (both qualitative and quantitative) on "naturally occurring PLCs" will help ensure the implementation of effective models.

CONCLUSION

Improving teaching quality is the single most important investment we can make to prepare today's students for college and career success. But this need comes as states and school districts are struggling with dire reductions in funding. In the face of this fiscal reality, we need innovative ways to organize STEM teachers for better learning outcomes with a more cost-effective deployment of existing resources. The research we have today tells us that we can achieve this objective by enabling STEM teachers to team up for more effective teaching and learning.

ENDNOTES

[1] K. Fulton, H. Doerr, and T. Britton, *STEM Teachers in Professional Learning Communities: A Knowledge Synthesis*. Report supported by NSF grant DRL 0822013, awarded in August 2008 to the National Commission on Teaching and America's Future. The findings, opinions, and recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. (Washington, DC: NCTAF, 2011), http://www.nctaf.org/documents/STEMTeachersinProfessionalLearningCommunities.AKnowledgeSynthesis.pdf.

[2] E. Britton, *Roles of communities in mathematics and science teacher induction: Issues and international examples*. Working paper presented at the NCTAF Wingspread Symposium on the Induction of Mathematics and Science Teachers into Professional Learning Communities. Racine, WI (October 2007), http://www.nctaf.org/resources/events/documents/nctafbritton012908.final.pdf; See also: Linda Darling-Hammond, et al. *Professional Learning in the Learning Profession: A Status Report on Teacher Development in the United States and Abroad* (National Staff Development Council, Washington, DC, February 2009), http://www.learningforward.org/news/NSDCstudy2009.pdf; also: OECD, *Building a High-Quality Teaching Profession Lessons from around the world*, (Paris: OECD, 2011), http://www2.ed.gov/about/inits/ed/internationaled/background.pdf.

[3] T. Carroll & E. Foster, *Who Will Teach*? *Experience Matters*, (Washington, DC: NCTAF, 2010), http://www.nctaf.org/NCTAFWhoWillTeach.pdf.pdf; See also: MetLife (2009). *The MetLife survey of the American teacher: Collaborating for student success*. (New York: Metropolitan Life Insurance Company, 2010), http://www.eric.ed.gov/PDFS/ED509650.pdf.

[4] Note: Although there are myriad terms used to describe this kind of purposeful collaboration among teachers, for the sake of clarity in this report, we use synonymously the terms Professional Learning Community (PLC) and learning team.

[5] This analysis consists of an intensive 4-8-hour, PhD-level analyst inspection of each study against 31 standards of evidence (SOE) for study design, execution and reporting.

[6] D. Heck & D. Minner, *Technical report: Standards of evidence for empirical research,* (Chapel Hill, NC: Horizon Research, Inc., 2010), http://www.mspkmd.net/papers/heck_minner_oct2010.pdf.

[7] See, for example, http://www.iteaconnect.org/Networking/learningcommunities.htm.

[8] See, for example, S. Mundry & K. Stiles, eds., *Professional learning communities for science teaching: Lessons from research and practice.* (Arlington, VA: NSTA, 2009); See also: http://www.learningforward.org/standards/learningcommunities.cfm; or http://www.ascd.org/professional-development/oscb/plc-booklets.aspx.

[9] D. Slavit, T.D. Holmlund Nelson, & A. Kennedy, *Perspectives on supported collaborative teacher inquiry*. (New York: Routledge, 2009).

[10] L. Paine, Y. Fang, & S. Wilson, "Entering a culture of teaching: Teacher induction in Shanghai," In *Comprehensive teacher induction*, E. Britton, L. Paine, D. Pimm, & S. Raizen, (San Francisco: Kluwer and WestEd, 2003), pp. 20-82.

[11] T. Carroll & E. Foster, *Who Will Teach*? *Experience Matters*, National Commission on Teaching and America's Future, (Washington, DC, January 2010), http://www.nctaf.org/NCTAFWhoWillTeach.pdf.pdf. See also: E. Foster, "How Boomers Can Contribute to Student Success," (Washington, DC: NCTAF with Civic Ventures,

2010),
http://www.nctaf.org/resources/research_and_reports/nctaf_research_reports/documents/ElizabethFoster-HowBoomersCanContribute.pdf.

[12] ICF MACRO, "21st Century Learning Teams, Interim Evaluation Report" (Calverton, MD: ICF MACRO, July 2010),
http://www.nctaf.org/resources/demonstration_projects/documents/NASA21stCenturyLearningTeamsYear1Evaluation.pdf.

[13] K. Fulton, H. Doerr, & T. Britton, *STEM Teachers in Professional Learning Communities: A Knowledge Synthesis*. (Washington, DC: NCTAF, 2011).

[14] M. Ellinger, "Increasing elementary teachers' fundamental math content knowledge and developing a collaborative faculty," *Teachers in professional communities: Improving teaching and learning*, Anne Lieberman Lynne Miller, eds. (New York: Teachers College Press, 2008), pp. 73-84.

[15] M. Shinohara & K. Daehler, "Understanding science: The role of community in content learning," In A. Lieberman & L. Miller (Eds.), *Teachers in Professional Communities: Improving Teaching and Learning*. (New York: Teachers College Press, 2008), pp. 85-96.

[16] D. Slavit, T.D. Holmlund Nelson, & A. Kennedy, *Perspectives on supported collaborative teacher inquiry*. (New York: Routledge, 2009).

[17] I. Weiss, B. Miller, & J. Pasley, "Designing PLCs for enhancing student success: What do we know, and how can we learn more?" Paper presented at an annual meeting for NSF Mathematics and Science Partnerships (January, 2011).

[18] *Waiting for "Superman,"* D. Guggenheim, dir., (Walden Documentaries & Participant Media, 2010); *American Teacher*, V. Roth & B. McGinn, dirs., (The Teacher Salary Project, 2011). *Stand and Deliver*, R. Menéndez, dir., (Warner Bros., 1988).

[19] See, for example, NCTAF's Teachers Learning in Networked Communities (TLINC) project, funded by the U.S. Department of Education's Fund for the Improvement of PostSecondary Education, and TLINC 2.0, funded by Qualcomm, http://www.nctaf.org/resources/demonstration_projects/t-linc/index.htm.

LIST OF APPENDICES

APPENDIX A: REFERENCES

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Note: For a complete list of references for the full *Knowledge Synthesis* report, visit: http://www.nctaf.org/documents/STEMTeachersinProfessionalLearningCommunities.AKnowledgeSynthesis.pdf, Appendix A.

APPENDIX B
ADVISORY BOARD MEMBERS AND EXPERT PRACTITIONER PANEL

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APPENDIX C
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APPENDIX D
ORGANIZATIONS SEARCHED FOR PLC STATEMENTS

STEM Overall

- American Institutes for Research
- Biological Sciences Curriculum Study
- Education Development Center
- National Science Foundation
- Partnerships for Effective STEM Education
- SRI International
- STEM Education Caucus
- STEM Education Coalition
- TERC

Mathematics Education

- Association of Mathematics Teacher Educators
- National Council of Teachers of Mathematics

Science Education

- American Association of Physics Teachers
- American Chemical Society
- Association of Teachers of Science
- National Association of Biology Teachers
- National Earth Science Teachers Association
- National Middle Level Science Teachers Association
- National Science Teachers Association

Technology/Engineering

- International Technology Education Association

Educational Technology

- Computer Science Teachers Association
- International Society for Technology in Education
- Society for Information Technology and Teacher Education
- State Educational Technology Directors Association

Professional Development

- Association for Supervision and Curriculum Development
- Learning Points Associates
- National Staff Development Council (known as “Learning Forward” at time of print)
- SEDL
- West Ed

Policy/General

- Achieve
- All Things PLC
- American Federation of Teachers
- Center for Teacher Quality
- Council of Chief State School Officers
- Education Commission of the States
- National Comprehensive Center for Teacher Quality
- National Commission on Teaching and America’s Future
- National Education Association
- National Governor’s Association
- PBS Teacher Source
- Teacher Leaders Network

Publications

- *Phi Delta Kappan*
- *Education Week*

APPENDIX E
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