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Opening the Classroom Door: Professional Learning Communities In the Math and Science Partnership Program

This article highlights examples of professional learning communities (PLCs) in the National Science Foundation (NSF) Math and Science Partnership program.

Students come marching into the classroom and take their seats … the bell rings … the teacher closes the door and thinks, "This is my time with the kids. I have a lesson plan that I prepared, and they'll learn what I have to offer." The teacher never talks to other teachers about what to teach or how to teach, and the only time that anyone visits the classroom is when an administrator comes to evaluate the teacher once a year.

Although such a reality typified many classrooms in the 20th century, in the 1990s and the first decade of this 21st century, a new exemplar of K-12 teacher professional development has evolved—the professional learning community (PLC). This paper looks at how PLCs have become an operational approach for professional development with potential to de-isolate the teaching experience in the fields of science, technology, engineering, and mathematics (STEM). We offer a short synopsis of the intellectual origins of PLCs, provide multiple examples of PLCs employed in projects funded by the National Science Foundation (NSF) through its Math and Science Partnership (MSP) program, and consider benefits for varied aspects of the teaching and learning environment.

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Origins

Much has been written about PLCs. Fuller histories are available elsewhere (e.g., see Feger & Arruda, 2008), and countless articles and synopses are found online. The term 'learning community' began to enter the educational vernacular broadly in the early 1990s, following the publication of Peter Senge's book *The Fifth Discipline* (1990). Senge's philosophy called for a radical restructuring of business management strategies. The purpose of this restructuring was to transform corporations into *learning organizations*. Learning organizations were characterized by a shared vision among employees and management with team learning through group discussion of goals and problems. The concept of an environment in which "people are continually learning how to learn together" (Senge, 1990, p. 3) caught fire in the educational world.

Soon, the term was modified to 'learning communities' as educational practitioners and researchers began to create a collection of literature on this topic (Hord, 1997a, 1997b; Senge et al., 2000). In this period, Richard DuFour and Rebecca DuFour, along with an array of collaborators, became broadly influential as they popularized the term 'professional learning communities' and edited the seminal book *On Common Ground: The Power of Professional Learning Communities* (DuFour, Eaker & DuFour, 2005). Today, PLCs are used to describe a variety of circumstances that include bringing administrators and teachers together into discussion groups, envisioning the classroom environment as a community, and enhancing the classroom experience by including the broader community. Moreover, STEM educators have not been absent from the work with PLCs, and this is captured well in a recent volume edited by Mundry and Stiles (2009).

While educators in the United States exhibit a growing enthusiasm for participating in PLCs, it is interesting to recognize that educators across the globe already identify collaboration with peers as a common mode of practice (Wong, Britton & Ganser, 2005). Perhaps the strongest example of a learning community is the cultural norm among Japanese teachers to participate in lesson study groups as described, for example, by Stigler and Hiebert in *The Teaching Gap* (1999). Acculturating new teachers into learning communities is also well-developed in nations outside of the United States. As Britton notes, "Although all teachers in Shanghai and Japan participate in learning communities, beginning teachers receive particularly essential help from participating in them at the outset of their practice … What we observed in Shanghai and Japan contrasts with what we saw generally in the U.S. We have noticed places where lesson study groups exist as professional development for experienced teachers, but beginning teachers often are omitted" (2007, p. 9). To overcome this reticence on the part of American educators, the National Commission on Teaching and America's Future (Fulton, Yoon & Lee, 2005) has adopted recommendations that new teachers become deeply engaged in learning communities during the induction phase of their careers. Such efforts are meant to address the observation noted by Wong, Britton, and Ganser that "isolation is the common thread and complaint among new teachers in U.S. schools. New teachers want more than a job. They want to contribute to a group" (2005, p. 384).

As the notion of PLCs has entered the mainstream, concerns about the fundamental definition of the term have emerged. DuFour notes that "the term has been used so ubiquitously that it is in danger of losing all meaning. The professional learning community model has now reached a critical juncture, one well known to those who have witnessed the fate of other well-intentioned school reform efforts. In this all-too-familiar cycle, initial enthusiasm gives way to confusion about the fundamental concepts driving the initiative, followed by inevitable implementation problems, the conclusion that the reform has failed to bring about the desired results, abandonment of the reform, and the launch of a new search for the next promising initiative" (2004, p. 6). Michael Fullan identifies several "reasons to be worried about the spread of professional learning communities. First, the term travels faster and better than the concept. Thus we have many examples of superficial PLCs—educators simply calling what they are doing professional learning communities without going very deep into learning and without realizing they are not going deep … Second, people make the mistake of treating professional learning communities as the latest innovation. Of course in a technical sense it is an innovation to the people first using it, but the moment you treat it as a program innovation, you run two risks. One is that people will see it as one innovation among many—perhaps the flavor of the year, which means it can be easily discarded once the going gets rough and as other innovations come along the following year" (2006, p. 10).

The Math and Science Partnership program

Launched in 2002, the Math and Science Partnership program at the National Science Foundation is a research and development effort to build capacity and integrate the work of higher education, especially its STEM disciplinary faculty, with that of K-12 to strengthen and reform mathematics and science education. Ultimately, the MSP program seeks to improve student achievement in mathematics and science for all students, at all K-12 levels. MSP projects are expected to incorporate creative, strategic actions that extend beyond commonplace approaches in order to improve the depth and quality of K-12 mathematics and science education. A primary goal of MSP projects is to develop and embellish strategies that deal with issues of teacher quality, quantity, and diversity. Because the preparation and diversity of future teachers is also of concern, many MSP projects strive to improve undergraduate and graduate education for those seeking to enter the teaching profession.

The first call for proposals, MSP Solicitation 02-061, remarked that "teachers require support throughout the professional education continuum from recruitment, through preparation, induction and continued professional development in order to create and sustain an excellent teaching force" (NSF, 2002). Proposals were encouraged to offer solutions that would "[s]trengthen the mathematics and science teaching profession, especially in underserved areas, through (a) recruitment of qualified individuals to become teachers, (b) preparation of future teachers in significant content and pedagogy, (c) support of the teacher certification process, (d) policies that impact where teachers are employed, (e) induction into the field, and (f) continuing professional development." It is noteworthy that in 2002, and even in later years, PLCs were emphasized as a significant strategy for engaging K-12 teachers and higher education faculty in only a few proposals, including those that succeeded through the merit review process and thus were awarded funding. This has been true even though the intent of the MSP program is to forge partnerships among individuals and institutions.

However, as MSP-funded projects began to unfold and add to their repertoire of strategic interventions, it became clear at conferences of the MSP community and in early pre-publications from project investigators that PLCs have become a relatively common vehicle for professional development. Most often, PLCs have been implemented as school-based communities of teachers with a common purpose for their professional development, and they often also include higher education STEM and education faculty. PLCs occur in many of both the mathematics-focused and the science-focused projects of the MSP program, and with well over 100 MSP projects awarded to date, it is clear that STEM PLCs are new exemplars of professional development in the lives of thousands of teachers. This article discusses several examples—made available by investigators and staff—of science-focused MSP projects from across the nation.

North Cascades and Olympic Science Partnership (NCOSP), led by Western Washington University

During the first three years of the project (2003-2006), the NCOSP focused on developing a highly competent cadre of approximately 160 teacher leaders by increasing their knowledge and skills concerning: (a) science content, (b) considerations related to effective science teaching and learning (Bransford, Brown & Cocking, 1999), (c) tools for effectively structuring collaborations among teachers that aid in improving student learning (such as Lesson Study, Curriculum Topic Study, Formative Assessment Probes, and Looking at Student Work Protocols), and (d) strategies to develop effective professional learning communities (Garmston & Wellman, 1999). The teacher leaders were given opportunities to practice leadership through presenting, facilitating, coaching, and consulting with teachers.

Subsequently, in Summer 2007, 105 out of the 160 NCOSP teacher leaders involved in the project expanded the scope of the partnership by developing PLCs within their respective schools. Each teacher leader collaborated with higher education faculty and other teacher leaders for one week in July to develop three-day professional development activities that met the initial needs of his/her school-based PLC. Using what they had learned during their first three years with NCOSP, the teacher leaders focused their initial three-day professional development events on developing teachers' science content knowledge and understanding of the ways in which people learn. During the 2007-08 school year, most of the PLCs used Curriculum Topic Study, Formative Assessment Probes, and Looking at Student Work Protocols in a coherent sequence to better understand students' thinking and determine ways to improve classroom instruction and student learning in science. In the Summer of 2008, the teachers from the PLCs attended a week-long content immersion in physical science while their teacher leaders and administrators worked on developing an action plan to guide the work of the PLCs during the 2008-09 school year.

NCOSP examined the PLCs' working processes and impacts on teachers in order to obtain formative and summative evaluation data that the partnership could use to make programmatic decisions and that the PLCs could use to improve their foci and practices. Multiple methods were developed and used, including a *Professional Learning Community Observation Protocol* and a *School Capacity for Improvement—Survey of Science*.

A case study of one of the NCOSP schools illustrates the process through which a PLC became a key school advisory board. During the 2007-08 school year, the NCOSP teacher leader "Conny" provided leadership for the science PLC at an elementary school in rural northwest Washington State. The PLC included one teacher representative from each grade of the K-5 school. The principal participated in a few PLC meetings but mainly supported the work of the PLC by providing the teachers time to meet as a group. During the initial three-day professional development event that Conny developed and led for the teachers in the PLC in August 2007, she shared NCOSP tools and resources, made the case for science reform with a Minds of Our Own video, discussed the research on *How People Learn*, and had the teachers participate in a one-day content immersion on light. During this first professional development event and over the course of the school year, the PLC teachers were very willing to explore new content and their own misconceptions in order to develop further their content knowledge in science. They quickly determined their goals for the year and initially focused on overcoming the limited amount of science being taught at the school.

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The school already had FOSS science kits (see <www.fossweb.com>) available at each grade level, so the PLC recommended to the principal that science be reintegrated in the school by requiring that each K-5 teacher implement one FOSS kit per year. Conny, as the school's science specialist, would teach a second FOSS kit at each grade every year. As the FOSS kits began to be used fully, thus increasing the amount of time devoted to teaching science, the PLC shifted its focus to work on improving classroom assessment and grading in science, and began exploring ways to improve teachers' ability to assess students' understanding through the use of science notebooks, formative assessment probes, and questions similar to those on the statewide assessment that would better prepare students for these exams. In the spring of 2008, the school decided to deepen its emphasis in science by having a building-wide science fair in which the lower elementary students presented their results from whole class science projects and the upper elementary students shared their individual or group science projects. This inaugural science fair brought together teachers, students, parents, and community members at the school one evening in May. By this time, science appeared to permeate all aspects of the school. As the principal wrote in a school newsletter to all staff and parents, "I am not kidding when I say science is the bedrock subject that we hang all of our teaching on, we know science rules and we want our children to think like scientists."

The PLC had become a key advisory body in the school because they had the support of the principal and had structured the PLC so that each grade was represented and the role of each teacher representative was to facilitate the sharing of information between the PLC and the grade level teams. The group had made a lot of progress in increasing the amount of science instruction. Although it is difficult to make a direct attribution, the percentage of 5th grade students proficient on the state science assessment increased by 19.6% following the increase in science instruction that took place during the 2007-08 school year. This finding encourages the continued use of PLCs to increase emphasis on and awareness of teachers' roles in teaching and assessing science.

Boston Science Partnership (BSP), led by the University of Massachusetts - Boston

The BSP employs a professional learning community model called Collaborative Coaching and Learning in Science (CCLS). CCLS is adapted from a model originally developed for the Boston Public Schools to support teaching of literacy. In the CCLS model, a group of 3-8 science teachers in a building meets once or twice per week for an 8-16 session cycle. Each group is led by a teacher and supported by an "apprentice facilitator," both of whom receive training from the Boston Public Schools Science Department. A full CCLS cycle includes a course of study about science teaching and learning chosen by the participants, research, observations and debriefs, a review of student work, and reflective documentation. Recent topics have included writing in science, using notebooks, assessing student understanding, using evidence to support claims, student misconceptions, and analyzing standardized test results. CCLS groups were designed to have a greatly reduced dependence on external staff resources than the groups in the original Boston literacy model. To accomplish this, Boston Public Schools Science Department staff members spend much of their time providing specific on-site support to CCLS groups as needed, including co-facilitating and/or providing quarterly training sessions for teacher facilitators. Three part-time staff members support 30-35 CCLS groups each year. As a result of these efforts, some CCLS groups have successfully become independent, self-sustaining communities.

CCLS is an extremely flexible and adaptable model that includes the ability to address a particular mission of the school or district. CCLS has changed the nature of how teachers teach and reflect on teaching and learning science. This was accomplished by providing a context and culture that supports on-going, research-informed, in-depth conversations about science teaching and learning. The external evaluation, which consisted of observations, surveys, and interviews of participants, administrators, and district staff, found changes in teachers' feelings about their effectiveness in the classroom as well as a change to the overall community of science teachers across Boston. CCLS was shown to expand teachers' knowledge of the science curriculum, advance an atmosphere of professionalism, and raise awareness among teachers and administrators of the resources available from the district's science department. Teachers also reported learning about and implementing new teaching strategies, focusing more on student success and student understanding, and gaining content knowledge. By the spring of 2010, the BSP will have findings that look at student outcomes as a function of teacher participation in CCLS; however, the formative evaluations, feedback from participants, and informal observations indicate that there have been important changes to the community of science teachers in Boston. Teachers feel they have support and connections across the district. They are familiar with their peers' teaching and are known by their peers. They have a structured format in which to talk about teaching and learning in science. Teachers at all stages of the professional continuum can participate equally. Furthermore, opportunities for professional growth and recognition, such as the facilitator and apprentice facilitator positions, are made convenient through the training and support. Participation in the BSP (CCLS and other programs) is a statistically significant contributor to teacher retention. CCLS provides an incentive to remain in Boston by supporting a vibrant community of practice. A core group of teacher leaders in the district, many of whom were first recruited through CCLS, even formed a monthly science social rotation that is hosted each month by teachers from a different school. The socials have continued for two years now, and 50 to 100 science teachers from across the district, as well as STEM faculty and BSP project staff, typically attend each social. Teachers credit their desire to remain in the school district to the professional atmospheres of their schools and the cohesive learning communities they have formed.

BSP evaluators have found that there are several characteristics common to successful CCLS groups. These include: 1) support by school administrators, 2) a course of study chosen by the teachers participating in the CCLS group and alignment of that course of study with the school's mission, 3) a sincere desire by teachers to participate and development of trust among the teachers in a CCLS group, 4) effective facilitation and clear structure in CCLS meetings, 5) authentic feedback offered by peers that includes both praise and challenges with discussions that focus on improving teaching practice, and 6) recognition by participants of connections between the chosen course of study and the lessons observed. Implementation of CCLS has also included challenges that mirror most of the common characteristics. Three key contextual considerations emerged as the most critical factors necessary for successful implementation of CCLS: 1) at least a minimal level of administrative support, 2) a trained facilitator with the ability to effectively lead a CCLS group, and 3) the prior existence of a moderately well functioning science program in the school. Lastly, it is critical that someone with an understanding of high-quality instruction is a facilitator or participant in the group in order for high quality and productive conversations to occur.

Institute for Chemistry Literacy through Computational Science (ICLCS), led by the University of Illinois - Urbana-Champaign

A significant component of ICLCS, which is now entering its fourth year, has been the use of the *Virtual Professional Learning Community (VPLC)* to support rural high school chemistry teachers who reside in different geographic areas across Illinois. Among the ICLCS Fellows, i.e., the teachers participating in ICLCS institutes, 24% are the only science teacher in their small district. The project has used Moodle, an open-source course management application, as a platform for a vibrant, active learning community in which the emphasis is on learning and the purpose of professional development is student achievement. ICLCS Fellows partner with University of Illinois faculty, students, and researchers as equals to improve student achievement. The total of 44,712 logins (June 2007-May 2009) and 16,428 postings among 100 Fellows, faculty, and ICLCS staff shows that the VPLC has become a powerful tool in the continued professional development of ICLCS Fellows.

The flexibility in time and space provided by the asynchronous communication of the VPLC is important, because it 1) allows for in-depth investigation and analysis of discussion topics, which promotes deep thinking/learning, and 2) creates opportunities for more teachers and faculty to participate in the same discussion session, which enhances collaboration and social interaction. It also effectively creates a network of experts and peers who communicate regularly. Through the use of social network analyses, the interwoven web of communication is being further studied over the remaining years of the project as ICLCS continues to gather longitudinal data on the VPLC. However, there are definite indications of early success. As one Fellow noted, "[t]he networking with others in my field has meant a great deal to me. I have taught chemistry in Illinois for over twenty years and knew virtually no other chemistry teachers. Now I have a HUGE network of fellow teachers I can use for support and resources."

The project implemented a randomized selection research design to measure the impact of ICLCS strategies on students in participant classrooms. Over the past two years, ICLCS has observed a significant difference in achievement between students of Cadre I teachers (treatment group) and those of the control group (Cadre II). The Cadre I Fellows had completed a full year of professional development, including participation in the VPLC. In the following year, using an American Chemical Society standardized test, ICLCS found that students of Cadre I teachers had a 45% greater gain in terms of content acquisition than students of the Cadre II teachers. ICLCS staff is continuing to examine these trends and the VPLC at large in order to understand the impact of its interventions on teacher learning and student achievement.

Project Pathways, led by Arizona State University

In their original design, Pathways staff included PLCs as part of the intended plan. However, the project team initially underestimated the support that teachers in PLCs would need to shift their instruction to have a primary focus on student thinking and learning while utilizing inquiry as a primary mode of instruction. Pathways also did not anticipate the many school-based obstacles that emerged during its effort to establish PLCs in the schools. Over the past four years, the Pathways PLC research team has utilized qualitative methods to code videos of PLC meetings in order to identify the essential attributes of highly effective content-based PLCs.

The Pathways PLCs are composed of 3-7 teachers who teach the same course. These teachers meet weekly to discuss issues of knowing, learning, and teaching the ideas that are central to that course. The PLCs are initially structured with an agenda that aids the facilitator in promoting meaningful reflection and discourse among all members of the PLC. In the absence of a PLC facilitator who holds teachers to high standards for verbalizing the processes involved in knowing, learning, and teaching content, Pathways research has revealed that PLC discussions tend to be superficial and teachers make little progress in shifting their classroom practices (Carlson, Moore, Bowling & Ortiz, 2007). As a result, Pathways PLCs currently designate a lead teacher to serve as a facilitator. All facilitators within a school attend a four-day facilitator training workshop and weekly coaching meetings that are designed to support them in learning to guide the PLC conversations so as to assure that teachers "speak meaningfully" about the processes involved in knowing and learning the content (Clark, Carlson & Moore, 2007). If a teacher is vague in expressing what it means to understand, learn, or teach an idea, the facilitator is responsible for posing questions that will encourage members of the PLC to express clearly ideas about the issue under discussion. A good facilitator must have strong content knowledge about the subject area that is the focus of the PLC. The facilitator must also be interested and able to inquire into the thinking of other members of the PLC. This requires the facilitator to be a good listener who is able to make sense of the meanings conveyed by others (Carlson, Moore, Bowling & Ortiz, 2007).

Pathways researchers have found that before teachers are ready to develop new lessons to improve the teaching of specific ideas, they must first inquire into: 1) student thinking relative to these specific ideas, 2) the processes involved in learning the specific ideas, and 3) the degree to which their students are currently learning about the specific ideas. In the most recent iteration, Pathways found that after one year of meeting weekly in PLCs that emphasized content, the teachers were ready for extended work in the summer that prepared them to make substantive shifts in their curriculum, assessments, and pedagogical approaches. At this stage of their development, the teachers also express willingness to videotape their new lessons and present video clips from their classrooms as artifacts for discussion with other members of their PLC.

Additionally, the Pathways team has found that the school principal and STEM department chairs are critical to the institutionalization of PLCs within a school. For the purposes of institutionalizing PLCs, desirable qualities of a principal include: 1) willingness to rearrange schedules to accommodate content-focused, school-based PLCs for one hour during the work week, 2) support of inquiry-based and conceptually-oriented teaching, and 3) willingness to work through logistical obstacles to facilitate participation by all teachers' in the workshop or course and weekly PLC meetings. The researchers have concluded that shifts in secondary mathematics and science teaching practice are achieved when teachers have opportunities to re-conceptualize and revise their curriculum and instructional practices to align with inquiry-based instruction. Research on the practices of secondary mathematics and science teachers has revealed that teachers' images of teaching and curriculum are deeply rooted in their experiences and that often these experiences have been predominately stand-and-deliver, procedurally-oriented instruction. Because of their deep rooted beliefs about teaching and learning and previous experiences, teachers typically need an external support system in addition to more developed content knowledge in order to realize substantive shifts in their classroom practices[1].

Vertically Integrated Partnerships K-16 (VIP K-16), led by the University System of Maryland

VIP K-16 has brought together several Maryland institutions of higher education and high schools in the Montgomery County (Maryland) Public Schools district in order to promote inquiry-based learning in the sciences, both in high schools and at the undergraduate level. Learning communities became the commonly accepted strategy for teachers and faculty to exchange information, interact and observe instruction, share research endeavors, reflect on teaching practices, and reform curriculum at all levels. Although several PLCs included only faculty or only high school teachers (usually because of geographical limitations), several had participants from across the K-16 spectrum.

In one example of developing PLCs, project leaders at the University of Maryland, Baltimore County developed bi-annual colloquia that brought faculty, graduate students, and high school teachers together to explore inquiry instruction in science. Nearly 80 people were involved in three colloquia. At the first such colloquium, participants self-selected into smaller, sustained PLCs that met as small groups (of 1-2 faculty and 1-3 teachers) throughout the year. Ultimately, 7 faculty and 10 teachers participated in these groups. The PLCs designed inquiry-based lesson plans for high-school and undergraduate courses, and some teachers and faculty spent time visiting each others' classes. One PLC contributed to the development of a graduate teaching assistant training program for the mathematics department.

Another type of PLC was designed by project leaders at the University of Maryland Biotechnology Institute. Over a four-year period, the program placed nearly 40 high-school teachers (8-10 each year) in research laboratories during the summer and supplemented their experience with a pedagogical learning community that was established to help teachers translate their laboratory experiences into inquiry lessons in the classrooms. During the summer and in follow-up meetings during the academic year, the teachers and faculty (in science and in science education) met regularly to talk about and challenge their own notions of scientific inquiry and redesign their instructional practices in response to those discussions. Survey instruments and learning-community observations were employed as well as an inquiry-teaching rubric modified from Llewellyn (2002). The results indicate significant increases in teachers' understanding and use of inquiry instruction over the course of the year. This strategy, dubbed "ExPERT" (Extended Professional Experiences in Research for Teachers), was one of the most successful learning community strands in the project.

Measuring PLCs

Implicit in the design of MSP projects offering professional development for teachers is the belief that these projects will result in new learning among the teachers, which will then translate into improved learning opportunities for students. How do investigators know that creating PLCs results in new and meaningful interactions among teachers or that PLCs result in changes in classroom practice that benefit students? As part of a national research and development effort, MSP projects are expected to collect data to document their work and use that data to inform future

1. In the Pathways project, teachers either enrolled in a two sequence graduate course or attended 8 half day workshops that were focused on improving teachers' content knowledge for teaching.

directions and provide insights to the field on methods of analysis that are effective at measuring indicators of success. Rigorous assessment of the impact that professional development has on teachers and their students requires the development of tools and instruments accompanied by piloting, revision, and field-testing.

Two of the projects discussed above have developed instruments for observing PLCs. In NCOSP, the investigators developed and used the *Professional Learning Community Observation Protocol*, which is an instrument structured around the project values that had been identified as key elements of an effective PLC: Shared Vision and Ways of Working, Collaboration, and Reflective Dialogue. These three elements combine to help foster open communication among group members so that they develop common norms, vision, and goals. The two main purposes of this protocol are to: 1) build and deepen a shared understanding of what it means to work effectively as a PLC, and 2) provide a meaningful tool for self-monitoring a PLC's development.

Project Pathways researchers are currently refining its *Learning Community Observation Protocol (LCOP)*, which is a tool used by project staff to determine the degree to which a PLC is engaging in genuine inquiry and meaningful conversations about knowing, learning, and teaching specific content (Sutor, Oehrtman & Carlson, in preparation). The LCOP is being designed to determine if PLC members are "productively engaged" during sessions and if group members reflect on and discuss problems related to student thinking and understanding, problems of teaching practice, ways to unpack mathematical or scientific ideas, and/or problems related to communication with peers. The Pathways team has found that productive engagement in PLCs is characterized by PLC members contributing to the discussion in meaningful ways, and encouraging others to do the same, with the group engaged in a reflective rather than routine way, and the group taking important issues as problematic. In contrast, unproductive characteristics appear when the PLC group works routinely through the agenda without reflective engagement with the material, allowing a) some members not to be engaged in the intended activity of the group, b) exclusion of some members of the group by more engaged members, c) an excess of time to be spent on extraneous discussion, and/or d) a failure of the group to value the time spent in the learning community.

Other projects funded by the MSP program have developed additional methods to measure impacts of PLCs, and it is anticipated that this research, such as the two examples that follow, will be made available to others across the nation who are interested in assessing the effects of professional development.

Partnership for Reform in Science and Mathematics (PRISM), led by the University System of Georgia

PRISM is a large-scale project with state and regional partners. The state partners include the University System of Georgia, which is the public higher education state agency, and the Georgia Department of Education, which is the K-12 state agency. Four regional P-16 ('P' is for preKindergarten) partnerships include at least one institution of higher education (IHE) and one K-12 system, which results in a total of 6 IHEs and 15 school districts participating in PRISM. In order to increase the quality of science and mathematics teaching and learning in Georgia, PRISM initiated 10 focal strategies. One of the strategies is to "engage higher education and P-12 faculty in learning communities" (see <http://www.gaprism.org/about/strategies.phtml>). Over multiple years, PRISM has developed evidence showing consistent, positive effects of PLCs on teaching and learning practices (Monsaas, 2006; Hessinger, 2009).

To provide evidence about the impact of PLCs, PRISM has used the *Inventory of Teaching and Learning (ITAL)*, which is a self-report survey that was developed by a team of PRISM evaluators to assess teachers' reported emphasis on reformed teaching and learning practices (Ellett & Monsaas, 2007). Reformed teaching was characterized as primarily learner-centered, whereas more traditional teaching was characterized as primarily teacher-centered. The inquiry questions on the ITAL were derived from the observation categories and assessment indicators of the Reformed Teaching Observation Protocol (RTOP) developed at Arizona State University (Sawada et al., 2000). Additional items were developed to assess teachers' reported use of standards-based teaching and learning practices and traditional practices. The inquiry items reflected reformed teaching and learning activities (e.g., encouraging students to evaluate their own thinking throughout the lesson) and the traditional scale reflected more traditional teaching practices (e.g., evaluating learning and performance on the basis of right and wrong answers). Teachers used a six-point scale ranging from 1=No Emphasis to 6=Very Strong Emphasis to rate the extent to which they emphasized each ITAL teaching and learning activity in their classrooms. Principal components analyses supported three subscales of the ITAL: Inquiry-Based Teaching and Learning (30 items), Standards-Based Teaching and Learning (10 items), and Traditional Teaching and Learning (12 items) (Ellett & Monsaas, 2007). In addition to the ITAL questions about teaching and learning practices, several demographic questions (e.g., grade level and science and/or mathematics courses taught) and questions about participation in PRISM activities were asked, including if the responding teacher participated in a PRISM learning community and if a higher education faculty member participated in the PLC.

The ITAL has been given to thousands of teachers across Georgia, including those who participated in PRISM PLCs and those who did not, and statistical analyses were run separately in the Springs of 2006, 2007, 2008 and 2009. The dependent variables were the three subscales of the ITAL and the independent variable was participation in a PRISM PLC. The results were consistent over the four collection times and showed that participation in a PRISM LC is associated with greater emphasis on standards-based teaching and learning practices in both mathematics and science K-12 classrooms. Moreover, the PRISM team also found that participation of an IHE faculty member has an additional, positive impact on teachers' reported use of inquiry-based teaching and learning.

Developing Distributed Leadership, led by Northwestern University in collaboration with the Math in the Middle Institute Partnership of the University of Nebraska - Lincoln

This collaboration between an MSP-funded research project and a partnership project (entitled Math in the Middle) focuses on PLCs for mathematics education (see Pustejovsky, Spillane, Heaton & Lewis, 2008) that examining different dimensions of middle school mathematics by comparing them to other subjects (e.g., Language Arts). One component of this work explored the validity of a social network instrument (the *Social Network Survey*) for studying subject-specific leadership and social influence in schools, with particular attention to question-order effects (Pustejovsky & Spillane, 2008; Pitts & Spillane, 2009).

The Social Network Survey was administered to all certified staff in each of the ten middle schools in the partnership. School-level response rates ranged from 70% to 94% for teaching staff and were slightly lower for administrators and other certified staff. The survey collected data on different dimensions of the PLC. Seven sets of measures, comprised of 46 items in total, measured teachers' views on the social norms within their school, including:

- Trust among teachers (6 items)
- Trust between teachers and the Principal (8 items)
- Teachers' evaluation of the Principal's instructional leadership (7 items)
- Collective responsibility for student learning: peer-assessed (7 items)
- Collective responsibility for student learning: self-assessed (7 items)
- Teachers' control over classroom practice (5 items)
- Openness to innovation (6 items)

Network data were collected in order to measure the structural and content aspects of the PLC, and network ties (i.e., linkages between individuals) were measured by asking respondents to list the people "to whom they go for advice and information" about several topics. All teachers were asked about mathematics and reading/writing/language arts. Additionally, all subject-specific teachers were asked about their primary subject. For each tie listed by a respondent, data was collected on the tie's designated role, the frequency of contact between respondent and advisor, the influence of the advisor on the respondent's practice, and the content of the interaction between respondent and advisor. Content was measured along five dimensions: deepening content knowledge, planning or selecting course content and materials, approaches for teaching content to students, strategies specifically aimed at assisting low-performing students, and assessing students' understanding of the subject.

The collaboration's ongoing analyses suggest that there is considerable variation across schools in the structure of the PLCs, even though the norms and substance of PLCs appear to be relatively homogeneous across schools (e.g., regarding norms, between-school variation ranges from only 2% for teacher control over classroom practice to 7% for instructional leadership). Although school-level averages do not vary greatly, there do appear to be differences in the homogeneity of attitudes within each school; respondents in some schools have a high level of agreement about the principal's instructional leadership, while respondents in other schools show a much greater range of opinions. There is also considerable variation in terms of the structure of PLCs, both by school and across subject-areas. Schools varied in the degree to which the subject-specific networks spanned the formal organization of the school and the degree to which teachers' networks reached outside the school to access advice and information. Schools and subject-areas also varied in their network concentration. For example, math networks generally appeared more concentrated than reading/writing/language arts. Finally, the researchers observed that Math in the Middle associates are prominent brokers of information both within schools and between schools and their environment. The associates tended to be named as advisors by more individuals within their schools as compared to other teachers in similar roles. Moreover, associates sought advice from more sources outside of their schools, compared to their colleagues, and many of their external ties were with other Math in the Middle associates at different schools. All in all, this work on PLCs in schools shows great promise. The collaboration of the research and partnership projects is now exploring relationships between teacher networks and student achievement.

Conclusion

Over the past decade, professional learning communities have been identified by many schools as an effective approach to increasing collaboration among educators. As such, PLCs challenge the stereotype that teachers work in isolation and, instead, open the classroom door wide so that teachers can discover ways to improve their craft through group effort, discuss with others ways to improve the education of all students, and generally create a culture of mutual support within school walls. A literature on PLCs in science education has begun to appear, and the projects of the National Science Foundation's MSP program, which emphasizes partnerships within and across schools as well as with institutions outside of schools such as colleges and universities, have become especially fruitful sources of new experiments with PLCs in varied manifestations. With the development of new tools and instruments to measure their impact, MSP projects anticipate identifying additional outcomes from their work and, thus, will inform the decisions that all educators must make to improve teaching and, ultimately, learning.

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