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ABSTRACT

The PUMP Algebra Project was a systemic effort in a mid-size urban city focusing on professional development of middle school mathematics teachers, which had a long-term goal of enabling more minority students to be algebra-ready by the end of 8th grade. The development of teacher leaders was not a targeted focus of the Project; it was a major unanticipated benefit of the Project. Through summer content and pedagogical courses, academic year seminars, and classroom-level support, teachers began to provide leadership in their buildings with regard to four PUMP classroom strategies: emphasizing that mathematics is for all; engaging students in worthwhile mathematical tasks; enhancing students' mathematical discourse; and involving students in collaborative mathematical activities. These teacher leaders also played key roles in their district in revamping their lowest level high school mathematics courses, integrating technology into instruction, and adopting broader approaches to assessment. PUMP teachers also emerged as leaders in the Urban League-sponsored after-school and summer algebra programs for middle school students, a big brother/sister after-school mathematics mentoring program, the collaborative design of an applied mathematics student module with Caterpillar engineers, and the creation of an affiliate mathematics education group of the National Council of Teachers of Mathematics (NCTM). (Contains 12 references.) (Author/MVL)

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9 The Emergence of Teacher Leaders Through Professional Development

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The PUMP Algebra Project was a systemic effort in a mid-size urban city focusing on professional development of middle school mathematics teachers, and having a long-term goal of enabling more minority students to be algebra-ready by the end of 8th grade. The development of teacher leaders was not a targeted focus of the Project; it was a major unanticipated benefit of the Project. Through summer content and pedagogical courses, academic year seminars, and classroom-level support, teachers began to provide leadership in their buildings with regard to four PUMP classroom strategies: emphasizing that mathematics is for all, engaging students in worthwhile mathematical tasks, enhancing students' mathematical discourse, and involving students in collaborative mathematical activities. These teacher leaders also played key roles in their district in revamping their lowest level high school mathematics courses, integrating technology into instruction, and adopting broader approaches to assessment. PUMP teachers also emerged as leaders in the Urban League-sponsored after-school and summer algebra programs for middle school students, a big brother / sister after-school mathematics mentoring program, the collaborative design of an applied mathematics student module with Caterpillar engineers, and the creation of an affiliate mathematics education group of the National Council of Teachers of Mathematics.

In response to the need for improved opportunities for student learning of mathematics at all levels (National Academy of Sciences, 1990; Beaton, Mullis, Martine, Gonzalez, Kelly, & Smith, 1996), the mathematics education community has called for significant changes in mathematics teaching and learning (National Council of Teachers of Mathematics [NCTM], 1991, 1998). Classroom teachers are central to this change process and play a critical role in enacting new visions of teaching and learning mathematics (Ferrini-Mundy, 1998). Thus,

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the professional development of teachers of mathematics has received unparalleled attention in recent years (Aichele & Coxford, 1994; Friel & Bright, 1997). A critical part of this process of teacher enhancement is the development of teacher leaders.

Teacher leaders play key roles in initiating and supporting change. These roles include: planning and initiating professional development for other teachers, collaborating in the writing and development of curriculum, addressing instructional problems with administrators and community members; and facilitating networks of communication (Friel & Bright, 1997; Loucks-Horsley, Hewson, Love & Stiles, 1998). The contributions of teacher leaders to the long-term success of teacher enhancement projects have been widely recognized in the literature (Friel & Bright, 1997; Fullan, 1993; Loucks-Horsley, Hewson, Love, & Stiles, 1998).

There are two approaches to developing teacher leaders. One approach involves identifying exemplary teachers as potential leaders and engaging them in programs designed to prepare them to assume leadership roles. While this approach has merit (Friel & Bright, 1997), Gregg (1997) observes that the early identification of teacher leaders may not result in the selection of teachers with the greatest potential for leadership, as not every good teacher of children is necessarily a good leader of adults. A second approach to the identification of teacher leaders is one that promotes the emergence of leaders through teachers' participation in general professional development programs. This latter approach to leadership is the one that evolved during the PUMP Algebra Project and is the focus of this chapter.

The PUMP Algebra Project: Fostering the Emergence of Teacher Leaders

The PUMP (Peoria Urban Mathematics Plan for) Algebra Project, funded by the National Science Foundation and directed by faculty from the Mathematics Department of Illinois State University, is an example of a teacher enhancement effort that evolved in the emergence of teacher leaders. The development of teacher leaders was not a targeted focus of the PUMP Project. However, we did recognize that if the Project was to have sustained impact on the quality of mathematics instruction and learning in the school district beyond the period of funding, teacher participants would need to remain committed to Project philosophy and continue to support curricular and pedagogical reforms when the Project was no longer active.

The fact that this continuing commitment to the philosophy of the Project has occurred can be attributed to the emergence of teacher leaders among the participants in our project. In retrospect, we find it possible to analyze the elements of the Project to highlight instances of this emergence and target specific features that fostered the development of teacher leaders. As a precursor to examining this emergence, we provide a summary of major Project activities and set this in the framework of the Loucks-Horsley et al. (1998) strategies for professional learning.

The PUMP Algebra Project and Goals

A systemic effort in a mid-size urban city, the PUMP Algebra Project was designed to enable more minority students to be algebra-ready by the end of eighth grade. The Project was a collaborative effort involving district administrators and 48 teachers representing each of the district's 14 middle schools and 4 high schools; faculty and graduate students from the University; and significant involvement and support from community and business groups. The major goals of the PUMP Algebra Project were:

- To provide teachers with enhanced content, pedagogical, and professional knowledge through intensive summer sessions and follow-up academic year seminars;
- To encourage classroom-based implementation of new knowledge and practice through on-site staff support; and
- To positively impact student achievement and thereby increased entry into the algebra pipeline.

Believing that improvement in mathematics achievement begins in the classroom with teachers, the main thrust of the Project was a strong professional development program for teachers. An unanticipated outcome of this strong professional development program was the emergence of teacher leaders.

The Components of the Professional Development Program

In order to effect worthwhile and enduring change in mathematics teaching that increased student achievement and entry into the algebra track, the PUMP Project focused on the enhancement of teachers' knowledge through participation in activities that served to influence their beliefs about, and practices in, mathematics teaching and learning.

The major components of this professional development program included summer courses, academic year seminars, on-site classroom support for teachers, and community/business involvement. These four components of the PUMP Project professional development program are described below, followed by an analysis of how they relate to proven strategies for teacher learning (Loucks-Horsley et al., 1998).

Component 1: Summer Courses. Three intensive summer sessions involved teachers in *doing* mathematics and reflecting on mathematics teaching and learning. In essence, these summers engaged teachers in reflective inquiry centered on key mathematical ideas of the middle school curriculum. Over the three years, the summer mathematics courses addressed the content of rational numbers and proportional reasoning, algebraic thinking, geometry, probability and statistics. Each summer, specific lessons were also planned to familiarize teachers with graphing calculators and ways to effectively integrate their use in middle school mathematics instruction.

Four PUMP classroom strategies (Figure 1) were modeled during the summer sessions to help teachers operationalize the reflective inquiry approach. We consistently emphasized that all teachers should be engaged in completing rich, meaningful mathematical tasks. The expectation was that teachers would share their different solution approaches, explain and justify their reasoning. Teachers were often expected to work collaboratively with colleagues and this resulted in opportunities for teachers to assume leadership roles.

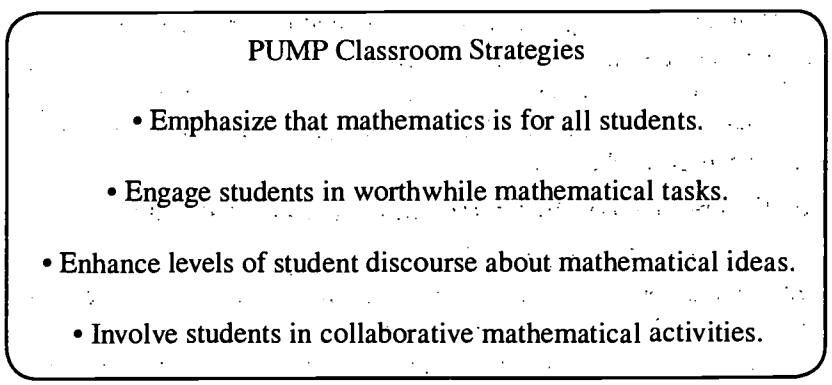

Figure 1. PUMP Classroom Strategies

Replacement units from the Connected Mathematics Project (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1997, 1998) were used as the texts for these summer courses and provided a springboard for teachers to study new content, to revisit familiar content from a new perspective, and to analyze new approaches to teaching these topics. Teachers were given opportunities in the summer to rethink and reorganize their mathematics program to incorporate enhanced forms of instruction. Part of each summer's assignment was to collaboratively develop and share instructional plans that either outlined specific units of study or organized the entire year's scope and sequence. These experiences strategically positioned teachers to provide leadership in their buildings for the coming year.

Component 2: Academic Year Seminars. During each academic year teachers attended six half-day seminars. For these seminars teachers met in grade-level clusters (5-6 and 7-8) to:

- improve articulation across grade levels;
- facilitate grade-level sharing; and
- provide a broader base for analyzing and implementing instructional strategies in mathematics.

During the first year, seminar discussions were based on the four PUMP classroom strategies shown in Figure 1. Each seminar focused on one of the classroom strategies and utilized problem-centered tasks, research findings, or a video as the context for discussion. Teachers were engaged in tasks such as the following:

- Reflecting briefly in writing on how they used one of the PUMP strategies in their classroom since the last seminar;
- Sharing samples of student work that reflected the levels of thinking and strategies used by students in their classrooms; and
- "Opening up" a traditional textbook lesson by restructuring it to include problem tasks that allowed for multiple solutions or encouraged different solution approaches.

At the conclusion of each seminar, teachers were given a specific task related to one of the PUMP strategies to carry out in their classroom before the next seminar. In a number of cases these assignments provided a catalyst for some teachers to be innovative in their classrooms and, in essence, to show leadership in implementing the PUMP pedagogy.

Seminars in the second and third years adopted a similar format to that developed during the first year. However, in year 2, seminars focused on proportional reasoning, technology, and issues surrounding standardized testing. As part of an effort to disseminate Project ideas more broadly, teachers also participated in two seminars with other teachers from their buildings who were not actively involved in the PUMP Project. These sessions provided another opportunity for PUMP teachers to demonstrate leadership among their peers.

During the third and final year, teachers shared the responsibility of leading five seminars which again emphasized the PUMP classroom strategies. One of these seminars included non-PUMP teachers that had participated in PUMP seminars during the previous year. A key element of all these seminars was the initiatives demonstrated by teachers in better aligning their curriculum and instructional practice with the vision of the PUMP Project. While the third-year seminars were not initially intended to promote teacher leaders, it was clear to both the Project staff and the teachers themselves that leaders had emerged. Moreover, the leadership of these key people resulted in several powerful outcomes. For example, the mathematics departments in all four high schools came to consensus on revamping their lowest-level mathematics courses using new standards-based middle school curriculum materials.

Component 3: Classroom-Level Support. Throughout the school year, four to six project staff members spent one day a week in PUMP classrooms. During these visits, staff were available for a variety of support activities including: teaching a demonstration lesson or co-teaching a lesson (with a follow-up debriefing session), observing and providing feedback to the teacher, or serving as consultant on specific curriculum or instructional issues. Each year some teachers were targeted for weekly visits; all others were visited at least twice during the year. These visits provided further opportunity for project staff to identify evidence of teacher leadership within their own buildings.

Component 4: Community and Business Collaboration

The PUMP project had significant community and business support. The Urban League sponsored a diversity workshop for teachers, established an after-school tutor program for middle school students, established a PUMP Algebra Club that met after school once each week, and instituted a six-week summer PUMP Algebra

program for middle school students. Both the Algebra Club and the algebra summer program had separate grade 5-6 and grade 7-8 components. The after-school tutor program involved college interns from Caterpillar, Inc., college students from local universities, parents, and other adult volunteers as tutors. All activities were planned and implemented under the leadership of PUMP teachers who generated the curriculum programs and provided mentoring for the various tutors.

The Chamber of Commerce sponsored Big Brother/Sister type mentoring in mathematics at the middle schools before and after school and during lunch periods. As part of their Adopt-a-School program, they also provided incentives for students who showed ongoing improvement in mathematics achievement. Once again, a number of PUMP teachers took the lead in coordinating and implementing these programs.

A significant number of businesses collaborated in a fundraising campaign to purchase graphics calculators for all of the district's middle schools. In particular, Caterpillar and Central Illinois Light Company provided direction for this effort and continued, throughout the project, to serve as resources. Some of the PUMP teachers with a strong interest in technology assumed leadership roles in providing graphics calculator workshops for teachers across the district. In essence, the Project had the effect of galvanizing PUMP teachers to take initiatives beyond the scope of the Project.

Within the same timeframe, engineers from Caterpillar worked with lead PUMP teachers to design a wheel-in-motion unit that was subsequently taught in many of the district's middle school classrooms by the engineers in collaboration with PUMP teachers. Caterpillar also sponsored a PUMP Teacher Appreciation Day at corporate headquarters which included teaming and leadership activities.

Relationship Between PUMP Project Activities and Strategies for Professional Learning

In designing and implementing the PUMP project, we strove to incorporate proven strategies for teacher learning. In fact, the strategies we enlisted are among those recently described by Loucks-Horsley et al. (1998): (a) immersion in inquiry, (b) curriculum replacement units, (c) curriculum development and adaptation, (d) workshops, institutes, courses, and seminars; and (e) examining student work and student thinking (see Table 1).

Table 1. Strategies for Professional Mathematics

† Immersion in inquiry	Immersion in the world of mathematicians
Curriculum implementation	Curriculum development and adaptation
† Curriculum replacement units	† Workshops, institutes, courses, and seminars
Action research	† Examining student work and student thinking
Case discussions	Partnerships with mathematicians in business, industry, and universities
Study groups	Developing professional developers
Coaching and mentoring	
Professional networks	

*Loucks-Horsley, Hewson, Love, & Stiles (1998)
†Relevant to the PUMP Algebra Project's emergent leader experience

Immersion in Inquiry

The major approach to mathematics learning during the summer courses was immersion in inquiry. An inquiry approach to mathematics learning involves engagement in rich problem tasks that invite different solutions or different solution approaches. During the summer sessions, we provided teachers with repeated opportunities to grapple with complex mathematical problem tasks, usually in collaboration with teacher colleagues. Our expectation was that teachers would explore and share their different solutions and reasoning, and benefit from ideas shared by others.

Our overriding goal was consistent with the benefits Loucks-Horsley et al. (1998) identified for immersion in inquiry: (1) to increase teachers' mathematical understanding in content areas central to school mathematics instruction; and (2) to broaden teachers' perspectives and understanding of their own process of learning through investigation. PUMP staff felt that, to be effective in promoting inquiry during mathematics instruction, teachers must be mathematically knowledgeable, fully understand and be committed to the inquiry process. We believed it was important to challenge teachers at their own level of mathematical understanding and allow them to both experience and reflect on the same practices that we were encouraging them to carry out with their students.

Curriculum Replacement Units

Loucks-Horsley et al. (1998) highlighted the potential that well-designed replacement units have for shifting teachers' thinking and beliefs about teaching and learning. Our belief in this potential for improving mathematics instruction lay at the heart of our decision to use selected units from the materials (Lappan et al., 1997, 1998) during the PUMP Project's summer sessions. Although we modified some activities for adult learners, we also provided time for teachers to try student activities first-hand, thus enabling them to better understand the purpose and philosophy of the materials and the way that students approach such activities. Our intent was that teachers would incorporate some of the Connected Mathematics modules as replacement units in their classrooms during the school year, and that doing so would stimulate a larger-scale change in their instructional practice.

Following each summer session more and more teachers began to use some of the *Connected Mathematics* lessons or even entire replacement units in their classrooms. These teachers were encouraged to take this action both by having experienced the units themselves and by peers who had already taken the initiative in using the replacement units. Loucks-Horsley et al. (1998) suggested that replacement units allow teachers the chance to sample new teaching strategies without completely adopting a new mathematics curriculum. According to Loucks-Horsley et al., teachers also need time to reflect and "debrief" on new curriculum experiences; they need opportunity to interact both with grade-level colleagues and with supportive consultants during the period a replacement unit is first made part of classroom instruction. The real forum for professional learning in the use of replacement units is rooted in on-going opportunities for teachers to discuss what is happening, to share problems encountered, and to receive support and guidance.

As PUMP teachers tried ideas in a replacement unit with their students and interacted with their peers who were already using these units, they reported that they were challenged to rethink their teaching practice. Seminar sharing, especially by lead teachers, provided needed support for orchestrating effective ways to implement replacement units in classroom instruction.

Curriculum Development and Adaptation

When describing the benefits of curriculum development and adaptation as a professional learning strategy, Loucks-Horsley et al. (1998) point out that this activity pulls teachers away from the isolation of their individual classrooms. They also note that curriculum development and adaptation provides them with rare, needed opportunities to interact professionally with colleagues or other experts in the field.

The capstone experience of each of the summer sessions in the PUMP Algebra Project was the sharing of a curriculum unit directly tied to the topic(s) of the summer session or a year-long curriculum plan that set a timeframe for and highlighted activities associated with the mathematics content of a summer's session. The annual curriculum development/adaptation assignment of the PUMP Project's summer sessions proved valuable for teachers for this very reason: it gave them the opportunity to collaborate repeatedly with their colleagues and with professional mathematics educators. Our hope was that, as teachers collaborated to rethink their instructional goals in relation to specific mathematics concepts, skills, and attitudes their students needed to acquire, they would strengthen their own content and pedagogical knowledge.

Curricular development and adaptation continued to be emphasized throughout the academic-year seminars but focused on making modifications of specific mathematics lessons. This development and adaptation became very practical as teachers tried and refined new or modified lessons with their students. The basis for lesson modification was primarily the four PUMP classroom strategies (Figure 1); the forum for lesson modification was collaborative planning between seminar sessions and collegial sharing during seminars. Regular interaction with de facto teacher leaders in developing or adapting curriculum for improved classroom instruction became, as Loucks-Horsley et al. (1998) indicated, one of the strongest professional learning features of this experience.

Workshops, Institutes, Courses, and Seminars

The most obvious of the Loucks-Horsley et al. (1998) strategies utilized during the three sequential summers of our PUMP Project program was our use of courses to provide teachers with enhanced content, pedagogical, and professional knowledge. The summer

schedules provided teachers with time away from the classroom to grapple with mathematical problems in ways they had not previously thought about or experienced. While focused on the enhancement of content knowledge, however, these courses also engaged teachers in what Loucks-Horsley et al. (1998) refer to as a "taking action" (p. 90) stage--in which they applied newly-learned mathematical ideas and ways of learning to their own classroom situations.

As follow-up to summer work, the PUMP Project's regular seminar meetings with their focus on improved pedagogy created opportunities for teachers to learn more about reform recommendations for school mathematics. They also provided a forum for teachers to share their experiences and learn from colleagues. Both the summer and seminar activities served as a catalyst for teachers to take leadership in relation to issues associated with mathematics content, mathematics pedagogy, and technology integration. Each seminar offered new challenges to rethink the teaching and learning of mathematics.

Examining Student Work and Student Thinking

As part of each seminar, targeted teachers shared lessons they planned in relation to one of the four PUMP Classroom Strategies (Figure 1). During this sharing, teachers exhibited samples of student work from a lesson and engaged their colleagues in examining different strategies students used and different levels of thinking revealed by those strategies.

This activity served three purposes: (a) it held teachers accountable for trying new approaches to mathematics instruction; (b) it gave teachers precious time for reflection; and (c) it enabled teachers to observe and benefit from the modeling and sharing of recognized teacher leaders. What Loucks-Horsley et al. (1998) suggested might happen did in fact occur among many PUMP Project teachers: the practice of carefully reflecting on students' reasoning caused teachers to "develop for themselves the ability to understand the content [that their] students are struggling with ...[in order to determine] ways that they . . . can help" (p. 125). That is, by thoughtfully and regularly examining student work and thinking, teachers grew in their own understanding of the mathematics and obtained information that was important for on-going, instructional decision-making (Swafford & Thornton, in press).

Aspects of the PUMP Project that Fostered the Emergence of Teacher Leaders

In designing and implementing the PUMP professional development program, we strove to incorporate proven strategies for teacher learning. In retrospect the strategies we utilized, aptly characterized by five of the Loucks-Horsley et al. (1998) strategies for professional learning, became a forum of opportunity that fostered the emergence of teacher leaders. In reflecting on the PUMP Project, we are convinced that these strategies nurtured the emergence of teacher leaders by:

- engendering increased personal confidence in mathematics content as demonstrated in teacher modeling and sharing of problem solutions; (Components 1 and 2: Summer courses and academic year seminars);
- building teacher expertise in relation to reform-based approaches to mathematics instruction as revealed in the teachers' development of pedagogical ideas, instructional plans, and classroom implementations (Components 1, 2 and 3: Summer courses, academic year seminars, and classroom-level support); and
- providing repeated opportunities for teachers to assume responsibilities for team-building and sharing of mathematical, pedagogical, and technological ideas as evidenced by teacher initiatives during PUMP Project activities, in their own classrooms and after-school programs, and in their work with business and community groups(All four components).

Indicators of emerging teacher leadership at different points in the program have been highlighted throughout our discussion of the four Project components and in relating these components to strategies for professional learning (Loucks-Horsley, et al., 1998). While a number of key participants demonstrated leadership in many settings and roles, an interesting feature of this Project was the change in leadership as teachers were involved in different aspects of the Project.

Teachers also assumed leadership at different levels. Some exhibited leadership only with their own cohort of grade-level teachers; others demonstrated more pervasive leadership roles within their own schools or at the district level. This broader leadership, for example, was evidenced in PUMP participants giving presentations at district, state, and national mathematics teacher conferences and in their initiation of a local affiliate mathematics teacher group.

This new affiliate group of the National Council of Teachers of Mathematics was formed by PUMP teachers near the end of the Project because they wanted to keep the momentum of the Project alive. The first officers of this organization, the Heart of Illinois Council of Teachers of Mathematics, were all PUMP teachers. At the time of writing this chapter, the organization included 80 members and had just elected its second president and its second president-elect. Both of these newly elected officers are PUMP Project participants. For Project staff, the formation of this organization has been one of the highlights in the emergence of teacher leaders because it provides an on-going mechanism for maintaining and enhancing the spirit of the PUMP Project.

Concluding Comments

The PUMP Project not only enhanced the professional development of teachers, it acted as a catalyst for fostering the emergence of teacher leaders. The emergence of these teacher leaders has been an unanticipated benefit--one that may well have more long-lasting effects than other components of the Project .

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