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AUTHOR Miller, Anne-Courtney S.; Wallace, Josephine D.; DiBiase, Warren J.; Nesbit, C. R.

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ABSTRACT

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Pebbles in the Ocean or Fountains of Change? New Insights on Professional Development: Examining the links-professional development, teacher leaders, and school change

Anne-Courtney S. Miller, Josephine D. Wallace, Warren J. DiBiase,

and C. R. Nesbit

University of North Carolina at Charlotte

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Abstract

A holistic approach to research design was used in this analysis of a long term, large scale

professional development project held at 8 university sites in one state over a 3 year period that involved 360 teacher leaders and their principals from 180 elementary schools. The purpose of this analysis was to examine the links among professional development, teacher leaders, and change in the teaching of science and mathematics. Qualitative and quantitative data were gathered over the 3 years on a number of different aspects of the project, some of which have previously been reported. Data sources included observations, interviews, and written program documents. Detailed analyses examined models of professional development, the lead teachers' implementation of these models in schools, design and components of professional development experiences, and important factors for professional development cited by lead teachers. The qualitative methodology revealed important links, connections, and implications that emerged from the multiple data sources. Findings indicate three important categories (Content and Pedagogy, Leadership Content, Leadership Planning and Practice) that should be included in professional development. The components of these categories are identified and described and reveal new insights on professional development. Recommendations are provided for professional development enhancing school change.

Pebbles in the Ocean or Fountains of Change? New Insights on Professional Development: Examining the Links-professional development, teacher leaders, and school change

It was a strange sight: a man, standing before a fountain, watching the falling water and tilting his head from side to side. Drawing closer, I saw he was rapidly moving the fingers of his right hand up and down in front of his face. I was in the seventh grade, visiting Princeton University with my science class, and the man at the fountain was Albert Einstein. For several minutes, he continued silently flicking his fingers. Then he turned to me and asked, 'Can you do it? Can you see the individual drops?' Copying his, I spread my fingers and moved them up and down before my eyes. Suddenly, the fountain's stream seemed to freeze into individual droplets. For some time, the two of us stood there perfecting our strobe technique. Then, as the professor turned to leave; he looked me in the eye and said, 'Never forget that science is just that kind of exploring and fun'(p. 177).

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Rethinking the role of professional development has been emphasized by new goals and standards formulated by the National Science Education Standards (National Research Council, 1996), the National Council of Teachers of Mathematics Curriculum and Evaluation Standards for School Mathematics (1989), and the Professional Standards for Teaching Mathematics (1991), and the goals of the National Education Goals Panel (1995). The call for reform by national groups such as AAAS (1989), NCTM (1991), NRC (1996), and NSTA (1992) indicates a need for change in the teaching of science and mathematics. "The growing realization among all of those who care about this nation's future is that something must be done to fundamentally reshape schools in order to make them more effective..." (Pellicer & Anderson, 1995, p. 142). Business and government leaders, too, echo this call for change that must occur in order to prepare students and schools for the next century.

"Educators agree that the fundamental changes required to produce both academic excellence and equity rest largely on the continued growth and professional development of the Nation's teaching force" (Carey, Frechtling, & Westat, 1997, p. 1). These new roles for teachers "are critical in any effort to initiate and sustain educational change" (Pellicer & Anderson, 1995, p. 218). Furthermore, they believe that the focus of change should be at the school level "because the evidence is overwhelming that individual schools held the greatest potential for meaningful change" (p. 143).

Professional development needs to be designed to "actually contribute to the lasting change our education system critically needs" (Loucks-Horsley, 1997, p. 134). "Although traditional professional development still dominates most schools and districts-consisting of a series of workshops, a long-term consultant to a district, or decontextualized staff development days-there is increasing awareness that new forms are both possible and desirable" (Lieberman & Grolnick, 1997, p .192).

The traditional approach to professional development is like a pebble dropped in the ocean-it may create a small disturbance but has little or no lasting effect as the medium quickly returns to its original state. What is needed now is a new type of professional development-one that is like a fountain of change. A fountain that incorporates new ideas and structures, renews, recycles, and invigorates.

The importance of professional development is indicated by its inclusion as one of eight National Education Goals. According to Loucks-Horsley, Hewson, Love, and Stiles (1998), "clearly, the traditional ways in which professional development has occurred are inadequate" (p. xi). Howe and Stubbs (1997) state, "It seems clear that past and present methods and approaches to continuing professional development for teachers have not produced the desired results and that new methods and approaches are needed. If we continue to do the things we have always done, we will continue to get the results we have always gotten--and those results are not serving us well" (p. 168). A goal of many professional development programs is that of dissemination of new practices at the school level. Often, the belief "is that by investing resources in the training of one or two teachers, many more teachers will be reached" (Frechtling & Westat, 1997, p. 21). In Best Practice in Action: Final Report of the Multi-Agency Study of Teacher Enhancement Programs, Frechtling and Westat state "both the case stories and the survey data strongly indicated that formal dissemination of knowledge and practice was a relatively rare event" (p. 21).

Researchers (Darling-Hammond & McLaughlin, 1995; Guskey, 1994) have also cited the need for new approaches to professional development, for understanding the change process (Fullan, 1993; Hall & Hord, 1987), and for examining the role of professional development (Guskey, 1994) related to school improvement. Additionally, Loucks-Horsley (1998) cites professional development as "one of the critical links" (p. 1) in the chain and has identified experiential learning and collaboration as being important components of professional development. Ball

(1997) emphasizes the importance of content knowledge in order for teachers to teach for understanding and adds that "teacher educators and staff developers should model the approaches which they are promoting" (Ball, p. 90). Creating a climate of change at the school level is a process that takes time (Hall & Hord, 1987). "Teachers-not administrators, not programs-provide the stability in schools, the stability needed to promote and sustain change" (Pellicer and Anderson, 1995, p. 215).

Recent research indicates that while the primary goals of current teacher enhancement programs as stated by Frechtling, Sharp, Carey, Vaden-Kiernan, and Westat (1995) include increased teacher knowledge in a content area, teacher renewal and networking, increased leadership and empowerment, and changes in classroom practice in order to improve student achievement, these characteristics reveal little about the overall dynamics of the professional development process. "For a number of years, there has been general agreement that K-12 mathematics and science teaching in the United States is in critical need of major reform" (Friel & Bright, 1997, p. 1). Hyde, Ormiston, and Hyde (1994) add that "effective professional development experiences [for mathematics] should provide methods, materials, and activities" (p. 51) and should encourage collaboration.

The need for leadership as a key component of professional development has been identified by researchers such as Friel and Bright, (1997), Loucks-Horsley et al., (1998) and Bybee (1993). The need to develop and enhance the role of leadership for elementary teachers is especially important if they are to take on the roles called for in current goals. "For students to reach the goals to which the system aspires, teacher learning and changing are essential" (Loucks-Horsley, 1998, p. 2).

Since "both the mathematics and science education professions have identified leadership development as a component of effective professional development programs" (Loucks-Horsley, et al., 1998, p. 199), ways and methods of developing or enhancing teacher leadership becomes more important. Researchers such as Zinn (1997) have identified supports and barriers to teacher leadership, but little research is available on the balance between science and mathematics content and leadership in a professional development program.

In a study on educational reform networks, Lieberman and Grolnick (1997) reported that "networks, unlike conventional professional development efforts, build commitment by encouraging teachers and administrators to participate in shaping an agenda that is responsive to their questions, their learning, and their need for support as they tackle tough issues of teaching and learning" (p. 199). Lieberman and Grolnick also report that successful programs of this type have included collaboration among members, opportunities for leadership, and provide for adult learning in new and challenging ways (p. 212). In analyzing 34 teacher enhancement programs in science and technology, Ruskus, Luczak, and SRI International (1995) identified "four key elements of best practice: instructional approach, immersion in science, systemic approach, and followup" (p. S-2). Additionally, they reported that "Institutes with exemplary instructional approaches emphasized hands-on/minds-on activities and provided opportunities for participants to construct personal meaning from these activities...and they structured time for practicing new learning and planning for classroom application" (p. S-2).

This new look for professional development (Lieberman & Grolnick, 1997) includes a "strong contextual nature" (p. 213). Several studies (Clarke, 1994; Coble & Koballa, 1996; Friel & Bright, 1997; Loucks-Horsley et al., 1998) have identified elements of effective professional development programs. Loucks-Horsley et al., (1998) identified seven principles of professional development as programs that are: "based on a image of effective classroom teaching and learning... provide opportunities for teachers to build their knowledge and skills, ...use or model with teachers the strategies teachers will use with their students ...build a learning community ...support teachers to serve in leadership roles ... provide links to other parts of the education system, and ...are continuously assessing themselves and making improvements" (pp. 36-37). Friel and Bright (1997) identify "the importance of teachers' role in making choices and planning agendas" (p. 11). Common components of effective professional development identified by Friel and Bright (1997) include the importance of addressing teachers' beliefs, collaboration, teachers' participation in

planning, teacher leadership, long-term support , and professional development that models for teachers best practice.

"School improvement depends totally and completely on the renewal of individual teachers and administrators. No meaningful, long-lasting school improvement can occur without renewal" (Pellicer & Anderson, 1995, p. 208). What factors contribute to a type of professional development that is like a fountain of change-one that enables, supports, and enhances continuing school-wide change in the teaching of science and mathematics? Since "changes in educational practices do not come quickly or easily," (House, 1994, p. 214), what is needed are new insights on the structure, supports, and organization of professional development experiences as well as on their relationship to school change. What are the linkages and the critical elements among professional development, teacher leaders, and school change?

This analysis is important is because it bridges the gap between knowledge and practice. Additionally, Loucks-Horsley et al., (1998) state, "Nowhere is there an accumulation of the knowledge of effective professional development strategies and structures for teachers of mathematics and science, nor is there any one place where guidance about how these teachers can best be assisted in their professional growth can found" (p. xii). Further, there is "a large body of literature on adult learning and staff development; it is not, however, connected to the disciplines of mathematics and science and many of the mathematics and science educators who design and conduct professional development programs for teachers do not know about this literature" (p. xii).

Background

This study provides a holistic analysis (Patton, 1990, p. 49) of a long term, large scale science and mathematics professional development project which was conducted by the Mathematics and Science Education Network (MSEN) of the University of North Carolina (Franklin, 1993) from 1990-1993. The project, which was funded by a three year grant from the U. S. Department of Education, Dwight D. Eisenhower Mathematics and Science Education Programs, Fund for the Improvement and Reform of Schools and Teaching (FIRST), was composed of 15 two year professional development programs held at 8 university sites over a 3 year period (one university site did not participate in the first year of the project). Each university site recruited schools to participate with priority given to schools which met one or more of the following criteria: minority population greater than the North Carolina average of 33%, a high percentage of students in the federal lunch program, or location in a small town (less than 5,000) or rural area. Of the 183 participating schools, 21% met all three criteria, 56% met two criteria, and 20% met one of the criteria (Franklin, 1993, p. 5). The schools were recruited in a variety of ways by each university sites, with approximately 12 schools participating in each of the 15 professional development programs. There were 88 schools that participated in the first year of the project and 95 schools during the second year. The majority (55%)of the schools had a student enrollment in the medium range of 250-500 students (p. 5). There were 45 schools (25%) with a minority population of less than 15%, 41 schools with a minority population of 15-33%, 47 schools with a minority population of 34-50%, 36 schools with a minority range of 51-75%, and 14 schools with greater than 75% minority population.

There were 354 lead teachers who began the project and demographic data was available for 349 (Franklin, 1993). Most of the lead teachers were female (94%) and 80% of the lead teachers were white, 17% African-American, and 3% other. The educational level included 67% with a Bachelor's degree, 31% with a Master's degree and 2 % other. Sixty-one percent of the lead teachers taught in grades 3-6, with 33% in grades K-2, and 6% in other grades or areas. The average length of experience for the lead teachers was 11 years with a range of one to 30 years. Most teachers had majored in elementary or intermediate education in college with only 8% majoring in either mathematics or science. The lead teachers and the other teachers in their schools were similar with respect to gender, ethnicity, and educational level. One difference between the two groups was that the other teachers included 46% who taught in grades K-2.

The project was designed to help improve science and mathematics teaching in North Carolina elementary schools. The overall project plan included site-based planning based on needs assessments, professional development that was responsive to the needs of the lead teachers at that site and that reflected national standards, involvement of the lead teachers and principals in the change process, and "fostered[ing] collegiality through peer teaching" (Franklin, 1993, p. 2). Additionally, the project was designed to be long term, include follow-up activities, provide support to lead teachers and schools, and to encourage the development of groups of teachers who could help each other in the change process, and be responsive to the instructional level of the participating teachers.

Each participating school was represented by a team comprised of two teachers and their building principal. The lead teachers from each participating school conducted a Needs Assessment in science or mathematics or both with the teaching staff and the principal of that school. This Needs Assessment (Franklin, 1990) was based on the National Science Teachers Association Self Assessment (Voss, 1987) and rated items on importance and achievement. The Needs Assessment data for each participating school was used by that school to identify perceived strengths and weaknesses in order to develop a School Improvement Plan (SIP). The SIPs were used by each program coordinator to plan a unique professional development program that was responsive to the needs of the 12 schools in that program.

The professional development programs varied from 110 to 141 contact hours, with incomplete data on one program. Project guidelines suggested a leadership component be included in the professional development program, that principals be involved in the development and implementation of school improvement plans, and that lead teachers would work with other teachers at their school to share activities, strategies, and equipment. Participating teachers attended three academic year sessions (about 10 contact hours), an intensive (approximately 75 contact hour) Summer Institute, about six follow-up sessions during the second academic year (10 contact hours), and a 25 contact hour Summer Workshop the final summer. While principal support and participation was a project requirement, actual support and participation varied. Lead teachers developed a variety of ways in which to share with their peer teachers; sharing strategies ranged from one-on-one contact to formal workshop presentations to the entire school faculty.

Additional demographic data, project timelines, and findings related to the project objectives are found in the Project Final Report (Franklin, 1993). Project Outcomes reported by Franklin (1993) included increased use of a hands-on, activity based approach to teaching mathematics and science, increased positive attitude by both teachers and students, and increased availability of mathematics and science resources. Studies that have examined different aspects of this project include the following: a reliability studies of the needs assessment instruments by Penta, Mitchell, and Franklin (1993); a case study by Vesilind and Jones (1993, 1998); and mathematics professional development by Bright, Miller, Nesbit, and Wallace (1997).

This paper, using a holistic perspective, examined data from the Project Final Report (Franklin, 1993) and four studies that examined particular aspects of this project related to professional development, teacher leaders, and school change. The four studies include the following: one that examines the models (Table 1) of professional development used at the different university sites (Wallace, et al., 1996); the use of these models in the schools by the lead teachers (Nesbit, et al., 1995); the designs and components of the professional development experiences (Miller, et al., 1997); and the factors lead teachers said were important to include in professional development (Nesbit, Wallace, Miller, & DiBiase, 1998). This paper, using qualitative methodology and a holistic approach that "gathers data on multiple aspects of the setting under study in order to assemble a comprehensive and complete picture of the social dynamic of the particular situation or program," (Patton, 1990, p. 50) examines the links among professional development, teacher leaders, and change in the teaching of science and mathematics that emerged from the multiple data sources.

This study does not attempt to be prescriptive or to provide a formula for implementing

professional development. Rather, the long term in-depth analysis of this large scale project, reveals some unique relationships among the various facets of professional development and school change in the teaching of mathematics and science. The linkages and insights can be used as a framework by professional developers in mathematics and science to help guide and structure new meaningful professional development experiences. This research is significant to designers of professional development in mathematics or science who are concerned with meeting a variety of needs in different contextual situations while being responsive to current national reform goals. Recommendations are made on the essential components of professional development that enhance school change in the teaching of science and mathematics. Additional recommendations are made with respect to the balance of time spent on content and pedagogy and leadership experiences, the components of these experiences and the types of learning experiences that are important for personal mastery of new knowledge, skills, and strategies.

Definition of Terms

Change in Instructional Practices in Teaching of Science and Mathematics-was provided by evidence that included written work and other products such as student products or documented experiences, planting gardens, observing animal behavior in the classroom, and that provide physical evidence of experiential learning on the part of the students as well as written student work.

Content and Pedagogy-a category within the professional development experience which included "presentations directly related to science, mathematics or both" (Miller et al., 1997, p. 10). Topics and activities related to pedagogy and those that integrated content and pedagogy were assigned to this category.

Leadership Content-"refers to formal presentations of leadership skills or topics that focused on developing teachers knowledge and skills in leadership and included topics such as leadership styles, change process, and workshop design" (Miller et al., 1997, p. 11).

Leadership Models (Table 1)- the names of the original models emerged from observational analysis by the Statewide project director of the projects' 15 professional development programs. The Project Director identified 7 models and gave them names that exemplified the characteristics of that model. The models and their names were not imposed by the researchers. The models of teacher leadership that emerged across university sites during this three year project were originally identified and named by Franklin (1993) then refined and clarified by Wallace, et al., (1996).

Leadership Planning and Practice-includes the opportunity to develop and use leadership skills such as working on school improvement plans, presenting lessons to other lead teachers, and processing and discussing leadership experiences" (Miller et. al., 1997, p. 11).

Lead Teacher-a regular classroom teacher who volunteered or was selected to participate in a professional development program then return to the school and work with other teachers; the responsibilities assumed by the lead teacher were in addition to their regular teaching schedule (Miller et al., 1997, p. 11).

Lead Teacher Activity Reports-were written program documents related to implementation and activities at the school or class level and that could include other documentation such as newspaper articles, newsletters, photographs or other forms of documentation.

Linkage-for the purpose of this study a linkage, as identified in the cells of the process outcome matrix, describes a connection or theme between a program component or process and a program outcome (Patton, 1990, p. 416).

Proactivity-is defined as the lead teachers "initiating the support of other teachers in bringing about school change" (Nesbit, et al., 1995, p. 7).

Professional Development-consists of learning experiences designed to help teachers and educators help themselves become more effective. In these learning experiences, educators can learn, develop, plan, practice, and enhance new skills, knowledge, strategies, and techniques.

School Level Dissemination -dissemination was substantiated by individual oral interviews at the school of two randomly selected teachers who were not involved in the study, as well as of the principal. Additional evidence was often provided by other documents or artifacts.

Sphere of Influence-refers to the area within the school that is influenced by the lead teacher, that is "where the change takes place" (Nesbit et. al., p. 7).

Research Questions

The research questions that guided this study were:

1. What are the links and connections among professional development, teacher leaders, and school change? How do they inform planners of professional development for teacher leaders?

2. What are the essential components of professional development for teacher leaders and how do they enhance school change in the teaching of science and mathematics?

3. How can professional development be designed to enhance and support school change in the teaching of science and mathematics?

Research Design

Patton (1986) states that the "holistic approach to research design is open to gathering data on any number of aspects of the setting under study in order to put together a complete picture; it also assumes that a description and understanding of a program's context is essential for understanding the program" (p. 40). This analysis "assumes that the whole is greater than the sum of its parts" (p. 40) and uses qualitative methodology as suggested by Lincoln and Guba (1985) and Patton (1986; 1990) to examine the connections and implications that emerged from the multiple data sources. The research questions guided and focused the search for patterns and linkages. The linkages and themes were not imposed by the researchers but emerged and unfolded from the data. As suggested by Patton (1990), a process-outcomes matrix (p. 415) was used to organize the data to identify linkages. According to Patton the cells in the matrix "describe linkages, patterns, themes" (p. 416) and the matrix itself helps present the "qualitative connections between program implementation dimensions and program impacts" (p. 416).

The design of this study is strengthened by the use of triangulation. According to Patton (1990), it "is possible to achieve triangulation within a qualitative inquiry strategy by combining different kinds of qualitative methods...and including multiple perspectives" (p. 188). Patton also suggests combining qualitative and quantitative methods to achieve triangulation. Both data triangulation and investigator triangulation as recommended by Lincoln and Guba (1985) were used in this study. The technique of triangulation improves "the probability that findings and interpretations will be found credible" (p. 305). Methods triangulation (Patton, 1990, p. 464) through different data collecting methods, triangulation of sources through interviews with different data sources, and analyst triangulation through the use of three independent researchers "contribute to verification and validation of qualitative analysis" as suggested by Patton (1990, p. 464). As recommended by Lincoln and Guba (1985, p. 301) credibility was established through prolonged engagement, persistent observation and triangulation of data and investigators. In this study, multiple sources, multiple methods, and multiple investigators were used to increase credibility and data collection occurred over a long period of time (three years) with a variety of data collection strategies.

Investigator triangulation is provided through the use of three different researchers (Miller,

Wallace, and DiBiase). These researchers independently analyzed the data and recorded the linkages and themes that emerged. The researchers compared findings with agreement needed from all three to establish a linkage or theme; as noted by Nelson (1993) the degree of consensus "indicated that the categories that emerged were effective for organizing and explaining the data" (p. 154). Interpretation of the themes and linkages "means attaching significance to what was found, offering explanations, drawing conclusions" (Patton, 1990, p. 423). The researchers compared interpretation with agreement needed from all three. This study identifies and examines the links and connections among professional development, teacher leaders, and school change in the teaching of science and mathematics.

Data

As part of the statewide project, qualitative and quantitative data were gathered from multiple sources throughout the three years of the project. Descriptive data on participants and schools were gathered during the first two years of the project. A school Needs Assessment (Franklin, 1990) was completed in either mathematics or science or both by all teachers and the principal at each of the 180 participating schools at the beginning and end of the project. At the end of the project, 173 schools and 325 lead teachers were still participating. Attrition was due to school closings, faculty turnover, deaths, and scheduling conflicts.

The Statewide Project director attended the initial visioning session and the leadership component of each of the 15 programs. She recorded observations and compiled written field notes on each of the programs. Throughout the three years of the statewide project written program documents such as program agendas and lead teacher activity reports, annual reports from program directors and site coordinators were gathered.

Structured Individual Interviews were conducted with fifteen schools (one from each of the 15 programs) that were randomly drawn. The individual, face to face Structured Interviews (MSEN, 1993) with the principal, lead teachers, and two randomly selected other teachers at that school were audiotaped and transcribed. The Structured Individual Interviews, Final Reports, Likert Scale Survey, and Open-Ended Assessment were gathered during the last year of the project with 288 Lead teachers across all sites and years completing the Likert Scale Survey (Franklin, 1993).

Data sources included qualitative data, such as individual, face-to-face Structured Interviews (MSEN, 1993) with each lead teacher, principal, and each of two randomly selected teachers. The Statewide Project Director with the help of Program Coordinators developed the structured interview protocol, which contained 50 questions for lead teachers, 26 questions for principals, and 21 questions for the other teachers in the school. The protocol was pilot tested and refined. Interviewers, who were members of the project staff, were trained.

During the academic year after the three week Summer Institute lead teachers completed formal activity reports as well as other informal and formal reports detailing information about project activities. Quantitative data included a Likert Scale Survey, an Open-Ended Assessment, and written Program Documents. The data for this research was provided by the Project Final Report (Franklin, 1993) and four related studies (Nesbit et al., 1995; Wallace et al., 1996; Miller et al., 1997; and Nesbit, Wallace, Miller, & DiBiase, 1998).

Data Sources

Written Documents

1. Demographic data-on each school, principal, lead teacher, and other teachers at the school.

2. Needs Assessment Data (Pre and Post Program Assessment) -completed by each teacher and principal at each school-included rating 30 items on achievement and importance in either

mathematics, science, or both. This form also included one Open-Ended Question relating to changes in the teaching of science and mathematics and Pre and Post-Program Attitude, the Pre-Program Attitude Survey was not collected from lead teachers in the first year of the project.

3. School Improvement Plans -for each school based on results of the Needs Assessment at that school, designed by the staff of the school, and modified over time if needed.

4. Lead Teacher Activity Reports -written documents that were not available at the time of the Project Final Report but were used to refine the models of professional development, and were collected throughout the second and third year of the project.

5. Written Program Documents-such as structured annual reports from program coordinators (which included a question asking for specific details of leadership activities), meeting agendas describing topics, speakers, and activities for all sessions; summer institute schedules; and presentations by lead teachers.

6. Lead Teacher Project Assessment-which consisted of a Likert Scale Survey for Lead Teachers (MSEN) and Open-Ended Questions. Using a 5 point Likert Scale, lead teachers were asked to rate the importance of 17 different aspects of the project. Additionally, two open ended questions were asked: "What aspects of the project helped you the most?" and "What would have helped more?"

Observations and Field Notes

The Statewide Project Director attended all presessions for each of the 15 programs as well as the leadership component of each of the 15 programs and recorded observations on each program in the form of field notes. These field notes were used in the initial identification of the models of teacher leadership.

Individual Interviews

1. Telephone interviews of each director and site coordinator from each of 15 programs that were audiotaped and transcribed with anonymity assured.

2. Telephone interviews with all university teaching staff and master teachers at each program which were audiotaped and transcribed with anonymity assured.

3. Face-to-face individual interviews at one randomly selected school from each of the 15 programs which were audiotaped and transcribed with anonymity assured of two lead teachers and the principal and each of two randomly selected other teachers.

The taped interviews were mailed directly to the Statewide Project Director at the Mathematics and Science Education Network, where they were transcribed. The Director made the transcribed interviews available to the researchers.

Additional Data Sources

The additional data sources used in this study include the Final Report of this statewide project (Franklin, 1993) as well as four studies that examined specific aspects of this three year project. A brief summary of the final report and each of the 4 studies that were used in this analysis to identify the links and connections is provided.

Project Final Report

The initial analysis of project data was by the Statewide Project Director who used four data sets:

written program documents, her field notes and observations, transcribed oral interviews of project staff, and transcribed interviews from the Structured Interview protocol. This analysis was reported in the Final Report of Project R168D00258-92 (Franklin, 1993), however, the teacher activity reports were not available for this report.

From this analysis the following emerged:

1. Descriptive demographic data on schools, teachers, and principals.

2. Initial description of 7 models of teacher leadership used by the 15 programs with the models varying in the dimension of proactivity of the lead teachers.

3. A description of each of the 15 programs, with the model of teacher leadership identified by the Statewide Project Director, amount of total time in the program, an estimate by program coordinators of the amount of time devoted to Content and Pedagogy and to Leadership and Planning, an estimate of the amount of direct and indirect leadership content (low, medium, high), an estimate of the amount of time for lead teachers to practice leadership, and the expectations of the lead teachers when they returned to their schools (Franklin, 1993, p. 66).

4. A list of leadership topics and activities used by the 15 programs (Franklin, 1993, p. 68).

5. Lead teachers rated the most important aspects of the Program for Project Implementation on a 17 item 5 point Likert Scale.

6. Documentation related to project goals, objectives, and outcomes.

Study 1: A Comparison of Program Coordinators' Leadership Models in Science and Mathematics and Lead Teachers' Implementation of Those Leadership Roles in the Schools: Is there a Match? (Nesbit, Wallace, & Miller, 1995).

This study compared the Leadership Model used in a particular program with the model used by the lead teachers when they returned to their school. Using the initial models from Franklin (1993), three researchers refined and clarified the models. The seven models varied on proactivity and sphere of influence of the lead teacher. The lead teachers' implementation of the model in the school was identified by analyzing and comparing individual in-depth transcribed interviews of five individuals at the school level, the principal, each lead teacher, and two other randomly selected teachers. This triangulation of data sources provided verification. Findings from this study indicate that in 10 of the 15 schools lead teachers did replicate the model of leadership that was presented to them in their professional development program. In one school, there was no evidence of any project implementation, in 4 schools, the lead teachers implemented a different model than the one presented to them in their professional development. An additional finding was that interview data at the local school level provided evidence of project dissemination.

Study 2: Six Leadership Models for Professional Development in Science and Mathematics (Wallace, Nesbit, & Miller, 1996)

The purpose of this study, was to clarify and describe the Leadership Models (Table 1) that emerged during this three year statewide project. An additional data source, lead teacher activity reports, that was not available for the project final report or Study 1 was used to further refine the models. Additionally, the Statewide Project Director and the three researchers reviewed and reanalyzed the data and refined the revised six leadership models: Classroom Teacher, School Facilitator, Resource Manager, Instructional Manager, Change Agent, and Leadership Choice. These models varied on the level of proactivity of the lead teacher. Of the 15 interviewed schools, 3 were identified as Classroom Model, 8 as School Facilitator Model, 1 each for Resource Manager and Instructional Manager, and 2 for Change Agent Model.

Study 3: Design of Professional Development for Science and Mathematics Teacher Leaders and

Resulting Implementation in Schools (Miller, Wallace, & Nesbit, 1997)

The purpose of this study was to analyze and describe the components of the professional development experience for each of the six leadership models as well as to identify relative percentages of time devoted to specific components. This study also examined the connection between the components of the professional development experiences and the resulting implementation of these programs at the school level. The relative percentages of time devoted to specific components of professional development as reported by Franklin (1993) were estimates by each program coordinator. For this study, three researchers analyzed all project documents including agendas and course syllabi for each of the 15 programs. To determine total time involvement, the number of hours was determined by recording 5 minute intervals. Analysis of the data revealed four emergent categories: content and pedagogy, direct leadership, leadership content, and leadership planning and practice. The three researchers refined and clarified these categories and refined the terminology for consistency across programs.

No attempt was made to quantify the amount of time spent in indirect leadership, as this was a part of all 15 programs and program documents did not provide this information. Content and Pedagogy refers to "presentations directly related to science, mathematics, or both such as biological concepts, energy concepts, fractions, and those topics or presentation that integrated content and pedagogy" (Miller et. al, 1997). The category of Direct Leadership includes the two categories of Leadership Content and Leadership Planning and Practice. Leadership Content included the following leadership styles, roles, and models; teacher change and the change process; and formal peer coaching. Leadership Planning and Practice included developing and using skills in working with peers and administrators. Examples of this category include: processing and discussing their leadership experience, problem solving, and planning for school implementation. Comparison of the professional development programs' design and time involvement (Miller et. al, 1997, p. 42) with ratings assigned to each category of low, medium, or high indicated significant differences among the models with the greatest differences seen between the least proactive, Classroom Teacher Model, and the most proactive, Change Agent Model. The total hours of professional development varied from 102 to 141 hours. The number of hours devoted to Content and Pedagogy ranged from 67-109 hours, Leadership Content varied from 3-28 hours, and the time for Leadership Planning and Practice varied from less than 10 hours to 31 hours. In some cases, complete data were not available for each professional development program. The very and highly proactive models devoted 27 or more hours of professional development to the category of Leadership Planning and Practice. The less proactive models devoted less than 17 hours of time to Leadership Planning and Practice.

Study 4: What Science and Mathematics Teachers Say Are Important Aspects of Professional Development for Teacher Leaders (Nesbit, Wallace, Miller, & DiBiase, 1998)

This study identified the most important factors for professional development as stated by teacher leaders. Data sources included a Likert Scale Survey, an Open-Ended Assessment and Structured Interviews. Lead teachers identified factors in three categories: content and pedagogy, leadership skill development, and delivery of professional development.

Learning content and pedagogy by using hands-on activities was identified as the most important part of the professional development. Other important aspects included learning pedagogical strategies, enhancing in depth knowledge in the content area, learning about curriculum materials and resources, and managing resources.

Developing leadership skill was also an important aspect to teachers. This category included learning about making presentations skills, the change process, nature of leadership, adult learning, sharing instructional information, sharing challenges and solutions, working on school improvement plans, and sharing activities and resources with other teachers.

The delivery of the professional development experience and the on-going support by the project staff were important to teacher leaders. Teacher leaders cited the modeling and demonstration of

techniques by project staff and master teachers as being valuable. Teachers also identified receiving instructional materials and resources to use in the schools as beneficial.

In summary, each of these four studies examined a specific facet of this statewide project. Analysis of what was learned from each of these studies suggested further investigations. The researchers gathered insights from each study, however, it was not until all 4 studies had been completed that it became clear that much could be learned from a holistic analysis.

Data Analysis

Three researchers independently read and analyzed the Final Report (Franklin, 1993) and each of the four related studies listing any connections or links related to professional development, teacher leaders, and school change in the teaching of mathematics or science. The researchers were explicitly looking for connections and reexamined studies to identify key aspects of each study and its relationship to the following points: professional development, teacher leaders, and school change in the teaching of mathematics and science. The links that emerged were not apparent until all studies were completed. Links emerged from an analysis of results or what was learned from each of the studies. The links, therefore, built on each other but did not necessarily follow a chronological order.

The three researchers then compared their findings and refined the list of links and connections with agreement needed among all three for inclusion of a linkage or theme. The researchers agreed on an explanation for each link and provide descriptions that are needed to clarify these connections.

To further clarify the linkage between the design and components of the professional development experience and lead teacher proactivity, the researchers re-examined the data on the professional development programs of the most proactive lead teachers, where lead teacher proactivity was evidenced by school change as indicated by interview data and program documents. The researchers used the following three categories that emerged in a related study (Miller, et al., 1997): Content and Pedagogy, Leadership Content, and Leadership Planning and Practice. The three researchers identified the components of the categories related to the most proactive lead teachers, identified emerging themes for those components, the relative percentage of time for each category, and compared and compiled their findings with agreement needed among all three researchers for inclusion of categories, themes, and relative percentages of times.

Results

The linkages that emerged in this study are reported in Table 2. This process-outcome matrix describes the relationship among the data sources, the linkage or outcome, and the theme of that linkage. Each link and theme is explained and illustrated. The initial analysis by three researchers identified the following links: Link 1- Different models of teacher leadership presented in professional development programs varied in proactivity; Link 2- Lead teachers tended to reproduce the model of professional development they experienced; Link 3-The greatest evidence of school change was from schools with highly proactive teacher leaders; Link 4-Design of the professional development experience impacts the proactivity of the teacher leaders; Link 5- There is a critical mix of key components of professional development that enhances teacher leader proactivity.

Link 1: Different models of teacher leadership presented in professional development programs varied in proactivity

Explanation of Link 1

The models of teacher leadership (Table 1) that emerged across the 15 professional development programs were initially identified by Franklin (1993) and refined by Wallace, et al., (1996) and varied on two dimensions-proactivity and sphere of influence. The least proactive lead teachers

were proactive in their own classroom-their sphere of influence, but their influence was rarely felt beyond their own classroom. The most proactive lead teachers were highly involved in initiating change, involving other teachers on their faculty, and facilitating and enhancing change at the school level, these teachers' sphere of influence was often the entire school. Were there differences in the design of the professional development programs that impacted the proactivity of teacher leaders?

Theme of Link 1 "Pebbles in the ocean or fountains of change?"

Teacher Leader proactivity varied with models of professional development.

The professional development programs provided different views on the proactivity of lead teachers. In the case of the Classroom Teacher Model, the lead teacher was viewed as one who was a role model in the classroom rather than at the school level and is characterized by a lead teacher who said, "If people come and say, 'what should we do with this?' I'm available."

In contrast, other professional development programs viewed the lead teacher in a more proactive role. Addressing this more proactive role a lead teacher said, "We practiced the leadership skills of enabling others to act in order to promote input from others. In order to maintain the process necessary to make changes and to inspire the faculty to be persistent with their efforts, they planned celebrations along the way." Another lead teacher said it this way, [we saw the importance of] " ... planning for small wins that promote consistent progress."

"The entire faculty at the school was to be active in making decisions, implementing and supporting changes in the way science was taught at their school and it was the role of these lead teachers to get this faculty involvement. In order to get this collaboration, the lead teachers needed to develop their own leadership skills as well as the leadership skills of their faculties" (Wallace, et al., 1996, p. 24).

In some professional development models, the role of lead teacher proactivity was like that of dropping small pebbles into the ocean, the lead teacher might be proactive in her own classroom, but caused few ripples in changing the teaching of science or mathematics across the grade or school. In other models, the proactivity of the lead teacher was viewed as a catalyst for collaboration and enabling school wide change-change like a continuously flowing fountain that recycles and renews.

Link 2: Teacher Leaders tended to reproduce the model of professional development they experienced.

Explanation of Link 2

Lead teachers tended to reproduce at the school level the model of teacher leadership they received in their professional development experience. The model of teacher leadership and the role of the teacher in that model used at each of the 15 programs was identified through program documents, observations, and interviews (Nesbit, et al., 1995; Wallace et al., 1996). One study (Nesbit, et al., 1995) compared the model of teacher leadership the lead teachers received with the model the lead teachers implemented in their school. In 10 of 15 cases, lead teachers replicated the model of teacher leadership presented to them in their professional development program, at 4 sites lead teachers' implemented a different leadership model, and at one site the lead teachers implemented no leadership model. Individual interviews with the two lead teachers, the principal, and each of two randomly selected other teachers at the school were used to provide evidence for the model of leadership implemented by the lead teachers at the school level.

Theme of Link 2 "Reflection in the water."

At the school level, teacher leaders replicate the professional development they experience.

The range of models of leadership that were implemented by the teacher leaders at the school level varied. In explaining the primary strategies to be used by lead teachers in one model, which would include demonstrating and modeling new techniques in their own classroom, "... [teacher leaders] would incorporate inquiry, hands-on types of activities for their own students, and try ...by modeling and demonstration to encourage other teachers ... to do that as well" (Wallace, et al., 1996, p. 17). Unfortunately, this sharing occurred "as they were passing each other on the sidewalk" (p.18).

At one school, a principal stated, "They [other teachers] have looked at our lead teachers as the experts on this area. And we are now in the process of setting up a math and science room here." One of the randomly selected teachers (not a lead teacher) at a school said that the lead teacher had "ordered books and ordered resources for us to use. She has been a tremendous resource person to order the things." One lead teacher stated that she remember a lady "coming and talking to us about leadership skills, but I don't remember that being beneficial that much. The thing I think was the most beneficial in leadership skills was the role model offered by the university instructors and master teacher." She added, "...your role model showed us more than anything...the role model was set for us in showing us what to do...I don't think there was anything else that could have been done that would have helped us."

One lead teacher described the role of the university site coordinator and instructor as follows, "I knew you were the lead [instructor] of the group, but then other people would come up and do different parts of it...and you all would help and cooperate and then you all would go around and actually did it with them. A lot of times, I thought you would lead and then step back and watch the other work, but I learned as a leader I would also get in and work with them to do the activities." She added, "I think that was important for me to see how you organized the project, and we tried to organize in a similar way here."

A principal was describing an example of a model that was replicated at the local level when sharing the following, "I think it's probably one of the most successful workshops [presented by the lead teachers] that I have had in my experience in the school-based workshops, because there were so many teachers involved and so much teacher enthusiasm ...it was planned by teachers...teachers in the building."

Only one school provided evidence of a lack of implementation of any model of teacher leadership, quotes from principals and other teachers at the school address this. One principal stated that "our faculty knows nothing of the project. They [the lead teachers] have shared very little [about the FIRST Project] with me. We have done very little implementation of the project." These thoughts were echoed by a fellow teacher who said "well, at this point, to be honest, not a whole lot "[has been done by the lead teachers]. As an image is reflected in the water, teacher leaders tended to reflect many aspects of their professional development experience.

Link 3: The greatest evidence of school change was from schools with highly proactive teacher leaders.

Explanation of Link 3

The schools with highly proactive lead teachers demonstrated the greatest evidence of school change in the teaching of science and mathematics. The models of teacher leadership varied in proactivity of lead teachers and ranged from less to more proactive, some teachers made changes in their own classroom in the way they taught science or mathematics while other teachers' influence was felt outside of their own classroom. In other cases the lead teachers actively collaborated with other peer teachers and promoted school change. The transcribed individual interviews at the school level (of the principal, each of two randomly selected other teachers, and each of the two lead teachers) provided evidence of school change in the teaching of science and mathematics. Examples of school change included but were not limited to the following: evidence from schools with less proactive lead teachers indicated little change other than at the classroom level, those schools with teachers who were more proactive indicated changes such as the establishment of a science room, or of lead teachers who were liaisons or who directly promoted science or math. Highly proactive teacher leaders empowered their peers to implement schoolwide change.

Theme of Link 3 "A trickle or a dynamic flow?"

Evidence of school change related to proactivity of teacher leader.

In schools with less proactive lead teachers, the change was often at the classroom level as evidenced by a randomly selected other teacher who stated, "you can go to them [the lead teachers] because you know that they are doing those kinds of things in their own class and they are always willing to help." This teacher indicated the less proactive role of the lead teachers in her school.

Another teacher described the slightly more proactive role of the lead teachers at her school as follows, "She [the lead teacher] goes through the activities and we actually do them. And then she gives us the information and things we'll need to do them in the class, and then we go back and try them. And then we'll get back with her and let her know how things went." This teacher's comments provided evidence of the more proactive role the lead teachers took at her school. A principal from one school describing this more proactive role stated, "They [lead teachers] have planned workshops and presented them...They started off at the first of the year just sharing ideas and materials with teachers whom they thought would be receptive to the ideas." At one school a teacher said, "I certainly see more 'sciency' things going on and we are establishing the science lab upstairs now so that we're beginning to see the good effects of that." This teacher described the more proactive role of the lead teachers in her school, as they were in charge of setting up a school science lab. Commenting on changes at one school, an interviewed teacher said, "I think some of the changes are because of the materials being there, ...but as far as here we all share everything." Speaking about the project impact this teacher added, "Not being afraid of science, knowing that we have the materials available. Knowing there is someone [the lead teachers] there to show you through an activity, to help you with it that's real important. Not being afraid."

The highly proactive lead teachers encouraged and supported the faculty in making changes at the school level. As one principal giving evidence of the proactivity of the lead teachers described changes at his school, "...reorganizing the science room, the materials room into units. So the whole staff was broken up into different groups and doing grade level units to better organize the materials." At a different school one lead teacher described her approach, "I do better getting people all working and cooperating. That's sort of how we evolved here. We've organized meetings...we made a book on weather for each grade level." At a different school, the highly proactive lead teachers "...organized Family Science Night and got a lot of parent involvement on that." Just as water in a fountain may trickle or flow dynamically, the impact teacher leaders have on effecting change in schools may be as minimal as a trickle or as powerful as a dynamic flow.

Links 4 and 5

Link 4 and Link 5 are related as indicated in Table 2 by their inclusion in the same cell of the

matrix. The actual design of the professional development included the categories, components, and relative emphasis given to each.

Link 4: Design of the professional development experience impacts the proactivity of the teacher leaders.

Explanation of Link 4

The design of the professional development programs for the 6 models of teacher leadership were described in a study by Miller, et al., 1997. This study identified three categories that emerged in the 15 professional development programs to improve science and mathematics teaching. These categories were "Content and Pedagogy," "Leadership Planning and Practice," and "Leadership Content." The design of the professional development programs varied in time and emphasis of these three categories. The design of the programs with more proactive lead teachers were those which in addition to emphasis on Content and Pedagogy provided Leadership Content and placed a strong emphasis on Leadership Planning and Practice.

Although all programs emphasized Content and Pedagogy, this emphasis ranged from about 60% to 80% of the total time for professional development. The emphasis on Leadership Content varied from approximately 3% to 20% of the total time, while that of Leadership Planning and Practice varied from 11% to 25%. The teachers whose professional development programs provided 20% - 25% of the time on Leadership Planning and Practice were more proactive lead teachers. In contrast, lead teachers in professional development programs that provided less than 15% of the time in Leadership Planning and Practice were less proactive lead teachers.

Theme of Link 4 "Design of the fountain influences flow."

Professional development design influences teacher leader proactivity.

One lead teacher related the importance of several components of her professional development experience, "...we sort of gained confidence in working with people that we didn't know, peers in our teaching profession that we didn't really know,...so I think that actually working with teachers at the Summer Institute is a big difference." She added, ... "when we came back that first summer and we were all gung-ho...I think some of the points she brought out on how to approach the ones [teachers] that were reluctant..." The inclusion of Leadership Content and Leadership Planning and Practice were revealed in this teacher's comments. An interview with a randomly selected teacher at this same school reveals the following when asked about the project at her school, "Well, basically [the lead teachers] came back really pumped up. And I think that's great! I mean we had a real good workshop [presented by the lead teachers] at the beginning of school....and they shared with us."

Commenting on the importance of the design of the three-week Summer Institute, one lead teacher said, "I think it helped that we had to teach the group [of other lead teachers]. I think that was a good idea of the summer institute that we had to get up and present something so you got used to being in front of adults...because I'm not used to teaching or working with them [adults]...and learning to work with adults in a leadership role is different than working with children."

At a different site one lead teacher describing part of the professional development experience said, "The person who did our leadership session was tremendous. She knew exactly how to get us fired up, and show us how to go about improving our leadership skills. And the other lead teacher was a tremendous support and we practiced leadership with each other." In much the same way as a fountain's design can restrict or enhance the flow, the design of the professional development experience can either diminish or empower teacher leaders' proactivity.

Link 5: There is a critical mix of key components of professional development that enhances teacher leader proactivity.

Explanation of Link 5

There is a critical mix of categories and components in the design of professional development that enhances lead teacher proactivity. The key components of the programs with highly proactive lead teachers were analyzed and are reported in Table 3. The three categories of the professional development experience were classified as (a) Content and Pedagogy, (b) Leadership Planning and Practice, and (c) Leadership Content and emerged in an earlier study (Miller, et al., 1997). The relative percentage of time as calculated from program documents devoted to each of the three categories is given in Table 3; the importance of the role of content and pedagogy is emphasized by the fact that 60%-70% of the total time was devoted to this category.

Table 3 identifies the specific components of each of those categories, the approximate percent of the total time devoted to each category, and the theme that describes or identifies that category. The themes that emerged were (a) the importance of content knowledge and pedagogical strategies and techniques in teaching science and mathematics, (b) the importance of developing and enhancing leadership skills, knowledge, and techniques, and (c) the importance of personal mastery of new techniques and knowledge through planning, practicing, and rehearsal.

The category of Content and Pedagogy included experiential learning for teachers; strengthening science and mathematics content knowledge; demonstration and modeling of techniques by project staff; curriculum materials and resources supplied to teachers; and using standards-based pedagogical strategies.

The components of the category of Leadership Content included the following: visioning sessions for best practice; skills in working with school faculty, team building, and involving others; teacher change, the change process, and the Concerns Based Adoption Model (CBAM) (Hall & Hord, 1987). This category also included learning about leadership styles, roles, and models; grant writing; adult learning and learning styles; management and use of resources; workshop design and presentation; time management; school culture; formal peer coaching; and leadership skills assessment.

The category of Leadership Planning and Practice included the following: working with principals; working on school improvement plans (SIP); sharing activities and resources formally and informally with other teachers; and presenting lessons to other lead teachers. Other components included processing and discussing their leadership experience, problem solving; obtaining funds; practicing informal peer coaching; networking with other schools; working with parents and business; assessing peer skills; and practicing formal peer coaching. Two factors that emerged in the design of the professional development for the most proactive teacher leaders were the time provided for planning for school and class implementation and the opportunity for co-designing and/or co-teaching the professional development experience. The differences between the highly proactive teacher leaders and less proactive teacher leaders was revealed by the relative emphasis placed on leadership planning and practice in their professional development programs.

Theme of Link 5 "Essential parts are critical for a fountain's dynamic flow."

Key components of professional development enhance teacher leader proactivity.

The goals of one professional development program with highly proactive lead teachers included: (a) "a climate that fostered the lead teachers investment, ownership and participation in decision making, and the knowledge to create this same climate for their peers, and (b) a setting that established administrative and collegial support for the lead teachers ... for every leadership content topic presented, time was given to the lead teachers to plan and practice using this new knowledge in the writing, implementing, and revising of their school improvement plans" (Miller, et al., 1997 p. 31).

The importance of Content and Pedagogy is illustrated by this teacher's statement, "Through this mathematics workshop, I began to understand and learned a little more about how teachers taught fractions. Or how they teach children to work with decimal points and things These are things that I never really thought about, but as a lead teacher, you have to learn more about it, because you are responsible for giving ideas to those teachers in other grades besides just the ones that you are comfortable with."

A different teacher describing the importance of Leadership Content knowledge said, "How to teach a workshop, how to make it interesting, how to plan for the comfort of the other teachers as far as just the physical things. Because I had never done a workshop before. That was very helpful in being a lead teacher."

The category of Leadership Planning and Practice is illustrated by this teacher's comments, "The leadership helped me tremendously because presenting is not my main thing. The other lead teacher was a tremendous support and we practiced leadership with each other. And when the other lead teacher came for observations with me, that helped me tune in on what I needed to do as far as presentations because several of her observations were of me presenting to the faculty." Designing professional development for highly proactive teacher leaders is a complex endeavor. A number of parts all working in harmony are required to give a fountain a dynamic flow. In similar fashion professional development programs that enhance teacher leaders' proactivity are carefully crafted with a critical mix of key components.

Limitations

Two of the three researchers had a vested interest in the statewide grant with one serving as a site coordinator for three years and one as a site director and coordinator for two years; both of those researchers also served as university instructors in portions of the professional development programs. The degree to which the professional development sequence for each program reflected the needs of the schools in that program could not be determined as complete data were not available. The categories and components of the professional development experiences were identified through program agendas, course syllabi, and other documentation; the degree of adherence to the scheduled topics and activities was not available from project data. Additionally, the categories and components reflected the needs identified by the schools participating in that particular program.

Discussion and Interpretation

The initial studies and analyses related to this project placed no value judgment on the different models of professional development valuing each as being appropriate in different circumstances. The introduction of new national goals (e.g. National Science Education Standards, 1996) call for a new type of organization for teachers and schools, for "...schools that are centers of learning in their communities, with different clientele and new learning goals. In such settings, collaboration is critical, teachers become co-learners, and building cultures and environments for learning replaces the traditional ideas of classroom teaching" (Loucks-Horsley et. al., 1998, p. xi).

This study reports and analyzes the links among professional development, teacher leadership, and school change in the teaching of science and mathematics. The results provide a framework for supporting professional development in mathematics and science. The importance of content knowledge to include knowledge of appropriate pedagogical strategies was emphasized by the amount of time devoted to that category in all 15 of the professional development programs. This study suggests the importance of embedding standards-based pedagogical strategies when developing new content knowledge. Kuboto (1997) in discussing the work of Lee Shulman and his colleagues stated that "expert teachers know not only their subject matter and possess a variety of teaching strategies but that they possess pedagogical content knowledge" (p. 141). Expert teachers can combine content and pedagogy to "come up with the most effective teaching strategy for that content" (p. 141). In addition to knowledge of content and pedagogy, teachers of science and

mathematics also need materials and equipment, as well as the knowledge of how to incorporate them for effective instruction.

While many studies report on the need for teacher leadership, few give information about specific factors, especially ones related to science or mathematics. The components of the category of Leadership Content that emerged in this project can provide guidance for designers of professional development. These components provided a base for teachers to enhance their leadership skills.

"Polishing the Stone"

The importance of the category of Leadership Planning and Practice that emerged in this study included several elements that fostered collaboration and collegiality. As one lead teacher said, "The training as a lead teacher was important; however, the relationship with fellow teachers was a learning experience and a valuable asset to me." Pellicer and Anderson (1995) state, "placing teachers at the center of the staff development process means they not only will determine the nature and scope of programs for their own professional growth but also will assume a major share of the responsibility for helping and supporting each other in their efforts to grow" (p. 152). Other components of this category allowed the individual teacher to focus on personal mastery of new knowledge, techniques, or skills. The focus on practice of new skills by teachers in a setting where teachers can take risk allows each teacher the opportunity to focus on personal mastery by practicing the new skill, technique or knowledge. This personal mastery is "polishing the stone" (Loucks-Horsley & Kuerbis, 1999). The category of Leadership Planning and Practice emerged as a critical component of this professional development experience.

The literature on professional development reveals that little attention has been given to the role of practice in helping teachers acquire new knowledge and skills. Pellicer and Anderson (1995) note that "...teaching is an extremely complex profession, requiring extensive training and practice before a reasonable level of proficiency can be obtained" (p. 140). The importance of practice (repetition) and rehearsal in forming connections in the brain has been recognized. Yet, if connections are not used they may be lost. "The quality of the connections and the extensiveness of the connections within the brain's systems constitute how well something is understood or how well an individual can perform" (Lowery, 1998, p. 6). The results of this study suggest that practice and rehearsal are important components to be included in the design of professional development to achieve personal mastery. As part of this internalization, the individual can also personalize the new knowledge and achieve personal mastery.

As Pellicer and Anderson (1995) state, "Although many teachers have consistently demonstrated their ability to lead, some have not had an ample opportunity to develop and practice leadership skills" (p. 13). While Leadership Planning and Practice emerged as an important category for enhancing proactivity in lead teachers, it is perhaps informative to note that the Likert Scale Survey of Most Important Aspect of Program as rated by 288 lead teachers in this statewide project, the item with the lowest importance rating on a 17 item scale was that of "Role playing the scenario of lead teachers working with other teachers at their school" (Franklin, 1993, p. 72). This might suggest that teachers do not recognize the importance of practice in developing their own new skills and techniques. The authors do not suggest that the practice component should be interpreted to mean lead teachers mimic or copy, but rather that each individual has an opportunity to practice and internalize the new knowledge, skills, or techniques to achieve one's own personal mastery.

Conclusions and Recommendations

Like dropping pebbles in the ocean, the traditional forms of professional development have resulted in little change. Yet the new forms of professional development that are called for by national standards and by business and government leaders cite a need for change in the status quo of current systems. Mandating changes in systems rarely works (Fullan, 1996), "it is people who change systems, through the development of new critical masses" (p. 423). Fullan further

suggests that one step in the development of this critical mass is by identifying the "strategies that mobilize large numbers of people in new directions" (p. 423). This study identified elements of professional development design that enhance change at the school level and, further, explicitly describes essential categories and components.

"Building a Fountain"

Findings of this study provide new insights in the design and delivery of professional development experiences as it relates to teacher leaders and school change in the teaching and learning of science and mathematics. Professional development programs must do more than drop pebbles in the ocean, they must build dynamic fountains of change. This new look for professional development according to Lieberman and Grolnick (1997) includes "formats for work more collaborative than individualistic; attempts at change more integrated than fragmented; approaches to leadership more facilitative than directive...an appreciation for both context-specific knowledge and generalized knowledge" (p. 213). The need for new forms of professional development to facilitate reform is indicated by Radford, Ramsey, and McGee-Brown (1998) who stated, "If reform of science teaching and learning is to be accomplished, it is necessary to understand the components that are essential to ensure the success of a professional development program" (p. 1).

Results of this study indicate categories and components in the design of professional development experiences for implementing and supporting school change. New standards and goals call for new forms of professional development. The "Professional Development Design Process for Mathematics and Science Education Reform" described by Loucks-Horsley et al., (1998, p. 17) includes the following four components: Set Goals, Plan, Do, and Reflect and takes into account context, critical issues, knowledge and beliefs, and strategies. This study would suggest that a critical component of this design process is in the "Do" component. It is in this component that attention should be given to the three categories of Content and Pedagogy, Leadership Planning and Practice, and Leadership Content. Further, attention should be given to the individual components of these categories and the relative emphasis to each category in the overall design of professional development. While leadership has been recognized as an important aspect of professional development (Friel & Bright, 1995; Loucks-Horsley et al., 1998; Pellicer & Anderson, 1995) the specific aspects of leadership and the emphasis on planning and practice has been a neglected part of professional development design.

This study was based on a three year statewide program to improve elementary mathematics and science teaching and used site-based planning based on needs assessments, professional development that was responsive to the needs of the lead teachers at that site and that reflected national standards, involved the lead teachers and principals in the change process, and fostered collaboration and collegiality.

Recommendations

The design and delivery of effective professional development involves numerous complex factors. While recognizing the important aspects that have previously been identified in other studies (e.g. Clarke, 1994; Friel & Bright, 1997; Hall & Hord, 1987; Loucks-Horsley, et al., 1998) such as the importance of long-term support, understanding the change process, developing knowledge and skills, and enhancing teacher leadership, this study identified categories and components specific to the needs of mathematics and science teacher leaders. Based on this study, recommendations are made on the design and specific aspects of professional development experiences for teacher leaders involved in implementing and supporting school change. The recommendations include the following:

1. Professional development should be designed to reflect the needs of the participating teachers and schools, be based on standards, on the desired goals, the desired outcomes, and contextual

issues.

2. The design of the professional development should include the three categories of Content and Pedagogy, Leadership Content, and Leadership Planning and Practice; in this study the components of these categories that emerged reflected the specific needs identified by the participating schools and are given in Table 3. The components of Content and Pedagogy include those experiences that would strengthen content and pedagogical knowledge. The components of Leadership Content are ones that provide the lead teacher with knowledge of the nature of the change process, adult learning, workshop design, and leadership skills. The components of Leadership Planning and Practice provide opportunity for collaboration, sharing, planning and practice, and internalizing new knowledge and skills and allows time for personal mastery.

3. In designing and delivering professional development for teacher leaders in science and mathematics, Content and Pedagogy should receive the greatest emphasis. Another important aspect is that of modeling techniques and pedagogical strategies by university faculty and master teachers. In addition, teacher leader participation in planning and coteaching the professional development experience emerged as a key component.

4. The category of Leadership Content is important in providing the lead teacher with the opportunity to develop skills and knowledge of how to work with others.

5. It appears that the indispensable aspect of professional development that is often neglected is Leadership Planning and Practice. The powerful influence of the components of this category, Leadership Planning and Practice provides the teacher with the opportunity to develop personal mastery through rehearsing, practicing, planning and internalizing new learning.

6. Providing the time, as part of the professional development experience, for teacher leaders to plan for school and classroom implementation is vital for enhancing school change.

In the design of professional development it is vital to include all 3 categories. With the recommendation of standards-based instruction, a major emphasis should be placed on Content and Pedagogy, however, significant emphasis should be given to Leadership Planning and Practice, with sufficient attention to the category of Leadership Content to prepare the lead teachers in working with peers to facilitate change. Yet, Leadership Content alone, is not sufficient. The key ingredients, that are often neglected, are found in the category of Leadership Planning and Practice, for these are the elements that teachers need to nurture and enhance school change.

More studies are needed to examine the mix and emphasis of these categories and their components (Table 3). The components described in this study enhanced lead teacher proactivity in bringing about change in the way science and mathematics was taught in their schools. This analysis is important is because it bridges the gap between knowledge and practice. One reason for this gap, according to Loucks-Horsley et al., (1998) is "the lack of rich descriptions of effective programs constructed in various contexts addressing common challenges in unique ways" (p. xii). This study provides detailed description of the categories and components of professional development programs that enhance change in the teaching of science and mathematics and illustrates these categories with teachers' voices.

Teachers are as vital to the change process as the individual droplets of water in a fountain. Teachers, energized with effective professional development, can enable and support a fountain of change in the teaching of mathematics and science at the school level. Professional development, teacher leaders, and school change are chelated and linked with multiple bonds. Professional development is a critical component that links "purposes and policies and influence[s] student learning through its impact on teaching" (Loucks-Horsley, 1998, p. 1). Yet, the importance of teacher leadership in improving professional development, according to Pellicer and Anderson (1995) "is the key to unlocking that potential and to releasing a tremendous wave of creativity and energy spawned by tens of thousands of teachers in classrooms across the country" (p. 167). With

new national goals and standards, the challenge is to design professional development that meets the needs of the teachers and serve as a catalyst for proactivity in fostering a fountain of change at the school level that will support and enhance the teaching of science and mathematics.

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Author Note

Anne-Courtney S. Miller is a Research Consultant with the Mathematics and Science Education Center of the University of North Carolina at Charlotte. Josephine D. Wallace is an Associate Professor in the Department of Reading and Elementary Education and Director of the Mathematics and Science Education Center at the University of North Carolina at Charlotte [email jdwallac@email.uncc.edu]. Warren J. DiBiase is an Assistant Professor in the Department of Middle, Secondary Education, and K-12 Education at the University of North Carolina at Charlotte [email wjdibias@email.uncc.edu]. Catherine R. Nesbit is an Associate Professor in the Department of Reading and Elementary Education at the University of North Carolina at Charlotte [crnesbit@email.uncc.edu].

The three authors who participated in the research process and in the writing of this article were Anne-Courtney S. Miller, Josephine D. Wallace, and Warren J. DiBiase. The fourth author, C. R. Nesbit, was included because of her work and research on previous related studies and was unable to participate in the research analysis or in the writing for this paper.

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At the time of the original statewide project (1990-1993), Anne-Courtney Miller was with the Department of Pedagogical Studies (now the Department of Curriculum and Instruction) at the University of North Carolina at Greensboro.

Correspondence concerning this article should be addressed to Anne-Courtney S. Miller, 173 Alexander Circle, Columbia, South Carolina 29206. She may be reached by telephone at (803) 787-6689, FAX at (803) 787-3924, or electronic mail via Internet to [acmiller@bellsouth.net].

Table 1

Leadership Models that Emerged from Lead Teacher Development Programs in Science and Mathematics

Model Name	Classroom Teacher	School Facilitator	Resource Manager	Instructional Manager	Change Agent	Lea
Level of Proactivity	Somewhat Proactive	Fairly Proactive	Very Proactive	Very Proactive	Highly Proactive	Sel
Sphere of Influence	Classroom	Classroom/ School	School	School/ District	School	Var
Description	• exemplify good content teaching in own class • provide support when asked • indirectly influence other teachers • responders not initiators	share information and resources with other teachers • share formally or informally • offer help to others without being asked	create, organize, and maintain science resource room • designated as contact persons for subject area • directly promote instructional change	designated by school as contact persons • directly promote instructional change • lead workshops to improve faculty's teaching skills	catalysts for change • inspire faculty to get involved in deciding changes initiating ideas and involving others	
Responsibility	• role models in own classrooms. • assist other teachers if asked.	• share new ideas and resources	• organize materials for school staff in lab. • coordinate workshops	• conduct numerous workshops • provide teaching demonstrations	challenge, inspire, motivate peers to initiate school wide change. • develop leadership skills in self and others	dep sele

Note. From "Six Leadership Models for Professional Development," by J. D. Wallace, C. R. Nesbit, and A.-C. Miller,

1996. A paper presented at the annual meeting of the National Association for Research in Science Teaching, St. Louis, MI.

Table 2

Matrix of Linkages and Themes related to Professional Development,

Teacher Leaders, and School Change

	Linkage	Theme
Link 1	Different models of teacher leadership presented in professional development programs varied in proactivity. (Franklin, 1993; Wallace, Nesbit, & Miller, 1996)	"Pebbles in the ocean or fountains of change?" Teacher leader proactivity varied with models of professional development.
Link 2	Teacher leaders tended to reproduce the model of professional development they experienced. (Nesbit, Wallace, & Miller, 1995; Wallace, Nesbit, & Miller, 1996)	"Reflection in the water." At the school level, teacher leaders replicate the professional development they experienced.
Link 3	The greatest evidence of school change was from schools with highly proactive teacher leaders. (Franklin, 1993; Wallace, Nesbit, & Miller 1997)	"A trickle or a dynamic flow?" Evidence of school change related to proactivity of teacher leaders.
Link 4	Design of the professional development experience impacts the proactivity of teacher leaders. (Miller, Wallace, & Nesbit, 1997; Nesbit, Wallace, Miller, & DiBiase, 1998)	"Design of the fountain influences flow." Professional development design influences teacher leader proactivity "Essential parts are critical for the fountains' dynamic flow."
Link 5	There is a critical mix of key components of professional development that enhances teacher leader proactivity. (Miller, Wallace, & Nesbit, 1997; and Nesbit, Wallace, Miller, & DiBiase, 1998)	Key components of professional development enhance lead teacher proactivity.

Note. Proactivity is defined as the lead teachers "initiating the support of other teachers in bringing about school change" (Nesbit, Wallace, & Miller, 1995, p. 7). The data sources for each linkage are listed under the link. Links 4 and 5 are related, as shown by their inclusion in the same cell.

Table 3

Professional Development Components for Preparation of Teacher Leaders in Science and Mathematics to Enhance School Change

Category	Components	Time (%)	Theme
Content & Pedagogy	• experiential learning for teachers • strengthening science & mathematics content knowledge • demonstration & modeling of techniques by project staff • curriculum materials & resources supplied to teachers • standards-based pedagogical strategies	60-70%	**Content Knowledge & Pedagogy** **Importance of content knowledge and pedagogy in science and mathematics teaching.**
Leadership Content	• visioning sessions for best practice • skills in working with school faculty, team building, & involving others • teacher change, the change process, CBAM model • leadership styles, roles, & models • grant writing • adult learning & learning styles • management & use of resources • workshop design & presentation • time management • school culture • formal peer coaching • leadership skills assessment	10-20%	**Leadership Skills** **Developing and enhancing leadership skills, knowledge, and techniques.**
Leadership **Planning & Practice**	• planning for school & class implementation • working on school improvement plans • working with principals • sharing activities & resources formally & informally with other teachers • presenting lessons to other lead teachers • processing & discussing their leadership experience, problem solving	20-25%	**Personal Mastery -** **Polishing the Stone** **Teachers' personal mastery of new techniques and knowledge through planning, practice, and rehearsal.**

	• obtaining funds • practicing informal peer coaching • networking with other schools • codesigning & coteaching professional development of lead teachers • working with parents & business • assessing peer skills • practicing formal peer coaching		

Note. Based on professional development programs of approximately 123-138 hours total time, extending over a two-year period.

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Research Consultant

Organization/Address: Telephone:803 787-6689 Fax:803-787-3924

University of North Carolina-Charlotte
173 Alexander Circle
Columbia, SC 29206
E-mail Address:
acmiller@bellsouth.net

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