This research examines grantees’ work to improve mathematics teacher quality in a nationally-funded program. The analysis employs qualitative methods using secondary source documents provided by 48 National Science Foundation Math and Science Partnership (NSF-MSP) grantees. Findings show that representations reported for mathematics teacher quality by the grantees mirror those used in previous research. Conditions used to influence mathematics teacher quality included research-based professional development, various roles for teacher leaders, and emerging collaboration between STEM and education faculty for the improvement of mathematics content knowledge for teachers at all levels.

The No Child Left Behind (NCLB) Act of 2001 and related changes to educational policies for teachers have escalated the focus on teacher quality and the need for more well-trained mathematics teachers in the United States. Teacher quality in mathematics has a significant impact on the teaching and learning process. While there is agreement that teacher quality matters, there is less agreement on the variables used to measure teacher quality characteristics (Rice, 2003). As research, policy, and public interests converge around this issue there is a growing impetus to seek answers that improve teacher quality. These interests have resulted in funding for national initiatives focusing on the quality of mathematics teachers. The purpose of this study was to examine the work conducted by grantees in one of these national programs.

**Research on Teacher Quality**

To establish a background against which to examine what represents and influences teacher quality in a national program, we first examined the literature to determine how these constructs are discussed in research. We identified six primary variables researchers have studied as representations of individual teacher quality: subject matter (content) knowledge; pedagogical knowledge; teacher behaviors, practices and beliefs; certification status; experience; and general ability. We discuss three of these in the paragraphs that follow.

Subject matter knowledge is a valued characteristic of mathematics teacher quality. Reviews of research indicate links between teachers’ subject matter preparation and teacher effectiveness, although these results are not always clear (Rice, 2003; Wilson & Floden, 2003). Results of studies examining the relationship between teachers holding subject specific degrees and student achievement vary, although mathematics results are generally positive (Goldhaber & Brewer, 1997). Similarly, studies measuring teachers’ subject matter knowledge using undergraduate or graduate coursework in the subject generally show a positive relationship with students’ mathematics achievement. While the data suggests a generally positive relationship between coursework and student achievement, there is evidence of a curvilinear effect (Monk, 1994).

Teacher education research often examines teachers’ pedagogical knowledge as evidence of teacher quality. These studies use measures such as degrees in education, educational coursework, and scores on exams measuring professional knowledge. Several studies indicate...
the positive effects of teachers’ pedagogical knowledge (Ferguson & Womack, 1993). Generally, studies of teachers’ pedagogical knowledge have found positive relationships between education training and teacher effectiveness (Darling-Hammond, 2000).

Teachers’ behaviors, practices, and beliefs are important characteristics of mathematics teacher quality. Although the observation of teachers’ behaviors and classroom practices provides a rich source of data, few large-scale studies have examined these practices. One such report (Weiss, Pasley, Smith, Banilower, & Heck, 2003) found that only 15 percent of observed mathematics lessons were categorized as high quality, while 27 percent and 59 percent were labeled medium and low quality respectively. Further results found that while teachers rarely make decisions about content, they often decide how to teach the content and those decisions are influenced by teachers’ beliefs about mathematics, about pedagogy, and about their students.

**Methods**

The present study is one sub-study of the Math and Science Partnership Program Evaluation (MSP-PE). The National Science Foundation Math and Science Partnership (NSF-MSP) Program is a major research and development effort with grants awarded to partnerships among preK–12 schools and institutes of higher education. One goal of the program focuses on improving mathematics teacher quality. The following research questions guided this analysis: a) How do grantees represent characteristics of teacher quality in mathematics? and b) What conditions do grantees identify as influencing teacher quality characteristics?

The data sources in this study come from 48 grants awarded in three cohorts (FY2002-04) in three categories (Comprehensive, Targeted, and Institute awards). Grantees’ reporting requirements called for them to submit Annual and Evaluation Reports describing the grants’ yearly activities. These secondary documents were the source for the analysis. Data were obtained from documents available to the MSP-PE team between January 2005 and February 2006. Researchers analyzed 123 reports. The examination was conducted using qualitative methods for a document analysis of secondary data sources (Miles & Huberman, 1994). The unit of analysis was the individual grant. Researchers analyzed documents in three phases. Six readers used an analytic protocol to code information and write summaries in the first phase. During the second phase, two PhD level researchers read and coded all of the written summaries using open and axial coding to examine themes (Strauss & Corbin, 1998). At the end of this phase, researchers identified main categories with examples from the reports. During the third phase, researchers used the categories in a key-word search process for the purpose of categorical aggregation (Stake, 1995) using the search tool on Adobe Acrobat Reader. By the end of this phase, researchers had created documents with lists of categories, examples from grantees’ reports, and frequencies of the main themes.

**Results**

The results are organized around two major themes: 1) how grantees represent characteristics of teacher quality in mathematics, and 2) the conditions they identify as influences on those characteristics. In this section, we discuss categories when their description was evident in at least 15 percent of the grants, showing the percentage of grants reporting a given category in parentheses. These percents are not meant to imply statistical relationships, but rather, to give the reader a sense of the proportion of grants reporting each theme and offer a “big picture” view of mathematics teacher quality in the program.
Representations that Characterize Teacher Quality

Characteristics of mathematics teachers described by grantees focus on subject knowledge, pedagogical knowledge, and behaviors, practices, and beliefs. The most common representation of teachers’ subject knowledge was a score on a test of mathematics subject knowledge (63%). Twice as many projects used test scores to represent teachers’ subject knowledge as any other representation. Additional representations of subject knowledge included improved student achievement (29%), teachers’ subject preparation (including subject-specific degrees and courses taken in mathematics content) (23%), observations of the teacher that focused on subject knowledge (19%), and teachers’ responses to surveys about subject knowledge (19%). Approximately the same number of grantees reported representations for pedagogical knowledge as subject knowledge, although the representations differed in type and frequency. Grantees reported responses on surveys as the most frequently used representation of pedagogical knowledge (52%), followed by observations of teaching (42%). Other representations of teachers’ pedagogical knowledge included improved student achievement (27%), and teaching practices reported during interviews (25%). Unlike subject knowledge, where scores on tests were the most frequently used representation of teacher knowledge, scores on tests were the least likely representation used for pedagogical knowledge. However, several grantees used instruments that examined a combination of subject and pedagogical knowledge (i.e., Learning Mathematics for Teaching, Hill, Schilling, & Ball, 2004). The most common representation of mathematics teachers’ behaviors, practices and beliefs was responses on a survey (58%). Other representations of teachers’ behaviors, practices, and beliefs included observations of teaching (31%), and responses to interview questions (31%). Essentially these representations are how grantees operationalize teacher quality characteristics.

Conditions Reported as Influences on Teacher Quality Characteristics

Grantees report a variety of conditions that influence characteristics of individual teachers. All grantees identify Professional Development and Teacher Leadership as conditions influencing teacher quality characteristics (100%). Another commonly reported condition was Linking STEM Faculty with Teachers and Schools (48%).

Professional development. Professional development focused on courses, workshops, and other training activities. The most common statements about professional development focus on content and pedagogy, and they are commonly described as intertwined. Grantees use terminology such as pedagogical content knowledge (Shulman, 1986) and mathematical knowledge for teaching (Hill, Schilling, & Ball, 2004) to show these interrelationships. While the focus on subject knowledge is traditionally emphasized for high school teachers, grantees focus on subject knowledge for teachers at all grade levels. Professional development frequently uses curriculum materials (71%) and includes work with student assessment items (54%) (i.e., developing various methods of student assessment, developing test items, and interpreting test item data). Grantees incorporate the use of mathematics standards documents (52%) in an effort to understand the contents of the standards documents and align standards with instruction. Professional development seminars also focus on analyzing students’ thinking using student products and videotaped episodes of students working (50%). Professional development uses teacher networks (48%) including peer observations and feedback, peer coaching, peer support structures, and study groups. Additional properties of professional development include the use of technology and other mathematics tools (46%), learning to conduct action research in one’s own classroom (27%), and lesson and unit planning (23%).
Teacher leadership. All grantees describe some form of teacher leadership and a majority discuss formal teacher leader positions (94%). The largest responsibility of teacher leaders described by grantees was to provide professional development for other teachers (96%). To a lesser extent, teacher leaders engaged in aligning curriculum, selecting and reviewing curriculum, and designing curriculum (35%). About one-fourth of grantees report teacher leaders engaged in setting, sustaining, and achieving school or grant goals (23%). Because the work of a mathematics teacher leader reaches beyond the work of a mathematics teacher, training for leaders was reported in many grants (81%). The most common attributes of leadership training included development of subject knowledge (42%), leadership skills and dispositions (42%), and pedagogical strategies (42%). Leadership training included such topics as conflict management and strategies for leading change in a school setting. About one-third of grantees include standards and curriculum (31%), coaching and mentoring strategies (29%), and how to provide professional development (27%) as part of leadership training sessions. Grantees are building capacity by developing local mathematics teacher leadership expertise for professional development and teacher induction. Examples of their leadership roles include coaches, mentor teachers, lead teachers, department chairs, curriculum specialists, master teachers, and locally-based staff developers. Teacher leadership was described in all grade bands (elementary, middle, secondary). In some cases grantees utilize teacher leadership roles already in place in the school system, while other roles were constructed as part of the grant.

Linking STEM faculty with teachers. Almost half of grantees report linking disciplinary faculty in the fields of science, technology, engineering and mathematics (STEM) with K-12 mathematics teachers as a condition influencing teacher quality (48%). STEM faculty worked with education faculty, teachers, and teacher leaders to design, revise, and teach courses for teacher education programs, summer workshops, and in-service teacher programs (33%). Reports discuss STEM faculty serving in management roles, such as directing project activities (27%), and advisory or “expert” roles, including attending professional development sessions to provide on-site support (25%). The increased presence of STEM faculty in programs for mathematics teachers was reported as a means for increasing teachers’ subject knowledge. In some grants it appeared that STEM faculty were engaged in the grant in name only. Courses taught by STEM faculty as part of the grant were sometimes the same ones taught before the grant began. STEM faculty “involvement” is often recorded in numbers of hours of participation. However, rather than being engaged in teaching or designing teacher workshops, STEM faculty may attend a workshop where they learn more about the grant itself. There are also reports that allude to concerns among STEM faculty and education faculty showing misunderstandings about each others’ professions, philosophical differences on pedagogy, and resistance by STEM faculty (and/or their departments) to engage in education work.

Discussion

These results provide one view into the work of grantees in a nationally funded program focused on influencing mathematics teacher quality. Although the descriptive nature of grantees’ reports was a limiting factor in the analysis, researchers believed the selection of what to include in the reports was indicative of what grantees found to be important. While certain aspects of reporting are required across the program, there is still great latitude in what the grantees are permitted to submit, as evidenced by the range in the length of the reports (29 to 707 pages). These findings illustrate how grantees represent teacher quality characteristics in their work and conditions they report as influences on those characteristics.
Improving Teacher Quality

Grantees’ language on teacher knowledge emphasizes the importance of subject knowledge, similar to recent policy and professional organization statements. Their descriptions of representations used (i.e., scores on tests, surveys, observations) for teachers’ subject and pedagogical knowledge closely align with variables used to measure teacher quality in research. The importance of subject and pedagogical knowledge as an influence on the quality of individual teachers is clearly based on research and policy statements (Monk, 1994; Wilson & Floden, 2003). It is clear from the findings that grantees have adopted research-based practices in the design of professional development (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Their work includes core features (content knowledge, active learning, and coherence) and structural features (type of activity, duration, and collective participation) that have been shown to have a significant positive effects on teaching (Garet, Porter, Desimone, Birman, & Yoon, 2001). Findings in the present study show that grantees report a strong emphasis on subject preparation. They report active learning, the use of standards, and the analysis of student work. Grantees foster coherence and collective participation by using teacher networks in the same subject areas, grade levels, and schools. It seems clear from the reports that grantees are knowledgeable on the conditions shown to be effective in improving individual teacher quality characteristics.

Negotiating New Relationships

Almost half of grantees described the involvement of STEM faculty in education activities for teachers. The results show that linking STEM faculty with K-12 teachers and schools is used to bolster the content of teacher learning activities. STEM faculty are involved in planning and teaching courses and workshops and participating as content experts. Grantees’ reports hint at a disconnect between some STEM and education faculty. In another report on the MSP, issues arose in one grant over differences of opinion about pedagogical strategies between STEM and education faculty (Zhang et al., 2006). Differences of opinion between STEM and education faculty on education issues are not isolated to the grants. In a publication of the American Mathematical Society, an opinion piece suggested taking the following approach to supporting the work of standardized testing: “If you have an opportunity to discuss K-12 pedagogy, pass. There are exceptions to this of course, but at the moment alienation is more likely than progress” (Quinn, 2005, p. 399). In contrast, other academic mathematicians have described their involvement with school mathematics and how essential it is that they be involved with K-12 education efforts (Bass, 2005). Bass highlights the importance of mathematicians developing an understanding of the work of K-12 mathematics so that they can see ways that their own mathematical knowledge can contribute to solutions for problems in mathematics education.

Traditional university reward structures for STEM faculty often hinder their involvement in mathematics education work. In the MSP Program, STEM and education faculty across the country are working together to improve mathematics education. These parallel efforts have the potential to influence the structure of future collaborative work in K-12 mathematics education. In addition to the teacher retention challenges faced by educators, reports show that the proportion of students earning degrees in STEM fields has declined, and that factors contributing to this decline include subpar teacher quality at the high school and college levels, among other factors (Ashby, 2006). These are interrelated challenges that face STEM and education faculty.
The Promise of Teacher Leadership

The findings suggest that grantees view teacher leadership as an important means of influencing teacher quality. While teacher leadership is a construct that has been examined in the literature for several decades (Rowan, 1990), recently, there has been increased interest in teacher leadership, including broader views of the construct, and its effects on teaching and learning (Spillane, Halverson, & Diamond, 2001). Much of the existing literature on teacher leadership focuses on formal roles of leadership, characteristics of teacher leaders, and conditions that facilitate teacher leadership development; less research focuses on the effects of teacher leadership, particularly on other teachers and students (York-Barr & Duke, 2004). Descriptions of teacher preparation and professional development programs which are, in part, intended to develop teacher leadership include three major foci: ongoing knowledge development of pedagogical issues; knowledge development of methods of school change; and knowledge and skill development of techniques for supporting colleagues’ growth (York-Barr & Duke, 2004). These elements are evident in the reports with 81 percent of grants describing teacher leadership training which includes these key features.

Teacher leaders in the present study are viewed as sources of local outreach for the grant by assisting in the development of, facilitating the implementation of, and communicating the goals and activities of the grants and they serve. There is an underlying assumption in the reports that teacher leaders influence teacher quality in this more systematic way. For example, when teacher leaders with subject specific skills mentor new teachers in their schools who are teaching in the same field, new teachers may be more likely to be successful in their beginning years of teaching. In this example, the teacher leader has the potential to influence new teacher induction. Most of the existing research on the effects of teacher leadership has focused on the effects on teacher leaders themselves. Evidence of the effects of teacher leadership outside the individual leader is more unclear. The grants in the present study are in a unique position to contribute to this research.

Conclusion

Several important insights have emerged from this examination. The representation of characteristics of individual teacher quality for mathematics teachers and the conditions identified as influencing those characteristics, in particular, professional development, appear to be well defined by the grants and are consistent with research findings. There is collaboration among STEM and education faculty for the support of K-12 mathematics teaching improvements; however, institutional structures, evidence of STEM impact, and intensity of STEM faculty engagement, are still being sorted out as faculty negotiate new roles and relationships. Teacher leaders may play an important role in influencing the conditions that influence teacher quality, and there is much research to be done in this area. Documenting and disseminating the new knowledge gleaned in these initiatives is the key to ensuring that others will learn from grantees’ experiences.

Endnotes

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2. This paper is an abridged version of a report submitted to the NSF for the MSP-PE June 2006 Quarterly Report.

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