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Science and Mathematics Teachers' Experiences, Needs, and Expectations Regarding Professional Development

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High quality teachers are essential to improving the teaching and learning of mathematics and science, necessitating effective professional development (PD) and learning environments for teachers. However, many PD programs for science and mathematics teachers fall short because they fail to consider teacher background, experience, knowledge, beliefs, and needs (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). To develop more effective PD systems, it is necessary to assess and identify teachers' PD needs, expectations, experiences and constraints. In this manuscript, we describe the findings from a study that examined the PD experiences, needs, expectations, and constraints of middle and high school science and mathematics teachers in one state in the U.S. We examine similarities and differences between science and mathematics teachers and among teachers from urban, suburban and rural schools. The findings from this study suggest that mathematics and science teachers participate in a minimal amount of PD and that a number of factors contribute to this reality. Furthermore, science and mathematics teachers do not experience effective PD learning environments described by Bransford, Brown & Cocking (2000) and there is a mismatch between teachers' PD needs and experiences.

Keywords: Mathematics and Science Teachers, Professional Development, Teacher Expectations

INTRODUCTION

To enhance science and mathematics learning in schools across the world, teachers need extensive opportunities to further develop knowledge and skills in both content and teaching in effective professional development (PD) settings (NRC, 1996; NCTM, 1991). This requires the design of effective learning environments for teachers (Bransford, Brown, & Cocking, 2000), including the use of successful PD strategies (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). The National Research Council's (NRC) publication, How People Learn, provides a four-perspective framework for designing effective learning environments (Bransford, Brown, & Cocking, 2000) for teachers:

Community-Centered: Values the search for meaning and understanding, builds collaborative relationships, and enhances participation in educational research and practice.

Knowledge-Centered: Focuses on the content that will help teachers develop an understanding of the discipline, including an emphasis on sense making.

Learner-Centered: Pays careful attention to the knowledge, skills, attitudes, and beliefs that teachers bring to the educational setting.

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Assessment-Centered: Continuously monitors and assesses teachers' thinking and understanding and provides feedback and opportunities for revision.

Therefore, PD must consider teachers as learners and build on participants' knowledge, skills, and beliefs; focus on knowledge and practice; provide opportunities for feedback, revision, and success; and require interactions with others (Bransford, Brown, & Cocking, 2000). However, many PD programs for science and mathematics teachers fall short of accomplishing this design because they fail to consider teacher background, experience, knowledge, beliefs, and needs (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). As a result, PD design has not given sufficient attention to the learner-centered or assessment-centered perspectives necessary for effective learning environments for science and mathematics teachers. Moreover, to create a more coherent PD system, attention to the learner-centered and assessment-centered perspectives should be considered for individual teachers, schools, districts as well as at the state level as argued by Corcoran (1995):

Historically, state policymakers have paid little attention to the form, content or quality of professional development. Such matters have been left to the discretion of local boards of education and district administrators. However, if today's teachers are to be adequately prepared to meet the new challenges they are facing, this laissez-faire approach to professional development must come to an end. The needs are too urgent and resources too scarce to simply continue or expand today's inefficient and ineffectual arrangements. (p. 1)

In some cases, effective and coherent PD for science and mathematics teachers in the U.S. has been designed and implemented at the school or district level (e.g., Elmore, 2002), especially in the cases of the districts receiving federal grants (e.g., National Science Foundation Local Systemic Change, Teacher Enhancement, or Mathematics and Science Partnership grants). However, these opportunities have been limited to a relatively small number of U.S. districts. Alternatively, individual science and mathematics teachers have pursued PD opportunities offered by higher education institutions, regional PD centers, and professional organizations such as the National Science Teachers Association (NSTA) and the National Council of Teachers of Mathematics (NCTM). Again, these opportunities have been limited to a relatively small number of teachers. Most U.S. school districts do not have the necessary resources to design, implement, and fund the PD that is required to improve the teaching and learning of science and mathematics. Therefore, in the U.S. it is necessary for most school districts to draw on and coordinate with other state resources such as government agencies and higher education institutions to develop a coherent PD system as Desimone, Porter, Birman, Garet, & Yoon (2002) proposed:

One method of designing and developing a program of professional development is to align the activities, pedagogy, and curriculum with standards and assessments adopted by the state or district and to coordinate funding with other programs in the state and district to develop a coherent professional development reform strategy. (p. 1269)

It is necessary to assess and identify the PD needs, expectations, experiences and constraints within states in order to develop more effective PD systems and reduce obstacles. This examination also needs to consider issues related to differentiation among teachers. For example, more experienced teachers have different professional needs than novice teachers. PD needs in rural and urban settings vary; many schools within a state do not have ready access to higher education institutions or regional PD centers due to their remote location.

Purpose of the Study

The purpose of the current study was to examine, on a state-wide basis, the PD experiences, needs, expectations, and constraints of middle and high school science and mathematics teachers. The research questions that guided the study were:

- How do science and mathematics teachers perceive their PD experiences?
- What do they perceive as their PD needs?
- What are their expectations for effective PD?
- What constrains them from participating in PD?
- How do the experiences, needs, expectations, or constraints differ for science and mathematics teachers and across subgroups?

Literature Review

Professional development is an intensive, ongoing, and systemic process that aims to enhance teaching, learning, and school environments (Fenstermacher & Berliner, 1985; Elmore, 2002). Researchers have argued that effective PD is critical to enhancing teacher and student learning as well as the organizational structures of school environments (e.g., see research conducted by Fullan; Sparks; Loucks-Horsley; Hall; Hord; Guskey; Lieberman; & Smilie). As a result, a number of researchers have investigated and documented effective PD at the district and school levels (Elmore, 2002). A consensus view of how PD should be designed and implemented exists (Bransford, Brown, & Cocking, 2000; Elmore, 2002; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). For example, Kennedy (1998) noted that PD experiences focused on subject matter knowledge and knowledge of students were

Table 1. Sample by County Size and Subject

County Size	Science	Mathematics	Mathematics/Science
Large (>100,000)	57	49	6
Medium (50,000 - 100,000)	13	16	4
Small (<50,000)	49	53	3
Total	119	118	13

more likely to have a greater impact on student learning than PD focused on teaching behaviors.

Researchers have also examined teachers' views and expectations regarding PD. For example, Park Rogers et al., (2007) found that both teachers and PD facilitators considered classroom application, teachers as learners, collegiality and collaboration as the important characteristics of PD. When Wilson and Berne (1999) observed PD and interviewed participants, teachers reported that they enjoyed PD that was relevant to their practice. In addition, teachers' beliefs, background, social influences, and practical circumstances shaped their reactions to PD (Wilson & Berne, 1999).

The typical PD experience for science and mathematics teachers is not aligned with teacher expectations or essential characteristics of effective PD identified in the literature. A number of factors influence this reality. First, the investment in PD has been insufficient; schools spend only 1-3% of their operating budgets on PD (Bransford, Brown, & Cocking, 2000). In addition, Randi & Zeichner (2004) argue:

Not all districts spend professional development funds wisely. One study, for example, conducted a cross-case analysis of professional development spending in seven elementary schools in a large urban district. Schools within the district varied widely in their levels of professional development funding, depending on school performance, availability of discretionary funds, and staff preferences (Fermanich, 2002). Other research found that even when districts allocate considerable funds for professional development, most of the investments are spent on district-controlled activities, typically in ineffective ways and for unclear purposes (Corcoran, 1995). (p. 197)

Second, science and mathematics teachers participate in a limited amount of PD. For example, from a national survey of 5,765 teachers, Weiss et al., (2001) reported that over 50% of science and mathematics teachers had participated in less than four days of subject-related PD in the previous three years. Third, typical approaches and formats to PD are antithetical to research on effective teacher learning (Bransford, Brown, & Cocking, 2000). Teachers do not have opportunities to determine the content or format of school-mandated PD (Bransford, Brown, & Cocking, 2000). The workshop is the most common teacher reported form of PD (Weiss, Banilower, McMahon, & Smith, 2001) and typical "one-shot" workshops deal with decontextualized information and often do not resonate with teachers' perceived needs (Bransford, Brown, & Cocking, 2000; Wilson & Berne, 1999). A National Center for Education Statistics study (U.S. Department of Education, 2001) surveyed 5,253 public school teachers in 50 states and the District of Columbia and found that teachers most frequently reported participating in PD related to state or district curriculum and performance standards at the district level. Furthermore, when teachers participate in PD, most of these experiences are disjointed and disconnected from classroom practice (Garet, Porter, Desimone, Birman, & Yoon, 2001). Finally, teachers often regard PD as having little impact on their responsibilities, and therefore, meaningless and a waste of time (Guskey, 2000). It is not surprising that less than a third of a national sample of teachers who participated in PD indicated that they changed their teaching practice as a result (Weiss et al., 2001). Ball and Cohen summarized, "Teacher learning has traditionally been a patchwork of opportunities—formal and informal, mandatory and voluntary, serendipitous and planned—stitched together into a fragmented and incoherent 'curriculum'" (as cited in Wilson & Berne, 1999, p. 174).

As demonstrated above, typical PD structures for science and mathematics teachers in the U.S. are problematic and have a limited impact on teacher practices or student learning (Weiss, Banilower, McMahon, & Smith, 2001). This suggests that there are obstacles that hinder the design and implementation of effective PD. Zimmerman and May (2003) surveyed principals from 450 schools in Ohio to identify obstacles to effective PD. Principals identified lack of time, lack of money, limited perceptions of teachers' roles as professionals, lack of both internal and external support for teachers, and difficulty of finding substitute teachers as the most common barriers to PD.

The PD research and policy literature clearly outlines problems with the current PD system for science and mathematics teachers in the U.S. Coordinated efforts to improve PD will require a state-level analysis related to teacher workforce as well as to PD resources and learning environments. The current study, building on prior research efforts, was designed to better understand the state-level PD context to assist future efforts at improving PD for science and mathematics teachers.

METHODOLOGY

Instrument

We designed a PD survey, using existing items, such as those available from Horizon Research, Inc. (2003) and creating new items, to collect data about science and mathematics teachers' experiences, needs, and expectations regarding PD. The survey consisted of 10 questions, including Likert scale, constructed response, and open-ended items, as well as a demographics section about school setting, teacher education, and teaching experience. The full survey is available at http://www.teach-math-or-science.org/docs/ PD_inventory_Summary.pdf.

Data Collection and Analyses

We mailed the survey to a stratified random sample of 1000 science and mathematics teachers, grades 6-12 from the state database of all science and mathematics teachers in the state of Missouri (N=7150). We stratified the sample by subject (science, mathematics, and both), grade level (middle or secondary), and county size (small, medium, and large). Every teacher in the sample was sent a letter describing the study, a letter concerning human subjects consent in addition to the survey including a return stamped envelope. We sent two follow up mailings to non-respondents. Surveys were coded to enable the team to ascertain the corresponding respondent within the subgroups. A total of 241 teachers across all subgroups returned the surveys (see Table 1).

Using the population size of 7150 Missouri science and mathematics teachers, we determined the confidence level of our results using the following equation:

$$n = \frac{N.z_{\alpha}^{2}.p.q}{[e^{2}(N-1)+z_{\alpha}^{2}.p.q]}$$

Setting zα=1.96 for α=0.05. Assuming a worst case law probability percentage of p=q=0.5, our level of confidence in the results was 0.062.

Data analyses included quantitative and qualitative methods. Quantitative analyses involved comparing different groups of teachers for differences in the frequency of their responses. We calculated chi-squared values from the contingency tables derived from these frequencies. To determine significance in the differences observed between science and mathematics teacher responses regarding teaching and learning, we carried out two different analyses. First, we paired science and mathematics teacher responses for each sub-item and calculated the $\chi 2$ statistic using 2x2 contingency tables. Then we compared teacher priorities in terms of their PD needs by pairing off each of the different ranges of teaching experience and calculating Spearman's rank correlation (rs) for each of the pairings, considering the rank for each particular item by the percentage of teachers selecting it.

Qualitative analysis involved coding data from the open-ended items into thematic categories. The open-ended questions asked the respondents to determine the characteristics of effective and ineffective PD, and then asked them to create their ideal PD. We began the analysis process by reading open-ended responses in the survey for comments related to teachers' PD experiences, needs, and expectations. We coded the data into thematic categories, which required several rounds of reading data, coding phrases, discussing possible categories and themes, and refining the definitions of each category. After the saturation of coding, we coded the remaining data using the list of categories we had developed. Next, we developed a frequency chart that included the number of comments for each coding category. This synthesis helped us to see which categories were discussed more frequently. We also compared the categories across years of teaching experience among the respondents. Then, we developed a set of assertions about teachers' PD expectations and returned to the data to find specific examples that supported our assertions. Finally, we compared and made connections between quantitative and qualitative data in order to answer the research questions.

RESULTS

The results are presented in three sections that reflect the research questions in relation to teacher PD experiences, needs, and expectations.

Teacher Professional Development Experiences

Table 2 shows the number of hours respondents reported they spent in PD activities within the last 12 months and the last three years. Teachers were asked to include attendance at professional meetings, workshops, and conferences, as well as job-embedded PD, but not to include formal courses for which they received college credit or time spent providing PD for other teachers. Fifty-seven percent of the teachers reported

Table 2.Time Spent in Professional Development within the Last 12 Months and 3 Years

	Percentage of Respondents	
Hours	12 months	3 years
	n = 236	n = 235
None	7	3
Less than 6	21	4
6-15	29	17
17-35	27	22
More than 35	13	50

spending 15 or fewer hours in PD within the last 12 months and 50% of the teachers reported spending less than 35 hours during the preceding 3-year period.

Table 3 summarizes the types of PD activities in which respondents reported involvement within the last three years. The most common type of PD activity that the science and mathematics teachers reported was reading professional literature. The least common type of PD activity the teachers reported was collaboration with other teachers using telecommunications.

When we compared the PD activities of urban, rural, and suburban teachers, we found four significant differences (see Table 4). Urban and suburban teachers reported more frequent opportunities to observe other teachers teaching, meet in study groups, read the professional literature, and serve as a mentor or peer coach than did their colleagues in rural settings.

We also asked teachers to report on the types of PD leadership activities that they had undertaken over the previous 12 months (see Table 5). The most common type of leadership activity that the science and mathematics teachers reported was serving on a school or district science/mathematics curriculum committee. The least common type of leadership activity reported was receiving a grant or award for science/mathematics teaching.

Table 3. Professional Development Activities within Last 3 Years

Activity	Percent of Respondents n = 241
Read professional literature	87
Attended a workshop on science/math teaching	74
Met with a local group of teachers on a regular basis to study/discuss science/math teaching issues	58
Observed other teachers teaching science/math as part of your own professional development (formal or informal)	58
Completed a college/university science/math course	43
Completed a college/university course in the teaching of science/math	35
Served as a mentor and/or peer coach in science/math teaching, as part of a formal arrangement that is recognized or supported by the school district not including supervision of student teachers	27
Collaborated on science/math teaching issues with a group of teachers at a distance using telecommunications	13

Table 4. Professional Development Activities within the Last 3 Years by School Setting

	Percentage respondents			χ^2
	Urban n=33	Sub urban n=80	Rural n=124	
Read professional literature	93.75	97.44	81.97	**12.36
Observed other teachers teaching as part of your own professional development	90.91	72.50	40.65	** 36.87
Attended a workshop on science/math teaching	84.85	73.75	71.54	2.41
Met with local teachers on a regular basis to study/discuss science/math teaching issues	68.75	71.25	46.77	**13.70
Completed College or University science/math course	45.45	42.50	41.94	0.13
Completed College or University teaching course in science/math	42.42	31.25	36.29	1.36
Attended a science/math teaching conference	38.71	54.43	56.56	3.21
Served as a mentor and/or peer coach in science/math teaching, as part of a formal arrangement that is recognized and supported by the school or district	33.33	37.97	22.13	*6.18
Collaborated on science/math teaching issues with a group of teachers at a distance using telecommunications	21.21	13.75	12.10	1.81

* $p < 0.05$

Table 5. Professional Development Leadership Activities within the Last 12 Months

Activity	Percent of Respondents n = 241
Served on a school or district science/math curriculum committee	63
Served on a school or district science/math textbook selection committee	46
Facilitated professional development in science or mathematics teaching	45
Facilitated professional development in science or mathematics subject matter	44
Mentored another teacher as part of a formal arrangement that is recognized or supported by the school or district, not including supervision of student teachers	34
Received local, state, or national grants or awards for science/math teaching	14

Table 6. Science and Mathematics Teachers' Perceived Professional Development Needs for Pedagogy

Topic	Percent of Respondents		X^2
	Science n=122	Math n=119	
Developing critical thinking in science/math	68.0	73.1	0.747
Using technology to teach science/math	63.1	68.9	0.901
Connecting science/math to the real world	55.8	60.5	0.562
Inquiry or problem-based strategies in science/math	55.7	67.2	3.356
How students learn particular topics in science/math	50.8	63.9	*4.189
Developing conceptual understanding in science/math	48.4	47.1	0.041
Writing in science/math	41.8	44.5	0.184
Questioning and classroom discussion techniques	41.0	47.1	0.902
Using the State standards to design instruction	38.5	49.6	2.988
Inquiry or problem-based science/math curriculum	37.7	57.1	**9.131
Involving parents in their children's science/math education	36.9	42.0	0.664
Designing instruction for gifted students in science/math	36.1	34.5	0.069
Designing instruction for special education in science/math	36.1	36.1	0.000
Assessing student learning in science/math	33.6	38.7	0.666
Co-operative/collaborative learning in science/math	31.2	44.5	*4.596
Classroom management in science/math	27.9	33.6	0.934
Involving girls or minorities in science/math	25.4	22.7	0.244
Designing instruction for ESL students in science/math	23.0	13.5	3.647

* $p < 0.05$ ** $p < 0.01$

Teacher Professional Development Needs

Table 6 summarizes the perceived needs of science and mathematics teachers for PD about various pedagogy topics. The top six perceived needs were the same for both science and mathematics teachers and the order of these needs was almost identical. Likewise, the bottom three needs were the same for both groups. Respondents noted a greater need for PD about critical thinking, strategies related to inquiry or problem-based approaches, student learning, making connections with the real world, and the use of technology in teaching both science and mathematics. Addressing the needs of English as a Second language (ESL) students and involving girls or minorities were reported as lower needs for PD.

Table 6 also presents a $\chi 2$ comparison between science and mathematics teacher respondents. We found no significant difference between science and mathematics teachers except for three topics: how students learn particular topics in science/mathematics, inquiry or problem-based science/mathematics curriculum, and co-operative/collaborative learning in science/mathematics. In these three cases, mathematics teachers reported a greater need for PD than did science teachers.

We also compared perceived needs in terms of years of teaching experience for science teachers (Table 7) and mathematics teachers (Table 8). Using a Spearman's rank correlation index, we found significant correlations across all levels of teaching experience related to the ranking of perceived needs for PD. In the case of science teachers, those with 0-2 years of experience only show significant correlation in their ranking of needs

Table 7.Ranking Comparison for Professional Development Needs by Teaching Experience: Science Teachers [a]

Years of teaching experience	Years of teaching experience						
	0-2	3-6	6-10	11-15	16-20	21-25	26+
0-2	-	0.416	*0.490	*0.482	0.399	0.260	0.437
3-6		-	**0.772	*0.533	**0.577	**0.935	**0.678
6-10			-	*0.454	**0.609	**0.839	**0.653
11-15				-	0.414	0.446	0.367
16-20					-	**0.602	**0.703
21-25						-	**0.748
26+							-

a. Spearman's Rank Correlation index (r_s), * $p < 0.05$, ** $p < 0.01$

Table 8. Ranking Comparison for Professional Development Needs by Teaching Experience: Mathematics Teachers [a]

Year of Experience	Years of teaching experience						
	0-2	3-6	6-10	11-15	16-20	21-25	26+
0-2	-	*0.467	*0.503	**0.761	*0.569	*0.462	**0.638
3-6		-	**0.892	**0.644	**0.728	**0.609	**0.692
6-10			-	**0.728	**0.645	**0.661	**0.832
11-15				-	**0.572	**0.648	**0.704
16-20					-	**0.682	**0.65
21-25						-	**0.692
26+							-

a. Spearman's Rank Correlation index (r_s), * $p < 0.05$, ** $p < 0.01$

Table 9. Science Teachers' Perceived Professional Development Needs in Science

Topic	Percent Respondents (n=122)
Electricity and magnetism (Physics)	55.7
Energy and chemical change (Chemistry)	50.8
Climate and weather (Earth Science)	49.2
Modern Physics (Physics)	46.7
Genetics and evolution (Biology)	45.9
Earth's features and physical processes (Earth Science)	45.1
Chemical reactions (Chemistry)	41.8
Structure of matter and chemical bonding (Chemistry)	40.2
The solar system and the universe (Earth Science)	40.2
Light and sound (Physics)	38.5
Forces and motion (Physics)	35.3
Energy (Physics)	35.3
Plant biology (Biology)	32.8
Interactions of living things/ecology (Biology)	32.0
Properties and states of matter (Chemistry)	30.3
Structure and function of human systems (Biology)	26.2
Animal behavior (Biology)	19.7
Others (Chemistry)	12.3
Others (Biology)	8.2
Others (Earth Science)	7.4
Others (Physics)	5.7

with those in the 6-10 years of experience and 11-15 years of experience groups. Regarding science teachers with 0-2 years of experience, the most significant difference in our findings was the fact that addressing the needs of ESL students and involving girls and minorities were ranked among their top 5 perceived needs. In the case of mathematics, correlation was less between those teachers with 0-2 years of experience and the other groups.

Tables 9 and 10 summarize teachers PD needs in terms of specific science and mathematics content topics. Science teachers ranked physics, chemistry and earth sciences topics higher than biology topics, except for genetics and evolution which ranked 5th with 45.9% of the teachers selecting it. The top-ranked topics where: electricity and magnetism (55.7%), energy and chemical change (50.8%), climate and weather (49.2%) and modern physics (46.7%). Mathematics teachers wanted PD about the following topics: technology in support of mathematics (60.5%), topics from discrete mathematics (54.6%), probability (51.3%), statistics (45.4%) and patterns and relationships (43.7%).

Teachers' needs for PD can also be discerned by their perceptions of constraints to participating in PD. Constraints that limit participation in PD as reported by respondents in different school settings (urban, suburban and rural) are detailed in Table 11. We ranked the constraints according to a weighted index derived from individual teacher ratings. The most constraining factor reported was time conflict, which ranked among the top two factors for respondents in all school settings. The least constraining factor reported was the availability of substitutes, ranking in the bottom two factors for respondents in all school settings. When we removed these two issues from the analysis, we found no significant correlation by school setting (using Spearman's index). Location of PD was considered more of constraint for rural teachers, while lack of interest in the available PD topics was considered more constraining by teachers in suburban settings. The perceived value given by the district to PD was a more important issue for teachers in urban settings.

Teacher Professional Development Expectations

To understand teachers' expectations for PD, we analyzed 215 responses to two open-ended items about the characteristics of effective and ineffective PD and 191 responses to an open-ended item that asked them to design an ideal PD experience in terms of length, location, topics, delivery formats, participants, and facilitators. When designing their ideal PD, respondents took into account their previous experiences with effective and ineffective PD. We found a great amount of similarity across the responses regardless of teachers' subject matter, school setting, or years of experience as we discuss below.

Professional Development Topics

The teachers identified both science and mathematics content topics and pedagogy topics. The most frequently mentioned topics were:

- Subject specific topics (e.g., biology, chemistry, electricity, algebra) that are aligned with state standards and tests
- Instructional strategies (e.g., inquiry, cooperative learning, motivation techniques, critical thinking)
- Technology integration
- Classroom management
- Assessment
- Lab/hands-on activities
- State standards and standardized tests

Some differences appeared in preferred topics in relation to years of teaching experience. Teachers with 0-5 years of experience mentioned both subject-specific topics and instructional strategies with equal frequency. Although some of the teachers with six or more years of experience mentioned content knowledge as part of their ideal PD, the majority of them expected the PD to address instructional strategies and activities that they could use with their students. Technology integration was another topic raised more often by the experienced teachers than the beginning teachers. Additionally, this topic was raised more frequently by mathematics teachers than science teachers. The more experienced teachers also mentioned an expectation that PD would help them improve their teaching in order to increase students' standardized test scores or to meet the state standards. None of the beginning teachers mentioned standards or testing, and only 3 of 37 respondents with 3-5 years experience did.

Effective PD Delivery

Teachers noted that the PD effectiveness was related to its relevance, delivery style, and opportunities to network with other teachers. These views held regardless of years of teaching experience or subject (science or mathematics). Respondents indicated that PD was most effective when it was relevant and useful in their classrooms. They described relevance as meeting one or more of the following criteria:

PD topic is focused on the content and grade level they teach.

PD participants include those that teach the same content they teach.

PD is aligned with state, district, and grade level curricular goals.

Table 10. Mathematics Teachers' Perceived Professional Development Needs in Mathematics

Topic	Percent Respondents(n=119)
Technology in support of mathematics	60.5
Topics from discrete mathematics	54.6
Probability	51.3
Statistics	45.4
Patterns & relationships	43.7
Geometry and spatial sense	40.3
Data collection and analysis	39.5
Numeration and number theory	38.7
Algebra	33.6
Functions and pre-calculus	31.9
Measurement	28.6
Calculus	26.9
Pre-algebra	26.1
Mathematical structures	25.2
Estimation	24.4
Computation	17.6
Others	6.7

Table 11. Perceived Constraints to Teacher Participation in Professional Development

	Urban		Suburban		Rural	
Issue	Rank	Index [a]	Rank	Index [a]	Rank	Index [a]
Cost	1	0.408	1	0.407	2	0.269
Family responsibilities	2	0.308	7	0.161	5	0.199
Lack of financial support from school/district	3	0.272	8	0.152	1	0.354
Lack of interest in PD topics available	4	0.198	2	0.225	6	0.178
Lack of relevance to job	5	0.173	10	0.069	9	0.085
Location of PD not convenient	6	0.161	3	0.216	4	0.229
Low value placed on PD by school/district	7	0.148	5	0.181	3	0.250
Reluctance to release from classroom	8	0.111	11	0.054	12	0.051
Time conflicts	9	0.099	4	0.196	7	0.167
Unavailability of substitutes	10	0.086	6	0.171	8	0.108
Unawareness of available PD	11	0.037	9	0.152	10	0.063
Other	12	0.025	12	0.034	11	0.057

a. Calculated by percentage teachers selecting an issue and weighted importance combined.

PD is not overly theory-laden, but focuses on classroom-based practice.

The ideas presented are practical for the classroom setting.

They will learn something or have a product that they can "use tomorrow in class."

Respondents commented frequently that PD effectiveness depended, in part, on delivery style. In particular respondents mentioned:

PD should be well organized and well structured, including efficient use of time.

PD should be well focused and preferably focused on a few big ideas.

PD should be convenient in terms of location and schedule.

These characteristics of effectiveness in delivery were mentioned by both science and mathematics teachers of all levels of experience. One additional criterion mentioned by a few of the more experienced teachers in regard to delivery characteristics was that they did not want PD forced on them by district or state mandates. Most likely the beginning teacher respondents had not yet experienced problems with mandated PD given their strong incoming need for continuing education.

Respondents wanted to be engaged as learners. They preferred interactive PD experiences. Most of the teachers preferred PD providers to present the activities and instructional strategies that the teachers could use with their own students as the following responses illustrate.

Give us (teachers) activities the students would be doing. The facilitator has to remember several of us have 30+ students in a room. We need activities to do w/ large groups and students of low to med. ability. (6-10 years experience)

Hands-on active learning-model good teaching / instructional strategies. Not just "cute" activities. (6-10 years teaching experience)

Half sit & listen, half get up & practice. Time could be given to actually develop strategies with my fellow teachers on how to improve my instruction in the classroom. (6-10 years teaching experience)

At the same time, teachers want to be considered as adult learners, not as students as the following responses demonstrate.

Tell me how to set it up or use it-I hate having to do what the kids would do. Give me the information and treat me professionally. (16-20 years experience)

Do not make participants do activities that are designed for young students—it loses relevance. (6-10 years experience)

I like to just listen and see/hear how the lesson/topic is taught. I also like to see student work if there are activities/projects involved. (6-10 years experience)

Respondents valued PD experiences in which interaction with peers was an explicit feature. They mentioned two ways in which networking with other teachers was valuable. First, they appreciated opportunities to get ideas from other teachers about how to implement innovations in their classrooms. Second, they wanted time to share situations and problems they faced in their own classrooms with other teachers in order to find practical solutions. The following response illustrates these ideas:

I think a discussion session among teachers teaching the same courses would be ideal. We could share learning strategies, homework collection ideas, activities, etc. (26+ years teaching experience)

These delivery formats for effective PD were mentioned by teachers from every experience group. Additionally, respondents with more than two years of experience made three other comments about PD effectiveness. First, they wanted PD that focused on new ideas, rather than rehashing topics they had previously learned. This desire most likely stemmed from their more extensive experience with teaching and PD. Second, the more experienced teachers found that PD was most effective when it was sustained over time rather than a "one shot deal." These teachers wanted ongoing, job-embedded PD. They did not want their time wasted, but they were willing to invest in PD over the long term as long as the content was new and relevant. Third, a few of the experienced teachers mentioned that effective PD included learning about assessment of student performance and ultimately resulted in improved student achievement.

Participants and Facilitators

Although most respondents preferred to attend PD with teachers from similar grades and subjects, some mentioned that PD should occasionally include participants from different fields (e.g., combining science and mathematics teachers, or teachers and administrators). Respondents believed that these individuals should have similar interests and be willing to share their experiences and expertise. Some respondents remarked that ideal PD is not mandated from above, but involves willing participants.

Age-specific teachers, administrators that would be interested. Content-specific teachers for one day and cross-content science teachers for additional viewpoints. (0-2 years teaching experience)

Volunteers (teachers that want new ideas). Forced professional development leads to lots of unhappy people (3-5 years experience)

Teachers held high expectations for PD facilitators. That is, they wanted facilitators who were knowledgeable, motivating, interesting, and credible (in touch with classrooms), and who treated them in a professional manner. The majority of respondents preferred experienced teachers who had been successful in classroom teaching and improving student achievement to facilitate the PD. Moreover, they valued facilitators with experience in their school district or in a similar school setting.

Teachers that use these things and can tell you how to get started, trouble shoot, etc. (21-25 years teaching experience)

A teacher who taught in a disadvantaged district for many years and had success with student achievement. (0-2 years experience)

Top teachers in subject area. College professors aren't really connected and [don't] know what goes on in HS-MS. (26+ years experience)

Some of the more experienced teachers put a premium on facilitators who were knowledgeable and understood classroom teaching at a particular grade level, regardless of an individual's current position. These respondents expected experienced teachers, university professors, and other experts to be ideal PD providers.

Middle school science teachers who have successfully used the activities being presented or college instructors who work with middle school science. (26+ years teaching experience)

The person should have "lived" this situation with 1st hand knowledge & experiences. (26+ years experience)

Someone who has realistic experience with teaching mathematics to middle school age people. (21-25 years experience)

The respondents to this needs assessment were consistent in their ideas about the characteristics that contribute to effective PD. They wanted 1) to learn both science/mathematics content and pedagogy that is aligned to standards and relevant to their classrooms, 2) to be engaged both as learners and as teachers, 3) to have opportunities to interact with other teachers in meaningful ways, and 4) to have facilitators who are organized, knowledgeable, and who understand the exigencies of schools and classrooms.

CONCLUSIONS

The findings from this study suggest that mathematics and science teachers participate in a minimal amount of PD and that a number of factors contribute to this reality (e.g., location of PD opportunities). Over the past three years only 50% of the teachers participated in a total of more than 35 hours of PD activities (including reading professional literature). This is similar to the results from the 2000 National Survey of Science and Mathematics Education (Weiss, Banilower, McMahon, & Smith, 2001) where 17–23% of grade 5–8 teachers and 31–45% of grade 9–12 teachers reported participating in more than 35 hours of professional development in the last three years. A study of the National Science Foundation-funded Local Systemic Change (LSC) PD Initiative suggests that this minimal amount of PD is insufficient for improving the teaching and learning of science and mathematics. Teachers who participated in 60 or more hours of LSC PD were more likely to report an impact on their content preparedness than teachers with fewer than 60 hours (Shimkus & Banilower, 2004). Furthermore, Bowes and Banilower (2004) found that lessons were more likely to be rated highly for actively involving all students, engaging students intellectually, and creating a climate of respect and rigor when taught by teachers with higher levels of LSC PD.

Science and mathematics teachers who responded to our survey also indicated that they do not experience effective PD learning environments described by Bransford, Brown & Cocking (2000):

Community-Centered: The PD experiences have not provided opportunities for teachers to build collaborative relationships with colleagues, and to enhance participation in educational research and practice.

Knowledge-Centered: PD experiences have not focused on the necessary science/mathematics content nor have they been designed to enhance the teaching and learning of science and mathematics.

Learner-Centered: PD experiences have not built on the knowledge, skills, attitudes, and beliefs that teachers bring to the educational setting.

Assessment-Centered: PD experiences have not involved a process of assessing teachers' thinking and understanding, providing feedback, or opportunities for revision.

Our data also indicate that rural teachers have significantly less opportunities to meet with other science and mathematics teachers and to observe other teachers teach science or mathematics. This would be explained by the fact that in many cases teachers in rural communities have sole responsibilities for teaching specific courses.

Teachers preferred PD that was specific to their grade level, content, and classroom practice. This suggests that PD needs to be tied to specific grade levels or courses, as well as to instruction and student thinking. Appleton (2005) indicated that teachers, both novice and experienced, use activities that work as a central role in the development of their knowledge. This supports our finding that teachers expected relevant and useful classroom ideas as part of PD. The relevance of classroom ideas is also related to teacher experience. In some cases, beginning teachers expressed different PD needs than did more experienced teachers. This suggests that, for example, high school biology teachers with less than two years of experience might need PD opportunities with more experienced biology teachers, as well as opportunities for PD with other novice teachers.

IMPLICATIONS

The results from this study as well as others (Weiss, Banilower, McMahon, & Smith, 2001) indicate that there is a mismatch between teachers' perceptions of their PD needs and their PD experiences. In order to organize successful PD that improves teaching practice in large numbers of classrooms (Corcoran, 1995; Elmore, 2002), understanding and addressing teacher PD expectations, experiences, needs, and constraints is essential. This suggests government agencies, organizations, and school districts responsible for funding, designing and facilitating PD must:

Seek input from teachers regarding PD through surveys, focus groups, or other mechanisms.

Work together to consider the recommendations that have been identified in the PD research and policy literature (e.g., Ball & Cohen, 1999; Corcoran, 1995; National Staff Development Council, 2005).

Invest more resources in preparing and supporting PD facilitators, especially those who have successful classroom experience.

Consider the PD needs of all teachers, especially those who do not have regular access to effective PD opportunities.

In Missouri, 3,293 of the 7,150 mathematics and science teachers (46%) teach in counties with populations of less than 100,000. Structures need to be created to support the professional growth of this large, isolated group of teachers. Most U.S. school districts and likely many school systems throughout the world do not have the necessary resources to design, implement, and fund the PD that is required to improve the teaching and learning of science and mathematics. Therefore, it is necessary for most school districts to draw on and coordinate with other state resources such as government agencies and higher education institutions to develop a coherent PD system. This would require designing and facilitating PD in regions throughout a state in coordination with school districts so that teachers can be released from teaching responsibilities in order to participate. For example, an ongoing series of PD could be designed to meet the needs of high school biology teachers within a certain region of a state. This focused PD would have the potential to address the four perspectives of effective learning environments identified by Bransford, Brown & Cocking (2000), teachers' expectations for effective PD identified in this study, and prior recommendations identified in the PD research and policy literature.

In addition to implications for policy and practice, the findings from this study suggest implications for future research efforts. Research is needed to more carefully examine PD design and implementation as it relates to specific groups of teachers (e.g., level of experience, content area, grade level, type of school) and the four perspectives of effective learning environments outlined by Bransford, Brown, and Cocking (2000). In addition, more research efforts need to investigate PD practices at the state, regional, national, and global levels as we work toward a more coherent PD system for mathematics and science teachers.

The current political and economic context in the U.S. that led to the National Academies' publication, Rising Above the Gathering Storm (Committee on Science, Engineering, and Public Policy, 2006), indicates the critical importance of science and mathematics in contributing to prosperity. High quality teachers are essential to achieving this vision, necessitating high quality PD. This national situation is reminiscent of the post-Sputnik era, when large federal investments were made to improve science and mathematics education in the U.S. This time around we need to consider carefully how to best use our resources to reach our goals. Collaboration at the state-wide level across groups with responsibility for PD—state agencies, institutions of higher education, professional organizations, and school districts—is essential. This collaboration must begin with recognizing the PD experiences, needs, and expectations of science and mathematics teachers in order to design effective PD learning environments for teachers.

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