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EFFECTIVE PROFESSIONAL DEVELOPMENT IN SCIENCE AND MATHEMATICS EDUCATION: TEACHERS' AND FACILITATORS' VIEWS

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ABSTRACT. This study compares the views of teachers and professional development facilitators about effective professional development (PD). We analyzed interviews with 72 teacher participants and 23 PD facilitators involved in nine science and mathematics PD projects. The teachers' themes for characterizing effective PD included classroom application, teacher as learner, and teacher networking. Similarly, the PD facilitators discussed effective PD as having classroom application and experiences for teachers as learners. In addition, PD facilitators shared the need to develop collegial relationships with teachers and improve teacher knowledge. These views correspond to some of the standards and recommendations described in policy and research documents on effective PD. Criteria of effective PD in these documents that the participants did not mention included: (1) challenging teachers' content and pedagogical content knowledge with transformative learning experiences, (2) encouraging teacher leadership for sustained support, and (3) focusing on student learning by instructing teachers on how to use student data to inform their teaching practice. Our findings have implications for designing PD that reflects the criteria of standards-based reform.

KEY WORDS: effective professional development, mathematics education, professional development, science education, standards

Professional Development in Science and Mathematics Education: Teachers' and Facilitators' Views

As the US approaches the 10th anniversary of the National Science Education Standards [NSES] (National Research Council [NRC], 1996) and the 20th anniversary of the Curriculum and Evaluation Standards for School Mathematics (National Council of Teachers of Mathematics [NCTM], 1989), we should stop and ask ourselves if the reform vision of these documents has been attained. The standards were developed to provide a roadmap for obtaining mathematical and scientific literacy. For example, the National Science Education Standards presented the vision

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that by the 21st century "all students should achieve scientific literacy" (NRC, 1996, p. 9). Yet, as performance on national and international tests indicates, US students continue to lag behind their peers in other countries on measures of mathematics and science literacy achievement (Gonzales, Guzmán, Partelow, Pahlke, Jocelyn, Kastberg et al., 2004; Lemke, Sen, Pahlke, Partelow, Miller, Williams et al., 2004).

Who is responsible for achieving the vision of the standards? As Collins (1997, p. 299) explained, "Although centered in classrooms, this vision calls for reform of all parts of the science education system." A significant part of this system is veteran teachers. However, many of these teachers entered the teaching profession before the standards existed. These classroom teachers rely on professional development (PD) experiences to keep them informed of reformed-based practices in mathematics and science education.

The developers of the NSES (NRC, 1996) were aware of the importance of PD in achieving the vision of scientific literacy for all, and as a result included specific guidelines for science PD experiences (Collins, 1997). Similarly, the Professional Standards for Teaching Mathematics (NCTM, 1991) support NCTM's goal of improving mathematics teacher education. Both sets of PD standards promote inquiry-based experiences for teachers that include authentic critical thinking and problem-solving opportunities.

Although policy documents recommend that PD models use reform-based practices in order to achieve scientific and mathematic literacy for all, a gap between ideal and actual PD practice of effective PD exists (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003). The purpose of this study was to explore why this divide endures. We addressed the problem in two stages: (1) by examining teachers' and PD facilitators' views of effective PD, and (2) by comparing both groups' views to the characteristics of effective PD as described in the literature.

Literature Review

Both research and policy documents contribute to our understanding of the characteristics of effective professional development. Three research groups (Guskey, 2003; Loucks-Horsley et al., 2003; Thompson & Zeuli, 1999) have summarized much of the PD literature and provide a consensus about the key features of effective PD.

Guskey (2003) reviewed 13 lists of characteristics of effective PD from publications produced by various research and policy organizations (e.g., Association for Supervision and Curriculum Development, Educational Research Service, Eisenhower Professional Development, Program). From these lists, he identified 21 attributes of effective PD. Of these characteristics, he focused much of his discussion on the five most frequently mentioned: (1) enhancing teachers' content and pedagogical knowledge, (2) providing sufficient time and other resources, (3) promoting collegial and collaborative exchange, (4) establishing procedures for evaluating the PD experience, and (5) conducting school or site-based PD. However, Guskey argued that there is a significant amount of research that asserts that school or site-based PD is not as important as once thought. Rather, "a carefully organized collaboration between site-based educators, who are keenly aware of critical contextual characteristics and district-level personnel, who have broader perspectives on problems, seems essential to optimize the effectiveness of professional development" (Guskey, 2003, p. 749), and not necessarily the location of the PD itself.

Loucks-Horsley et al. (2003) listed seven principles of effective PD for science and mathematics teachers. Although many of the principles overlap Guskey's key characteristics, Loucks-Horsley et al. outlined three additional ideas. These included: (1) establishing a well-defined image of classroom learning and teaching, (2) creating a PD design that is based on research and engages teachers as adult learners, and (3) developing a support system for teachers so they may learn to serve in leadership roles in their schools and districts.

Both Guskey (2003) and Loucks-Horsley et al. (2003) identified the use of student learning data as a key component of effective PD design, but claimed that it was rarely mentioned in the literature. Kelleher (2003, p. 752) noted a similar finding and explained, "The issue [of effective PD is] not the educators' happiness quotient−how satisfied teachers are with a particular workshop−but rather what effect professional development will have on student learning." Evaluation of PD often does not move beyond measuring teachers' happiness quotient. However, Kelleher recognized that measuring student learning is not an easy task, and suggested that aligning PD activities with district goals would increase the potential for improvements in student learning.

In a third review of the literature on effective PD, Thompson & Zeuli (1999, pp. 355–357) asserted that PD participants must experience a sufficient amount of dissonance to disturb their existing beliefs, knowledge, and experiences with learning and teaching. Thompson and Zeuli explained that providing teachers with this type of *transformative* learning experience requires the following:

- Create a high level of cognitive dissonance.
- Provide sufficient time, structure, and support for teachers to think through the dissonance experienced.
- Embed the dissonance creating and resolving activities in teachers' situations and practices.
- Enable teachers to develop a new repertoire of practice that fits with their new understanding.
- Engage teachers in a continuous process of improvement.

A common element of effective PD discussed across the literature is the need for sustained support for teachers as they return to their schools to implement the PD objectives (Desimone, Porter, Garet, Yoon & Birman, 2002; Garet, Porter, Desimone, Birman & Yoon, 2001; Guskey, 2003; Loucks-Horsley et al., 2003; Thompson & Zeuli, 1999). An important aspect of providing this sustained support is the development of a network of communication between PD facilitators and teachers, and among the teachers themselves. Jauhiainen, Lavonen, Koponen & Suonio, (2002) explained that when teachers return to their schools, lines of communication are critical for continuing to develop the knowledge and skills addressed during the PD experience. Classroom change depends on providing extended support throughout the school year with opportunities for teachers to collaborate and reflect on their own beliefs and practices (Borasi & Fonzi, 2002; LaChance & Confrey, 2003).

Clarke (1994) suggested that one way of developing this extended network is to initiate professional communities within schools. Clarke explained that these communities are more productive when they involve groups of teachers from the same school as opposed to individual teachers from a number of schools. Arbaugh (2003) reported similar findings about teachers who created study groups to investigate a particular teaching approach or strategy in mathematics. For these teachers, the professional community, or study group, promoted collegiality among them; they designed their meetings to meet both the needs of the individual and the collective group.

The characteristics of effective PD from the research are reflected in the policy documents produced by the National Staff Development Council [NSDC], NCTM, and the NRC. From a content-generic perspective on PD, the policy document from the NSDC (2001) provides 12 standards for the design of PD organized into three categories–context, process, and content. Each category focuses on the goal of PD to improve the learning of all students. The NSES (NRC, 1996) presents four standards focusing on science content knowledge, pedagogical content knowledge (Shulman, 1986), lifelong learning, and integrated design. The Professional Standards for Teaching Mathematics (NCTM, 1991) outlines six standards, placing an emphasis on teachers' development of mathematics content knowledge and pedagogical knowledge about teaching mathematics, as well as involving teachers in the design and implementation of mathematics PD. Overall, the vision of these standards is to provide teachers with PD opportunities to engage in the practice of science and mathematics themselves, reflect on this practice with respect to their classroom teaching and interactions with students, and improve their content and pedagogical content knowledge. Table I provides a comparison of the PD standards from these three policy documents.

Despite the consensus about effective PD suggested by research and policy, a disparity between that vision and how PD is carried out still exists. Loucks-Horsley et al. (2003) claimed that PD for science and mathematics teachers (a) lacks in the number and variety of opportunities for educators to participate; (b) is not aligned to the needs or learning goals emphasized in education reform; (c) is insufficient in providing sustained support to educators; (d) focuses on how to change the individual educator rather than organization/school; and (e) provides pockets of innovation with minimal means for impact at the classroom and system levels.

Until all PD stakeholders agree about the characteristics of effective PD, deficiencies in PD practices will continue. Therefore, it is critical for research to explore the views of PD facilitators, who are *most responsible* for the implementation of effective PD practice, and teachers, who are *most responsible* for determining the impact of PD on classroom practice. This study is significant because it provides a voice for PD facilitators and teachers to share their perceptions of effective PD and compares their views to what is identified in the policy and research literature as effective PD.

Purpose of the Study

The purpose of this study was to examine the views held by science and mathematics teachers and PD facilitators regarding characteristics of effective PD, and to compare these findings to research and policy documents. Thus, the research questions that guided this study were: (1) How are teachers' and PD facilitators' views of effective science and

TABLE I

Selected professional development standards

Standards for staff development (NSDC, 2001)	Standards for professional development for teachers of science (NRC, 1996)	Professional standards for teaching mathematics (NCTM, 1991)
Context	Standard A: Science content	Standard 1: Experiencing good mathematics teaching
• Organize learning communities and align goals with school and district.	Build on the teacher's current science understanding, ability, and attitudes through the perspectives and methods of inquiry.	Model good mathematics teaching by engaging teachers in mathematical discourse.
• Require school and district personnel to become leaders.	Standard B: Pedagogical content knowledge	Standard 2: Knowing mathematics and school mathematics
• Provide necessary resources to support adult learning and collaboration.	Use inquiry, reflection, interpretation of research, modeling, and guided practice to help science teaching.	Develop teacher knowledge of the content and discourse of mathematics; including mathematical concepts and procedures and the connections among them.
Process	Standard C: Promoting lifelong learning	Standard 3: Knowing students as learners of mathematics
• Use student data to determine learning priorities, monitor progress and help sustain improvement.	Provide regular, frequent opportunities for individual and collegial examination and reflection on teaching practice.	Provide multiple perspectives on students as learners of mathematics by developing teachers' knowledge of research on how students learn mathematics.

• Use multiple sources for evaluation. • Select learning strategies appropriate to the intended goal. • Apply learning theories. • Collaboration among content and education specialists.	Standard D: Coherent and integrated PD design Quality PD programs are characterized by their congruency with National Science Education Standards; the integration and coordination of program components; recognition of individual and group interests, as well as the various needs of teachers; collaboration among all stakeholders; recognition of the history, culture, and organization of the school environment; and continuous formative and summative evaluation of the PD program.	Standard 4: Knowing mathematical pedagogy Develop teachers' knowledge of and ability to use and evaluate ways to represent mathematics concepts and procedures. Standard 5: Developing as a teacher of mathematics Provide teachers with opportunities to examine and revise their assumptions about the nature of mathematics, how it should be taught, and how students learn mathematics.
Content • Prepare teachers to provide equitable learning experiences for students. • Improve the quality of teaching by deepening teacher content knowledge; modeling research-based instructional strategies; and preparing teachers to use various forms of classroom assessment. • Provide educators with knowledge and skills to involve families and other stakeholders.		Standard 6: Teachers' role in PD Encourage teachers to take an active role in their own PD by accepting responsibility for reflecting on learning and teaching individually and with colleagues.

mathematics professional development similar and different? (2) How do these views compare to what the professional development standards and the research literature describe as characteristics of effective professional development?

Methodology

Research Framework

This study is grounded in the research tradition of phenomenography. Phenomenographic research focuses on developing, recognizing, describing, and apprehending the qualitatively different ways in which people experience certain phenomena or certain aspects of the world around them (Hasselgren & Beach, 1997; Limberg, 1999; Marton, 1996; Marton & Booth, 1997; Marton & Fai, 1999; Trigwell, 2001; Uljens, 1996). Interviews gathered from more than one individual are the primary data source used to facilitate a better understanding of the different ways of thinking about a phenomenon (Booth, 1997; Limberg, 1999; Marton, 1994; Sevensson, 1997; Trigwell, 2001). The aim of phenomenographic research is to find the variation which differentiates the phenomenon for the participants, rather than finding the singular essence as in phenomenology (Marton, 1996; van Manen, 1990). The categories of description constitute the primary results of study. The phenomenon of interest for this study was effective PD for science and mathematics teachers.

Context and Participants

This study took place in the context of PD that was supported by the first cycle of one state's Improving Teacher Quality Grants program. Institutions of higher education across the state were funded to design and implement nine PD projects serving a total of 272 participants, elementary through high school, including 247 teachers and 25 pre-service teachers, paraprofessionals, and/or administrators. PD participants came from 143 different schools in 76 districts in the state. The three mathematics PD projects and six science projects varied in the content, method of delivery, and incentives offered to the teachers for participating. However, the overall structure of the PD program was similar across all nine projects. Each held a 2–3 week summer institute in 2003, where the teachers participated in hands-on, inquiry-based professional development projects. Following the summer institute, each project conducted several weekend or school visit sessions during the school year.

We selected a sample of participants from each PD project to participate in this study. There were two groups of participants: teachers and PD facilitators. Eight teachers from each of the nine projects for a total of 72 teachers (53 females and 19 males) participated. Twenty four of the teachers were involved in a mathematics PD project, and 48 participated in a science PD project. These teachers taught a variety of grade levels: 30 at the elementary level, 16 at the middle school level and 26 at the high school level. We also purposefully selected 32 PD facilitators from the nine projects. The PD facilitators were mainly from institutions of higher education, including nine teacher educators and 15 content specialists. Three master teachers and five PD consultants comprised the balance of this group. Of the 32 PD facilitators only 24 interviews were audible enough for complete transcription. All four types of PD facilitators were represented in this sub-group; we analyzed these for responses relating to the characterization of effective PD.

Data Collection

The primary source of data for the study came from individual, semi-structured interviews. These interviews took place toward the end of each PD projects' summer institute. We asked each teacher interviewee to characterize effective PD according to their previous and current experiences. Each teacher interview lasted approximately 30 minutes. We asked the PD facilitators to explain their previous and current experiences in designing and implementing PD, and to characterize effective PD. Each of these interviews lasted approximately 45 minutes. All interviews were audiotaped and transcribed verbatim.

Data Analysis

The analysis process began with reviewing interview transcripts for comments related to views of effective and ineffective PD. In the second phase of analysis, we used an inductive approach (Patton, 2002) to code the data into thematic clusters or categories. This process required several rounds of reading a subset of data from 35 teachers and 12 PD facilitators, coding phrases, discussing possible categories/themes, and refining the definitions of the categories. Once we reached saturation in coding this subset, we coded the remaining data using the list of categories we had developed. To assist us with this process, we employed qualitative analysis software.

Next, we developed a frequency chart that included the number of comments by interviewee within each project for each coding category. The synthesis of the data (Patton, 2002) allowed us to see which categories were discussed within each project; thus, we could compare across projects and between the teachers' and PD facilitators' perspectives. From this synthesis, we discussed broader ideas that encompassed two or three of the categories. It is from these broader ideas that our assertions emerged. We returned to the data with these assertions to find specific examples that supported or refuted the claims. Lastly, we analyzed the views of effective PD by the teachers and PD facilitators for similarities and differences and compared these to research and policy documents.

Findings

We selected the most frequently discussed themes to organize the findings about teachers' and PD facilitators' views of effective PD. We discuss the themes not in descending order of frequency, but with an order that provides logical connections among themes. Within each section, we make an assertion and provide evidence from the interviews to support it. To maintain confidentiality, we identify the teachers by grade level and subject area of the PD project (i.e., science or mathematics). For the PD facilitators, we identify their professional affiliation as content specialist, education specialist, or PD consultant, as well as the subject area of the PD project.

Teachers' Views of Effective PD

This section includes the most frequently discussed themes for effective PD as viewed by the teachers. Most important to teachers was classroom applicability, which included practical applications, meeting the teachers' curricular needs, and providing the necessary resources for teachers to successfully implement the PD ideas and activities into their classrooms. Secondly, teachers' valued PD projects that gave them the opportunity to experience activities and learn concepts in a manner similar to their students. Lastly, teachers viewed support systems or networks with colleagues as an effective component of their previous and current PD experience. We present frequency counts for these themes in Table II and elaborate on the themes using supporting evidence from the data in the following sections.

TABLE II

Frequency count for themes discussed by the teacher subset (n = 35)

Theme	Frequency
Classroom application (including classroom resources)	123
Teacher as learner	47
Teacher networking (including two sub-categories)	45

Classroom Application. Many teacher participants characterized PD projects as effective when facilitators provide activities teachers can easily implement in their classroom with little modification. This idea was interpreted from interview excerpts similar to the following, "As teachers we like to have practical applications, things that we can take right back and start using" (Elementary teacher, mathematics PD project). The need for receiving activities that can easily be put into practice was expressed by comments such as, "Teachers don't really have the time, especially during the [school] year, to sit down and modify things" (Middle school teacher, science PD project).

In addition to gaining practical ideas to use in their classrooms, teachers identified an effective PD program as one that takes into account their teaching needs and addresses their specific grade level curricular objectives. For example, teachers preferred to attend PD where the project's objectives matched what the teachers felt were weaknesses in their instruction. The following two interview excerpts are representative of several teachers' comments on the need for PD to pertain to their specific teaching needs.

> I think one of the things that people who set up professional development need to think about is the teachers' needs. And the only way for people to find out is to ask the teachers. What do you need, what do you want? What do you think would make you a more effective teacher? And then meet those needs as much as possible by doing that instead of just throwing something together and presenting it, especially for experienced and non-experienced teachers. (High school teacher, science PD project)
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> Using technology is relatively new to me. The school system, the school that I'm in, that's important to them and so one reason why I came to here is because it's important. I wanted to learn how I can implement [technology] into my classroom, and this does a lot with it. And they showed us how we could best use it...Effective professional development needs to have a purpose, as I said, providing new tools for teachers in the classroom. (Middle school teacher, science PD project)

The final aspect teachers discussed about *classroom application* was the importance of receiving the necessary resources (e.g., equipment, handouts, or curriculum materials) to successfully use the PD activities with their students. As one teacher described, “I can teach anything I want, but if [I] go back to [my] classroom and [I] don’t have materials, what good does it do [me]?” (Elementary teacher, science PD project).

With regards to the science and mathematics Improving Teacher Quality Grants (ITQG) PD projects in which they were enrolled, teachers appreciated receiving copies of curriculum materials and activity sheets used in the PD projects that they could use with their students. The following are a few of the comments that support this claim.

> [The PD facilitator] keeps giving us supplementary material to put into the binder so every activity that we do, we do it in class. She shows us how you would teach the children and how you present it and then any accompanying data sheet or graph or tally sheet, she gives us and we keep in our binder so we have that to use as a resource binder and it’s really meaningful because we’ve done all of the activities; it’s not just like you got a book full of ideas that you may or may not ever use. (Elementary teacher, mathematics PD project)
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> We’ve got handouts, a couple of the ladies have done this for several years have made handouts and student worksheets and all kinds of things that I think will be very helpful for me and the students. It’s really easy step-by-step instructions so that will help out. (High school teacher, science PD project)

Another teacher explained that receiving resources from PD projects benefited not only him, but other teachers within his school. He stated,

> In terms of the materials, it’s phenomenal the amount of materials that we are actually getting a chance to take back with us and so I like that...they have people from my school and we can share the resources and that’s our plan...I know another girl who took the workshop earlier at our school and so we have a strategy and we are going to work that strategy until it develops into a workable plan. (High school teacher, science PD project)

Teachers felt PD was effective when the activities could easily be applied in their classrooms, met their instructional needs to best teach their district’s curriculum, and provided the tangible resources to support immediate implementation of these activities in their classrooms. Teachers across all grade levels and subject areas frequently mentioned these three dimensions of classroom applicability.

Teacher as Learner. A second aspect of effective PD teachers discussed was how PD allowed them to be involved as a student learner. This role offered teachers the opportunity to experience PD activities in a manner similar to how their students experience them. A hands-on approach also required teachers to consider the practicality of using the activity in their classrooms.

Teachers believed that imitating their students' learning experiences provided them with a better understanding of the questions and frustrations their students could encounter while doing the activity. The following interview excerpts are representative of teachers' perceptions about experiencing an activity as a student learner:

[Effective PD is] something that's hands-on where you actually perform the project that the students would do in the classroom. You can see how the teacher models that for you, and feel the experiences that maybe your students would feel. (Elementary teacher, mathematics PD project)

We've participated in initial elicitation of ideas and testing it and then worked on the development of the concepts in a class with general class discussion afterwards. We've worked in groups, cooperative groups, which is, you know, what we do in science. So I've been the student in a format that I really like and think I can take into my classroom and use, and hopefully have a better understanding of how my students are going to feel in that same situation. (Middle school teacher, science PD project)

[With] this [institute] being 12 days—totally engrossed, totally intensive, has helped a lot because, I've had to actually go through it like I was a student, just like my kids are going to go through it in class. So I've got to experience the student side of it, not just the teacher side. (High school teacher, science PD project)

According to these teachers, a PD project needs to actively engage them as learners in order for it to be effective. To them, active engagement means working with the same materials and/or following the same procedures for investigations as their students. One teacher discussed a previous PD experience that did not provide her or her colleagues with the necessary hands-on experience to enable them to transfer what they learned back to her own classroom. The following interview excerpt describes how these teachers were unable to use the materials with their students once they returned to their classrooms.

Last year [when] we went to a workshop, and there was a computer program [that] in theory was supposed to be great and wonderful. You could individualize instruction to make your life easier. But at the workshop they didn't have computers where we could get on and try out and see how it works. They told us how it worked, showed us some handouts, and had a nice PowerPoint presentation. So, when we all went back to school we're like, "What?!" "How do we do that?" They ended up sending that stuff back and getting their money back for that equipment. Even at the workshop we [thought] "We are not going to know how to use this when we get back to school." (Elementary teacher, mathematics PD project)

Although teachers wanted to be engaged as learners, one teacher expressed caution for PD facilitators to respect teachers as adults when asking them to engage in the activities as their students would. She explained,

> [Effective PD] has to be structured in such a way that it's open and loose [in order] to respect the adult nature of the students. Teachers are teachers for a reason—they're well educated, and you have to respect that level. If you are just going in with a cookbook recipe it is not going to fit every teacher so you have to allow differences for every teacher and their needs in the classroom also. So those two combinations will make a very effective PD. (Middle school teacher, mathematics PD project)

Overall, teachers characterized an effective PD program as one that involves them as student learners. They viewed the ability to practice PD activities in a manner similar to their students as an important feature for science and mathematics PD.

Teacher Networking. For several teachers, effective PD provides opportunities to network with teachers from other schools, and in some cases, with teachers from other districts. Teachers often referred to their current ITQG PD project experience when discussing two types of networking opportunities. The first occurred during the structured time period of the PD project, when teachers discussed and problem-solved together. The following two interview excerpts demonstrate the type of networking described by teachers that occurred during the scheduled timeframe of a PD session.

> We have other people in the class that bring up new concepts, new ideas and that helps some people to better understand what's going on. It's kind of like we're bringing something to the table besides [the PD facilitator] just giving us this information. We're able to get a lot more than we would be getting if [the PD facilitator] taught as though there weren't other teachers there. (Middle school teacher, science PD project)
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> Working with the same grade level and knocking ideas back and forth... I know they are doing that [in this PD project], and I hope they continue doing that because it's nice to have that resource of another person out there to talk to. (High school teacher, mathematics PD project)

For these teachers, networking with colleagues during PD sessions offered additional learning experiences that they could not receive from instructor-led activities. Working and talking with fellow teachers during scheduled PD tasks initiated the development of a colleague-based support system.

A second opportunity for networking with colleagues occurred outside the PD project's regularly scheduled activities. One teacher described the opportunity for informal exchange with colleagues as a necessary component of effective PD because it "allow[ed] us time to share with other teachers of other districts and teachers of our own district" (Elementary teacher, mathematics PD project). In addition, teachers described the importance of this "sharing" time in interview excerpts such as the following:

> [This PD is] a good experience because I get to meet peers within my district. It's good to have peers that you actually relate to and you, you've gone through the same types of things, the same development within the district, which is good. You also get to know who's in other buildings, resources—these people could at some point become more [of a] resource to you [if] they are teaching similar things, [so] you can share more ideas. Often you're sent off to a conference somewhere else, you don't know anyone there, you maybe make some connections, but it's not the same as having someone locally that you can bounce ideas off of and work with for a long time, long term. (Middle school teacher, science PD project)

Non-scheduled or informal instances of networking included teachers sharing resources or general teaching strategies, and took place during summer institute free time and by email or web-based discussion boards throughout the school year. The following interview excerpt describes how technology afforded one teacher to use technology to continue networking with her colleagues at her own convenience.

> [I have] access to Blackboard—[a] kind of our communication board. And I really like that. The first thing that I do when I get home is see who's written something from my class. Isn't that crazy? Drive two hours and go home and check to see if anyone's written something. So, I like that communication. (Middle school teacher, mathematics PD project)

Whether the purposes for networking were to share resources and teaching methods, or ask for assistance with classroom instructional or management problems, teachers viewed opportunities to network with colleagues, both during and outside of a PD project's scheduled timeframe, as a necessary feature of effective PD.

From our analysis of 72 teachers' views about PD, the three themes of *classroom application*, *teacher as learner*, and *teacher networking* emerged as their beliefs about the essential features for a PD experience to be effective. We found no different patterns between science and mathematics teachers, or teachers of different grade levels, with respect to the importance of these three themes.

PD Facilitators' Views of Effective PD

This section includes the four most frequently discussed themes of effective PD by the PD facilitators. Similar to the findings about teachers, the PD facilitators most frequently discussed aspects of classroom applicability and the need to provide teachers with opportunities to be learners. PD facilitators viewed support systems as building collegial relationships between themselves and the teachers. Lastly, because of the science and mathematics focus of the PD projects involved in this study, PD facilitators also commented on the need for PD to improve teachers' knowledge of teaching science and mathematics. We present frequency counts for these themes in Table III and elaborate on the themes using supporting evidence from the data in the following sections.

Classroom Application. The majority of PD facilitators agreed that effective PD must have direct application to the classroom. Application was defined as providing teachers with instructional ideas specifically related to the grade level they teach, including practical activities that teachers can quickly utilize in their classrooms. As one mathematics education specialist stated, "[Teachers] want to be able to have something that they can take back to the classroom... [If] it deals directly with what they're teaching or doing and they can implement it." Likewise, a science PD consultant described a PD project as ineffective if teachers "can't take it, put it into play, and practice it." In general, most PD facilitators involved in this study viewed effective PD as providing teachers with practical and grade level relevant ideas and activities that are easily utilized in their classrooms. The following interview excerpt illustrated this view:

> One of the things I look at as maybe one of the most important [aspects] is to develop things [teachers] can use with the time constraints that they have. I recognize there are time constraints. [Effective PD provides] useful activities they will actually be able to use and also will develop concepts for children. (Content specialist, science PD project)

TABLE III

Frequency count for themes discussed by the PD facilitator subset (n = 12)

Theme	Frequency
Classroom application	15
Teacher as learner	15
Collegiality	13
Teacher knowledge	17

The second component of *classroom application* that PD facilitators discussed was the need to provide teachers with simple ready-made materials, equipment, or resources to assist them with implementing the activities in their own classrooms. The following interview excerpts demonstrate the PD facilitators' view that, to increase the probability of teachers implementing what they learned from the PD in their classrooms, they must also receive the necessary materials.

> If we don't have materials that [the teachers] can use immediately in the classroom, they will not do it in the classroom. So we have tried to fine-tune this over the years, to give the teachers want what they will use in the classroom. (Content specialist, mathematics PD project)

In general, PD facilitators in the ITQG PD projects believed effective PD design needs to include practical ideas, simple activities, and the necessary resources to support implementation into classroom practice. Many of the PD facilitators emphasized that these design elements need to be grade specific and address the grade level expectations of state and national standards. The views of PD facilitators and teachers paralleled one another regarding this theme. Both teachers and PD facilitators frequently mentioned the importance of classroom applicability for effective science and mathematics PD.

Teacher as Learner. Many PD facilitators shared the view that effective PD involves teachers in various roles as a learner. They explained that this is accomplished by considering the teachers' level of participation as both students and professionals. PD facilitators recognized the teachers as learners in three ways: (1) modeling research-based teaching (e.g., inquiry); (2) providing teachers opportunities to do the same activities that they would ask their own students to do; and (3) providing time for teachers to discuss and reflect on their instructional practice.

According to one PD facilitator, a PD experience that models research-based practices includes "a variety of strategies and strengths and builds their attitude and motivates them to learn more and learn concepts in a holistic manner" (Content specialist, science PD project). Another PD facilitator explained,

> I feel that a good professional development for teachers should give them a variety of things and model it to them as much as you can, from the instructional style to the theories of learning to different types of content. (Content specialist, science PD project)

Together these interview excerpts represent many of the participating PD facilitators' views that an effective PD experience requires modeling of research-based instructional strategies so teachers better understand how to change their approaches to teaching science or mathematics.

A second aspect of this theme was engaging teachers in the PD program's activities in a manner similar to those of their students. According to one PD facilitator, "[An effective PD] actually gives them experience where they're doing the activity themselves, and experiencing it for themselves. So it's important that [the PD experience is] activity based; that they aren't just listening" (Content specialist, mathematics PD project). Another PD facilitator echoed this idea:

> We want the teachers to learn, discover for themselves what's right and wrong, just the way we hope their students would. So I figured...we figured, if the teachers learn that way then they'll be more able to instruct their students to learn that same way. (Content specialist, science PD project)

One PD facilitator described an ineffective PD experience as one in which all teachers do is "Sit and get. Where [teachers] sit there forever and [they] just take notes. I think without involvement and activity and moving around... well, it models what's good to do with kids" (Content specialist, mathematics PD project).

The third aspect of *teachers as learners* shared by several of the participating PD facilitators was reflective practice. To them, this meant providing teachers with opportunities to think about their role as teaching professionals and as learners. During PD, periods of reflective thinking should include discussions about the research-based teaching strategies the PD facilitators modeled, as well as the teachers' experiences as students when working through activities. The PD facilitators believed that to affect change in teachers' practice, reflective practice is a necessity. This idea was elaborated on by one of the education specialists:

> If you get them to think about what they're doing, they will, as intelligent people, decide to make changes. If you can get them to make changes you'll have a successful in-service...I think the big thing you need to do is to get people to think about what they're doing. If you get them thinking, then you can make changes. (Education specialist, mathematics PD project)

PD facilitators saw the role of teachers as learners in two ways: (1) teachers are similar to their students in that they also need to learn the content and/or practice the mathematics and science skills, and (2) teachers are reflective practitioners. The PD facilitators agreed that these two roles could not be considered as separate entities. Instead, they should be incorporated into the PD design so that teachers are engaged in both roles simultaneously.

Collegiality. Another theme the PD facilitators frequently discussed was establishing a collegial relationship with the teachers, where teachers are respected as professionals. As one PD facilitator explained,

> I think professional development means I am, or we are, treating them as professionals and they are our colleagues, as I want to be treated. [That] they have a colleague that they can go to for help and they can trust the colleague to go for help. (Content specialist, science PD project)

For some PD facilitators, this idea of developing a trusting relationship begins with PD facilitators listening to teachers comments about what aspects of their teaching need improvement. For example, when describing PD, several PD facilitators shared the view that an effective PD project was "one that [was] modified and improved upon over the years by listening to and not assuming the needs of the teachers" (Education specialist, science PD project). Another PD facilitator explained that failing to listen to teachers requests about PD design was a mistake, because teachers know what areas of their teaching need improvement. The PD facilitators in this study believed it was their responsibility to consult with teachers as professional colleagues, and work together to design a quality PD experience.

For other PD facilitators, building a collegial relationship with teachers extended beyond the initial planning phase of a PD project. One PD facilitator explained that it was important for a PD project "to create an atmosphere [where they were] working with as opposed [to] preaching to [the teachers]... so it's a collegial atmosphere as opposed to someone dishing out information and expecting folks to respond" (Education specialist, science PD project). In addition, a PD facilitator from a different project believed that much of their project's effectiveness was due to the consistency in their approach of "combining the university, community college individuals, [and the] elementary teachers" (Content specialist, mathematics PD project).

We found the majority of PD facilitators characterized an effective PD project as one that encouraged the development of a collegial relationship between the PD facilitators and the teachers. This relationship included respecting teachers as professionals, involving teachers in the design of the PD, and maintaining a collegial relationship throughout the various phases of the PD project.

Teacher Knowledge. Lastly, science and mathematics PD facilitators considered PD most effective when it emphasized the improvement of *teacher knowledge*. In particular, mathematicians and scientists who delivered PD repeatedly shared their views that PD facilitators must work to develop teachers' content knowledge, as this will better prepare teachers to help their students understand the subject area. Throughout the PD facilitators' interviews, comments similar to the following appeared:

[Effective PD] is about giving them an understanding of the content they teach. [Teachers] need to be thinking at a much higher level and a good professional development always takes them through the process of thinking at a higher level. (Content specialist, science PD project)

[Effective PD includes] broadening their content knowledge. You can always use content. I always hope that [teachers will] walk away with something new in content knowledge that they didn't have before—a new way to look at math. (PD consultant, mathematics PD project)

I think teachers shouldn't just see the activity but they should also understand the science behind it. You shouldn't do a science activity if you can't explain the science behind it; you're not helping your students. (Content specialist, science PD project)

In a few instances, PD facilitators talked about the need for science/ mathematics pedagogy, in addition to subject matter, to be explicitly discussed. This idea of pedagogical content knowledge (PCK) (Shulman, 1986) was reflected in comments such as,

For teachers content and pedagogy cannot be separated. They really are inherently mixed together and I can't just stand to teach content without also talking about how children learn that content, and how the content is learned as an adult...[examining] what research tells us about how people learn content. (Content specialist, mathematics PD project)

If you address only content, you've only done part of it. If you just teach the content in isolation that's a problem. [However], if you teach pedagogical skills without actually connecting it to the actual content in the curriculum, that's a problem. You've got to have the whole picture. (Education specialist, science PD project)

Although the majority of PD facilitators agreed that improving teacher content knowledge was necessary, only a few, typically education specialists, asserted that without PCK teachers would not be prepared to teach the science and mathematics concepts to their students. Overall, regardless of their specialty area, science and mathematics PD facilitators identified the importance of *classroom application*, *teacher as learner*, *collegiality*, and *teacher knowledge* as necessary components for effective PD.

Discussion

Through our analysis of teachers' and PD facilitators' views, we gained an emic perspective of what constitutes effective PD. This insight is unique in the research literature on characteristics of effective PD. It is this insider perspective that provides a significant contribution to the body of literature on designing and implementing effective PD experiences for science and mathematics teachers.

We discuss the findings of this study in two ways: First, we compare the teachers' and PD facilitators' views of effective PD. Second, we examine how both groups of participants' views compare to characteristics of effective PD identified in research and policy.

Teachers and PD facilitators who were involved in science and mathematics PD projects had similar views about effective PD design. These similar perceptions included: (a) demonstrating activities and teaching strategies that apply to the teachers' curricular needs, as well as providing teachers with the resources necessary to easily implement the activities; (b) establishing opportunities throughout a PD project for teachers to experience activities from a student's perspective; and (c) developing a network of support for the teachers.

However, teachers' and PD facilitators' held slightly different interpretations of the latter two views. While the teachers spoke only of working through activities in a manner similar to their students, PD facilitators also discussed the importance of giving teachers the opportunity to reflect on the instructional aspects of an activity. Second, teachers described a network of support with their fellow teachers only, whereas PD facilitators described the need to develop collegial relationships between facilitators and teachers. Last, our findings showed a distinct difference between the teachers' and PD facilitators' views on developing *teacher knowledge* (both content and PCK). This characteristic of PD was rarely discussed by the teachers, but was a significant part of nearly all the PD facilitators' views of effective PD.

The characteristics of effective PD discussed by the teachers and PD facilitators were, for the most part, also identified throughout the research (Desimone et al., 2002; Garet et al., 2001; Guskey, 2003; Loucks-Horsley et al., 2003) and policy standards (NCTM, 1991; NRC, 1996; NSDC, 2001) as key features of effective PD design. However, three additional aspects of effective PD exist within the literature that neither participant group mentioned. These characteristics included: (a) challenging teachers' beliefs and knowledge of a subject area through transformative learning experiences (Borasi, Fonzi, Smith & Rose, 1999; Thompson & Zeuli, 1999); (b) encouraging teachers to serve in leadership roles in their schools to help sustain improvements resulting from a PD experience (Loucks-Horsley et al., 2003; NCTM, 1991; NRC, 1996; NSDC, 2001); and (c) using changes in student learning as a means of determining the learning priorities and measuring the effectiveness of a PD project (Guskey, 2003; Kelleher, 2003; Loucks-Horsley et al., 2003; NSDC, 2001). These "missing" elements are most informative for PD design and research.

Conclusion and Implications

Contrary to Loucks-Horsley et al's (2003) claim, our study reveals that there is not a consensus about what constitutes effective PD among PD stakeholders in one state's university delivered ITQG professional development program. In fact, differences were found in response to both research questions: (1) How are teachers' and PD facilitators' views of effective science and mathematics professional development similar and different? and (2) How do these views compare to what the professional development standards and the research literature describe as characteristics of effective professional development? We claim it is the difference in beliefs among the stakeholders of PD that has contributed to the gap between ideal and actual PD practice (Loucks-Horsley et al., 2003).

PD facilitators act as liaisons between the ideal and the actual. It is their responsibility to interpret what policy and research define as characteristics of effective PD to better inform and transform their own PD practice. However, we cannot assume that PD facilitators understand all characteristics of effective PD as described in the literature, nor that they know how to incorporate these ideas into their own PD practice. Our findings suggest several implications for the practice of science and mathematics PD that work toward a more unified view of effective PD.

1. If the aim of PD is transformative learning (Thompson & Zeuli, 1999) then there must be explicit effort for teachers to experience a sense of cognitive dissonance that challenges both their content knowledge and PCK (Shulman, 1986). Both the Professional Standards for Teaching Mathematics (NCTM, 1991) and the PD standards described in the National Science Education Standards (NRC, 1996) indicate the need for effective PD to improve teachers' content knowledge and PCK. However, our teacher participants did not mention transformative learning as a characteristic of an effective PD experience, and although the PD facilitators mentioned developing teacher knowledge, their views reflected an "addition" of

knowledge versus a transformation. Thus, PD facilitators need experience in transformative learning design, as well as practice developing these kinds of content and PCK transformation experiences for teachers.

2. If the goal of PD is to provide sustained improvement in schools, then teachers need to be prepared as leaders in their schools so they can share the knowledge and skills they gained from PD with their colleagues. This requires a job-embedded component to the PD design and continuing support by PD facilitators during and beyond the PD project itself. For example, one method of job-embedded support, the development of study groups (Arbaugh, 2003; Clarke, 1994), can be promoted by PD facilitators for teaching teacher leaders. Such approaches will foster change beyond a few select teachers, with the potential of creating systemic change across schools and school districts as well.
3. If the ultimate purpose of PD is to improve student learning (Guskey, 2003; Kelleher, 2003; Loucks-Horsley et al., 2003; NSDC, 2001), then PD must take into account the learning needs of students. For this to occur, PD facilitators must instruct teachers on how to use student data to inform their teaching practice. This task requires facilitators to learn for themselves and model for teachers how to design appropriate assessments, diagnose student needs from these assessments, and continually modify a standards-based curriculum to address their students' specific learning needs.

In addition, our study suggests several implications for further research in science and mathematics professional development. To attain the goal of providing effective PD, alignment of policy, research, and practice needs to occur. We believe that understanding stakeholders' views of PD is one step toward researching this goal. However, further research about PD needs to occur in this area, such as:

1. What constraints do PD facilitators face that limit them from enacting the kinds of PD that policy and research claim is most effective?
2. What happens in PD when teachers' and PD facilitators' views of effective PD practice are different? When their views are the same?
3. What does PD that includes a *transformative learning* experience look like?

To attain the vision of scientific and mathematics literacy for all, as discussed in the NSES (NRC, 1996) and NCTM (1989) standards, PD will continue to play a critical role. For PD to be most effective all stakeholders must agree about what constitutes effective PD and then they must put these views into practice. This study is a beginning step in closing the gap between ideal and actual PD practice.

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