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Systemic reform has been a key element of the mathematics and science educational agenda for the past decade. Systemic reform proponents advocate emphasizing mathematics and science from kindergarten through l2th grade; adopting new math and science education standards; providing ongoing professional development for teachers (Frechtling, Sharp, Carey, & Vaden-Kiernan, 1995); and aligning policy, practice, and assessment procedures. The National Science Foundation (NSF) has supported the development of systemic reform by funding statewide, urban, and rural systemic initiatives to improve K–12 mathematics and science education throughout the United States (Fitzsimmons & Kerpelman, 1994).

In the past decade, professional development has evolved in content, delivery, and style. The National Council of Teachers of Mathematics (NCTM) standards and the National Science Education standards clearly define a new direction for effective mathematics and science instruction. The standards incorporate constructivist teaching and learning techniques reflecting changes in learning theory and focusing on student-centered learning and real-life applications of concepts. These standards promote instructional approaches that prepare students to take more active roles in their learning and work independently and collaboratively. The goal is for students to construct more powerful and flexible knowledge and understanding. To use these approaches, teachers must think in ways substantially different from how many of them were taught about students, subject matter, and the teaching and learning process (Borko & Putnam, 1995). Effective professional development can provide teachers with the means to engage in exploration, research-based

inquiry, reflection, experimentation, and practice, while providing collegial sharing of knowledge and opportunities to draw on the expertise of others in the Community. Abdal-Haqq (1996) and Joyce and Showers (1982) have identified several factors essential in delivering effective professional development programs: providing training, practice, and feedback; providing opportunity for reflection; allowing opportunity for group sharing and inquiry; focusing on student learning and assessment practices; incorporating constructivist approaches to teaching and learning; recognizing teachers as professionals; and providing adequate time and follow-up support. Most of these elements were in the professional development workshops that were the subject of our evaluation.

Professional Development Workshops

The Nebraska Math and Science Initiative (NMSI) was one of the initial group of 11 statewide systemic initiatives NSF funded to develop projects leading to systemic change in mathematics and science education. One primary strategy of NMSI was the PEERS (Promoting Educational Excellence Regionally and Statewide) Academy—a series of 2-week professional development workshops to increase teacher understanding of mathematical and scientific processes, improve teaching methods in math and science, and create a supportive network for systemic change in the state. Nebraska classroom teachers who had earlier participated in two 5-week residential summer NMSI Institutes conducted the PEERS workshops. These workshop leaders, called Lead Teachers, were role models and advocates for change in math and science education by working with participating K–12 teachers to incorporate more constructivist, standards-based, and inclusive teaching practices in their classrooms. Conducted in grade-related groupings (e.g., K–3, 4–6, etc.) the PEERS workshops modeled best practices in K–12 teaching and included many key components of standards-based practices. Workshops were comparable in their goals across the different grade levels, but individual Lead Teachers tailored activities and lessons within workshops. Districts were required to commit funds for their teachers, ensuring that administrators were supportive and knowledgeable about the professional development efforts. In addition, at least one follow-up session during the school year was included as part of every PEERS workshop to help sustain the teachers' efforts toward change.

The NMSI PEERS Academy is the most comprehensive professional development initiative ever undertaken in Nebraska. From the initial involvement of 88 Lead Teachers in the Summer Institutes beginning in 1991, nearly 2,000 teachers were involved statewide by the end of 1996. The goals of the workshops were similar across the different grade levels and focused primarily on the skills that participants would have in seven main areas upon completing the workshop: (1) understanding mathematics and science standards, (2) creating an active learning environment, (3) using technology in the classroom, (4) integrating mathematics and science, (5) increasing multicultural awareness, (6) improving communication of PEERS teachers with other professionals, and (7) providing better assessment.

Because classroom teachers have the greatest capacity to influence educational change, any systemic reform effort must focus on them as primary change agents (Fitzsimmons & Kerpelman, 1994). The philosophy of PEERS was to put learning in context and provide

appropriate modeling for teachers. A primary goal was to help teachers shift away from explanation and drill-oriented instruction and toward hands-on, active learning methods emphasized in the new standards.

Evaluation Methods

At the conclusion of each PEERS workshop, participating teachers assessed their experience and evaluated the extent to which the workshop met the stated goals. This initial evaluation indicated that the PEERS Academy workshops were highly successful in meeting their objectives (Spiegel & Dethlefs, 1995; Wise & Spiegel, 1996). In PEERS workshops across the state, participating teachers consistently praised their workshop leaders and stated that they had provided activities and information congruent with the seven main goals. In particular, participants cited their experiences in working with manipulatives in a variety of hands-on activities, sharing experiences with colleagues, learning how to apply the standards in classroom teaching, learning to use real-life examples, and integrating mathematics, science, and technology in their lessons as strengths across all the workshops. At the high school level, teachers saw technology skills as a valuable component of the workshops, while the elementary teachers cited their improved understanding of science and math processes as a result of attending PEERS. Lower percentages of teachers at all levels agreed they had become more aware of multicultural and gender equity issues, and gained substantial knowledge about new methods of assessment.

Because resources for professional development and its evaluation are often quite limited, the evaluation of professional development efforts often end at workshop completion (Shavelson, Copelan, Baxter, Decker, & Ruiz-Primo, 1994). Teacher satisfaction with the workshops is generally considered sufficient; typically there is little follow-up (Fitzsimmons & Kerpelman, 1994). The immediate positive evaluation feedback on the workshops indicated that they were effective in delivering the intended content and experiences, but this evaluation provided only indirect information regarding the extent to which teachers can use these new skills in their classrooms. It provided no information concerning whether the teachers had translated their workshop experiences into their classroom practices. To gather such information, we conducted a follow-up study with PEERS participants, using a self-report reflective practice exercise in which teachers reported on their implementation of a new teaching strategy or activity learned in their PEERS workshop. This exercise provided documentation of the teachers' assessments of the value of those activities. Although this strategy cannot provide a detailed picture of a single teacher in his or her classroom and document change over time, it can provide a rich picture of how a large group of teachers chose to use constructivist methods in their classrooms and how they perceive their teaching as influenced by constructivist principles.

Reflective Practice Methodology

At the conclusion of the PEERS 1996 summer workshops, participants received the reflective practice form and reported on their use of a new teaching strategy or lesson learned in PEERS in their classrooms during fall 1996. We asked teachers to reflect on the strategy

or lesson, consider how it fit with the standards, reflect on how well it worked for the students, and report how they assessed student understanding of the concepts presented. We also requested that teachers make a signature commitment. Research in medical and counseling settings indicates higher rates of compliance when individuals formally agree to future action (e.g., Miller, Hersen, & Eisler, 1974).

The reflective practice form consisted of eight open-ended questions:

1. Please describe the new lesson/unit or teaching strategy you tried.
2. How does this lesson/unit relate to the national standards or Nebraska frameworks?
3. What were your objectives/goals in the lesson or strategy you used? (Why did you decide to use a new strategy or lesson?)
4. Did students respond differently than in a typical lesson?
5. What evidence did you see of differences in student learning or student attitudes? (Student comments? Student work? Assessments? Attach examples if desired.)
6. Will you do this lesson again?
7. What modifications will you make and why?
8. What have you learned from this experience?

We asked teachers to include their name, grade level, and subject taught on the form. Although the response form did not specifically ask about the seven PEERS workshop goals, questions were open-ended enough to allow for these responses. Teachers' use of these newly learned methods in their classrooms should be reflected in their descriptions.

Two independent raters coded teachers' responses to the questions. If a behavior, activity, or thought related to workshop goals was explicitly stated or could be easily inferred as having occurred, the raters marked 1 (*yes*); otherwise 0 (*no*). One rater initially coded each of the reflective practice forms on the variables of interest, and a second rater coded a 10% sample of the forms independently to check for consistency. The interrater agreement for the forms was 93%.

Results

During summer 1996, 1,016 Nebraska teachers participated in the PEERS Academy Workshops. Five hundred sixty-eight participants (56%) agreed to complete a reflective practice form describing their use of a new unit or teaching strategy learned in PEERS workshops in their classroom; 314 teachers returned reflective practice forms. Included in this group was a small number of teachers who did not sign the original agreement but returned a completed form. Of the teachers who originally signed an agreement, 275 (48%) returned a completed reflective form, while 39 (7%) of teachers who had not signed an agreement returned one. These teachers represented grades K–12, with 195 elementary, 54 middle school, and 56 high school teachers responding (seven teachers responded that they taught grades K–12; two did not report what grades they taught). The results, which are framed by the seven different workshop goals, illustrate what the participating teachers did as a

result of their experiences in the PEERS workshop. Table 1 shows the percentage of teachers who incorporated strategies learned in PEERS workshops into their classroom practices.

Table 1. Percentage of Teachers Who Incorporated Strategies Learned in the PEERS Workshops into Their Classroom Practices

Workshop Goals and Issues	High School	Middle School	Elementary School
Goal 1: Understanding mathematics and science standards			
a. applied standards and frameworks in their lesson	86	76	83
Goal 2: Creating an active learning environment			
a. used strategies to manage small groups of students working on projects in class	38	43	51
b. used *real-life* examples in the classroom	27	20	25
c. had a concrete plan to implement strategies, as articulated in their goals and objectives	99	97	99
d. provided activities that involve active, hands-on approaches	70	87	82
Goal 3: Using technology in the classroom			
a. used technology to enhance their teaching of mathematics and/or science	48	13	6
Goal 4: Integrating mathematics and science			
a. integrated mathematics, science, and technology in their teaching	27	33	29
Goal 5: Increasing multicultural awareness			
a. incorporated multicultural content in their lesson plans and teaching strategies.	4	6	2
Goal 6: Improving communication			
a. discussed ideas learned at the workshop with colleagues, administrators, and parents	4	6	2
Goal 7: Providing better assessment			
a. responded differently	87	76	89
b. increased learning	40	68	60
student presentations/projects	25	19	14
questioning students	22	19	11
student writing samples	18	20	13
auditory/visual assessment of students	77	81	80
c. changed attitude	68	76	81
d. changed behavior	59	72	74

Goal 1: Understanding Mathematics and Science Standards

Asked how their lesson/unit relates to the national standards or Nebraska Frameworks, the majority of teachers articulated the specific standard and/or framework to which their lesson or teaching strategy applied. Comments included *This lesson relates to the national standards and Nebraska frameworks by allowing children to solve problems by cooperatively work-*

ing together using a hands-on approach (elementary school teacher); *This lesson involves problem solving, reasoning, estimation and communication in the Nebraska Frameworks topic strand of measurement* (middle school teacher); *This lesson dealt with the Nebraska Frameworks topic strand of spatial relationships and geometric topics and the conceptual thread of problem solving* (high school teacher).

Goal 2: Creating an Active Learning Environment

Teachers reported using a variety of teaching strategies to create active learning environments. For example, elementary teachers included classification activities, estimation and graphing, Family Math units, patterning, and hands-on equations. Middle school teachers used metric measurement, classification activities, and pattern units. High school teachers used hands-on activities to teach energy and computer-based lab activities to teach physics, units of measurement, and graphing. Elementary and middle school teachers used hands-on activities more often than did high school teachers.

Asked what they had learned from implementing a new activity or teaching strategy, more middle and high school teachers emphasized the importance of hands-on activities, active participation, and the use of open-ended activities to keep students motivated and to improve learning. Teachers commented, *Students understand, remember, and think better when they question-when they are more actively involved* (elementary school teacher); *Hands-on reinforces concepts in memory and aids in recall* (middle school teacher).

Small-group activities were more predominant in elementary classrooms than in middle and high school classrooms. Approximately one quarter of the teachers specified how the activities used had real-life application. When directly asked, almost all teachers were able to state their goals and objectives for using a particular lesson or strategy.

Ninety-eight percent of all teachers said they would repeat the lesson; 80% stated they would make modifications in their teaching and activities when they did. Commenting on their planned revisions, elementary teachers stated they would make lessons more developmentally appropriate, provide more thorough explanations/directions, and add more active learning experiences for their students. Middle school teachers reported they will incorporate other equipment/learning materials into the activities, use different ways to assess student learning, and add more math and writing activities. High school teachers expected to incorporate other equipment/learning materials and allow more time for students to engage in activities.

Goal 3: Using Technology in the Classroom

Teachers reported using technology, especially graphing calculators and computers, in almost half of the reporting high school lessons. Much lower percentages of middle and elementary classrooms included technology-based instruction. One high school teacher commented, *The more we integrate technology into the curriculum, the more interested students will be*.

Goal 4: Integrating Mathematics and Science

About one third of all teachers stated that a goal of their lesson or teaching strategy was integration of math and science with one another and with other subject areas.

Goal 5: Increasing Multicultural Awareness
Overall, fewer than 10% of the responding teachers stated that they incorporated multicultural activities into their lessons.

Goal 6: Improving Communication of PEERS Teachers with Other Professionals
Fewer than 10% of the teachers indicated that they had discussed or shared ideas about the new lesson or strategy they were using with other teachers in their schools.

Goal 7: Providing Better Assessment Strategies
Asked about their assessment strategies and about their observations of changes in student learning, student attitudes, and student behavior, the majority of teachers stated that their students responded differently from how they did in typical lessons. Presentations and projects, questioning strategies, and student writing samples were the strategies teachers most often reported using for assessing changes in student learning. They less often used homework assignments, tests, and photography or videotaping to assess student learning.

Asked for evidence of changes in student learning, elementary teachers cited projects students created through hands-on activities; students' use of new terminology and understanding of science and math concepts; their abilities to explain strategies, ideas, and findings; their ability to extend the lesson to other content areas and activities; and their improvement in their graphing/writing skills. Middle school teachers reported that students gave evidence of learning by their ability to explain strategies, ideas, and findings and their increased understanding of concepts. High school teachers reported relatively fewer changes, but among those reported were that students demonstrated their learning by better understanding of math concepts, improvement in their graphing skills, and their ability to use new technology. Some comments were *Students* [*are*] *able to put concepts together into a whole* (elementary school teacher) and *Students used terms throughout the science unit and in other situations* (middle school teacher).

Although teachers often reported that student performance improved with the new lesson or strategy, many did not specify how they came to know this. It appears that most teachers assessed student performance through informal means. What they saw students doing differently and what they heard students say were their clues about students' level of understanding. One elementary school teacher expressed, *I noticed they were more aware of the misconceptions that they made and that they understood the concepts clearer and in more detail because of our corrections of the misconception*. The use of informal means to assess student understanding is not particularly surprising. In their review of the literature on teacher self-evaluation, Airasian, Gullickson, Hahn, and Farland (1995) report that teachers rely greatly on their power of intuition about classroom situations, often trusting it in place of other hard evidence.

A large percentage of teachers, particularly elementary teachers, reported that students' attitudes changed as a result of their new approaches to teaching. Across all grade levels, teachers reported that students showed more interest, excitement, and enjoyment in trying a new activity.

The majority of elementary and middle school teachers and about half of high school teachers reported that students' behaviors also had changed. Elementary and middle school teachers saw students as more actively involved, more on task, taking more initiative in their own learning, and working more cooperatively in collaborative groups. High school teachers reported students more on task, involved, motivated, and actively participating. Comments included *I saw an improvement in students' self-motivation toward tracking their own progress* (elementary school teacher), *Students tried more things on their own and visualized better* (middle school teacher), and *Students participated more and paid more attention* (high school teacher).

Other Reported Changes

A significant number of elementary (20%), middle (50%), and high school (36%) teachers expressed that they had learned a great deal about their beliefs and teaching practices. Some comments included *Do not be controlling in teaching methods, let children use their own learning styles to come to conclusions* (elementary school teacher) and *Be more willing to change teaching strategies* (middle school teacher).

Discussion

On the reflective practice form, we asked teachers to explicitly articulate their assessment of the new lessons they were trying. Their comments provided evaluative information about the effectiveness of the PEERS workshops in providing what teachers needed to make changes. Responses indicated areas of emphasis that made the most impact and that teachers chose to apply in their classrooms. At the conclusion of the workshops, the majority of teachers reported that they had learned how to apply the mathematics and science standards and create active learning environments. The reflective practice results replicated these findings: 76% to 86% of reporting teachers clearly linked the standards to the lessons they taught. Similarly high percentages reported using strategies such as group work, open-ended activities, and active learning approaches reflecting the intent of the workshops. Almost all middle and high school teachers agreed at the conclusion of the workshop that they would be able to use *real-life* examples more effectively in the classroom and had learned ways of integrating mathematics, science, and technology. In practice, the numbers were lower: About one fourth of the teachers focused on the real-life application of their lesson and about one third stated that a goal of their selected lesson was integration of math and science. The initial PEERS evaluation indicated that high school and middle school teachers, in particular, reported learning to use technology more effectively in the classroom (84% to 96%, respectively). The reflective practice results showed lower actual levels of implementation, with only 48% of high school teachers reporting incorporating technology into their lessons and much lower percentages of middle- and elementary-level teachers (13% and 6%, respectively) including technology. Low reported usage of technology by middle- and elementary-level teachers may be due to several factors: Teachers selected lessons or strategies for implementation that did not require the use of technology; teachers in rural areas have less access to technology; and/or teachers lack support at the school level for integrating technology in the curriculum.

The reflective practice evaluation indicated that a substantial portion of teachers implemented strategies they had earlier indicated they had learned in the workshop, lending validity to the initial evaluation findings. Elements of the PEERS workshops initially judged as somewhat less successful appeared infrequently in the lessons. Fewer than 10% of the teachers stated that they incorporated multicultural activities in their lesson plans, substantiating the earlier finding that PEERS was less effective in this area.

Although most reflective practice results paralleled the initial PEERS evaluation, we found some differences. A majority of participating teachers reported that most PEERS workshops were very successful in providing them with opportunities to communicate with peers about their own learning and that they would be comfortable sharing new strategies learned in the workshops with staff members, administrators, and parents. In practice, fewer than 10% of the teachers indicated they had discussed what they had learned from the workshop or from doing the lesson with others. Although teachers enjoy interactions and sharing with other educational professionals, in practice they have few opportunities to interact with other teachers. A number of studies emphasize the importance of the dialogue in helping teachers transform their teaching practices (e.g., Elbaz, 1988; Joyce, Murphy, Showers, & Murphy, 1989), yet continued interaction may be difficult to sustain.

Initial ratings of the PEERS workshops indicated that many teachers, particularly at the high school level, learned less about assessment strategies than about other workshop content areas and expressed less confidence in being able to use a variety of assessment strategies in their classrooms. In practice, teachers were relatively successful in using a variety of strategies for assessing student learning. Assessment strategies included the use of student presentations and projects, questioning students, and student writing activities.

Anecdotal evidence of the longer-term effects of the PEERS workshops on teachers' classroom practices came in the large percentage of teachers reporting changes in students as a result of the new lesson or strategy from PEERS. Teachers reported they saw changes in student attitudes and behaviors, with elementary teachers reporting the greatest change in attitudes. Teachers at all grade levels stated that students enjoyed the new activities and were more excited, involved, and on task than usual, suggesting that the skills and techniques the teachers learned in PEERS were effective in engaging students and, because of the positive feedback, would be likely to be maintained.

Teachers reported learning a great deal about their own beliefs and teaching practices. Asked what they had learned from implementing a new activity or teaching strategy, middle and high school teachers emphasized the importance of active participation, hands-on activities, and the use of open-ended activities to keep students motivated and to improve learning.

The information from this study came from both explicitly asked questions and from spontaneously offered information by teachers in written comments. This process limits the interpretation of the results, particularly as they relate to the explicit workshop goals. The reflective practice forms did not directly ask about all seven PEERS workshop goals. However, we designed questions to be open-ended enough to allow for these responses. The teachers' descriptions of the PEERS experience portrayed must be interpreted collectively because any single lesson would certainly not include all PEERS workshop goals simultaneously.

Conclusions

The PEERS workshops were designed to model best practices in K–12 science and mathematics teaching and encourage participating teachers toward more constructivist teaching approaches. This study provides evidence that teachers can put concepts and strategies learned in PEERS into practice in their teaching. The reflective practice exercise provided teachers with one method of looking at their classroom practices and beliefs and the impact they have on students' attitudes and learning. It provides important evaluative information about the extent to which the PEERS experience affected participating teachers' teaching practices. This information suggests that initial evaluation results are a good indicator of what teachers learned and are likely to implement in their classrooms.

This reflective practice approach to evaluation provides a clear link between a significant professional development activity and classroom practice. This evaluation method provides information to workshop designers and enhances the effect of the intervention itself. This single experience with reflective practice is unlikely by itself to produce long-term habits of reflection (Gore, 1987), but it is a starting point for the possibilities of how reflective practice may inform teaching practices and evaluation of professional development activities (Kremer-Hayon, 1993; McCutcheon & Jung, 1990).

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