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ABSTRACT

This project's goal was to design a professional development model to improve the skills of elementary teachers in providing quality science instruction. Surveys have concluded that lack of training, time, and instructional materials are obstacles for elementary science teachers. Eight elementary schools in a mid-sized west central Texas school district were selected for the project. These eight schools had a student of color population of 40% or greater and the average pass rate on the reading section of the Texas Academic Assessment of Skills test was 10 percentage points lower than the district average. The preliminary survey of elementary teachers in this district identified the following needs for improving their ability to provide quality instruction in science: interaction with the science consultant and other resource personnel to enhance their instruction; increased science preparation to enhance their confidence as science teachers; and additional activities that correlate to the content area using inexpensive materials. To meet these needs, a Summer Institute was conducted with follow-up meetings during the succeeding academic year. These activities provided: (1) a deeper and practical understanding of, and skill at, application of the scientific method in life-science problem solving; (2) hands-on application of methods including time to assemble the needed supplies; (3) increased knowledge of specific life science content; (4) opportunities of the teachers to develop a shared vision of the goals and science vocabulary for each grade level; (5) equipment; and (6) reading resources and manipulatives and materials for classroom science activities. The Summer Institute focused on content mastery and application. Several guest speakers were utilized and teachers had opportunities for hands-on learning in how to teach science concepts. (Contains 28 references.) (MVL)

PROFESSIONAL DEVELOPMENT FOR ELEMENTARY SCIENCE TEACHERS: IMPLICATIONS FOR PRACTICE

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The dawn of a new century has brought many challenges to our nation's schools. Ever higher standards, calls for greater accountability, a growing diversity among the student body, and explosive growth in information and technology are among many of the issues schools must successfully address in the coming years. So swiftly are these challenges arising that is it is becoming ever more difficult for the classroom teacher to keep his/her professional skills sharpened for the tasks demanded of today's, and tomorrow's, teachers.

Perhaps the greatest challenge facing our schools in this new century will be to maintain a teaching force that is knowledgeable and skilled at meeting the current and future needs of our students and our society. Nowhere is this more important than in science instruction. The scientific advances being made almost daily, and their impact on the quality of our life, bring into sharp focus the critical need for our future citizens to be well-grounded in scientific concepts and knowledge. This highlights the need for our students to have quality science instruction from well-prepared and well-qualified teachers.

The media has focused considerable attention on the shortage of secondary science teachers. However, just as critical is the inadequacy of science instruction in the elementary school. If students are to have an adequate foundation for science instruction at the secondary level that foundation must be laid in the elementary grades. Yet, many elementary teachers are ill-equipped for this task.

The Inadequacy of Elementary Science Instruction

Weiss (1987) found that only 31% of kindergarten to third grade teachers and 42% of fourth through sixth grade teachers had taken a science course. In addition, he found that fewer than half the states require elementary teachers to take a course in science methods. Many elementary teachers, therefore, complete their preservice preparation without knowledge or skills in the preparation, presentation, and application of science concepts in their classrooms. Wiess also reported that 82% of elementary teachers surveyed felt qualified to teach reading, while only 27% felt competent to teach life science and only 15% felt prepared to teach physical or earth/space science.

The inquiry method, which promotes critical thinking and problem solving skills, has been identified as an effective approach to quality science instruction (National Science Foundation, 1998; Rhoton, 1992). However, many elementary school teachers do not understand science content or methods well enough to utilize the inquiry approach in their teaching. According to Loucks-Horsley, Kaptian, Carlson, Kuerbis, Clark, Nelle, Sasche, and Walton (1990) elementary teachers encounter a number of obstacles to teaching science effectively through inquiry.

1. There is a lack of preparation in science for elementary teachers. The inquiry approach to teaching science requires an in-depth knowledge of the content to facilitate guiding students in active scientific inquiry. The National Science Teachers Association (NSTA), for instance, recommends one course each in biology, physics, and earth science for elementary science teachers.

2. The emphasis in the preparation of elementary teachers is on language and math and not science. In general, elementary teachers receive minimal exposure to science in their preservice preparation.

3. Insufficient time is often given to the teaching of science in elementary schools. The inquiry approach requires significant planning time for the science curriculum to be coherent and comprehensive. It also requires sufficient time in class to stimulate critical thinking and inquiry. The NSTA recommends that the minimal amount of time spent per week in science should be 2 1/2 hours in primary grades and 4 hours in upper grades. It is possible to integrate science with other disciplines, thus increasing the time spent on instruction. However, care must be taken to insure that science is not diminished when it is integrated with other subjects (Louckes-Horsley et. al, 1989).

4. There are an inadequate number of well-defined elementary science programs. Few school districts coordinate science goals, materials, and staff development offerings.

5. There is a shortage of adequate support materials for instruction. However, the relationship between the level of resources and educational quality is less important than how the available resources are used.

6. There is a lack of professional development for elementary teachers. Concurrent with limited understanding of science content on the part of elementary teachers is a limited ability to apply or use higher level reasoning in understanding science concepts, such as the utilization of controlling variables.

<u>Professional Development in Elementary Science Instruction</u>

Overcoming these obstacles will not be easy. A focused and concerted effort must be made to improve the ability of elementary teachers to provide quality science instruction. This will require a developmentally sequenced plan that provides pervasive reform, from preservice through inservice. Loucks-Horsley et. al. (1988; 1990) have proposed a three-stage plan for achieving this.

1. The early phase is in the university. Preservice preparation should combine an understanding of how children learn and hands-on experience in working with students in science.

2. The middle phase emphasizes teaching, the integration and application of the teacher's preparation. A new teacher should have a lighter work load and ample time to facilitate this process for the first two years of teaching.

3. The later phase involves improving and expanding teachers' skills in teaching science--allowing time to work together and observe each other. Finding adequate planning time is often the biggest obstacle to overcome. Principals need to work creatively with their faculty to support them in this area. O'Brien (1997) suggests a mix of personal time and release time to establish on-going networking for elementary science.

Networking with other teachers can also foster the implementation of inquiry by observing other teachers or having teacher coaches assist them (National Science Foundation, 1998; Luft, 1999). Teachers change grades and new teachers are hired. When teachers do change grade levels there is no guarantee that their preparation will be sufficient for their new assignment. The National Science Foundation (1998) proposes that mentor teachers be assigned to new teachers to provide support and assistance in successfully implementing the inquiry approach to science instruction.

Providing Effective Professional Development

It is obvious that a key factor in meeting the challenge of quality science instruction in the elementary school will be a well-designed, flexible and effective system of ongoing professional development. And, yet, for the most part, professional development for educators has a somewhat spotty and inconsistent record of success. McRobbie (2000) notes that well over half of U.S. teachers get less than a day's worth of professional development annually, in contrast to teachers in other countries who engage in professional development for 10-20 hours a week. Hilliard (1997), in claiming that a critical problem exists with traditional professional development activities, calls for fundamental change in how such activities are implemented.

The traditional method of providing professional development to teachers is the one-shot workshop squeezed in among a myriad of other activities during a teacher "work day." In our fast-paced, hurry-up world even providing this amount and type of training can be a challenge. Yet, a recent report by the U.S. Department of Education (2000) noted that eight hours is the threshold teachers say is critical for them to gain any value from a professional development activity.

Newman and King (2000) observed that conventional professional development has failed to improve teaching because it does not meet several key conditions for teacher learning. These conditions include:

1. Giving teachers sustained opportunities to study, experiment with, and receive advice on innovations. Most professional development activities involve brief workshops or conferences with no provision for follow-up or feedback.

2. Providing opportunities for teachers to collaborate with professional peers or to gain expertise through access to external researchers or program developers. Materials and programs

are usually presented by experts, but these resources are not integrated into existing systems of peer collaboration.

3. Giving teachers influence over the substance and process of professional development. Most professional development activities are dictated by local or state officials with little teacher input.

Newman and King concluded that teacher success in improving student achievement is dependent on teachers being able to implement knowledge and skills they have gained in a particular school and in a particular context. This was echoed to a certain extent by Guskey and Sparks (1996) who described a model for professional development based on the assumption that professional development is influenced by a number of factors including content characteristics, process variables, and context characteristics.

A number of writers have explored factors that can lead to effective professional development for teachers (Pennell & Firestone, 1998; Fitzsimmons & Kerpelman, 1994; Webb, 1996; and Sparks & Hirsh, 1997). Successful alternatives to conventional professional development were identified by McKenna (1998) as being job-embedded, mentor-dependent learning modes such as action research, small group problem-solving, and peer observation.

Ronnerman (1996) suggested letting teachers control their own professional development and allowing the problem, not the method, to guide teacher development. This is similar to a professional development program described by Crowther (1998) that has four components: clear expectations, focus on results, effective support systems, and good modeling. Crowther reported success by utilizing such practices as self-assessment, site-based decision-making, a focus on curriculum, and study groups.

A Project to Improve Elementary Science Instruction

Purpose and Description

This project's goal was to design a professional development model to improve the skills of elementary teachers in providing quality science instruction. Surveys have concluded that lack of training, time, and instructional materials are obstacles for elementary science teachers (Weiss, 1987). This project's goal was to address those critical elements.

Eight elementary schools in a mid-sized west central Texas school district were selected for the project. These eight schools have a student of color population of 40% or greater and the average pass rate on the reading section of the Texas Academic Assessment of Skills test was 10 percentage points lower than the district average. Our preliminary survey of elementary teachers in this district identified the following needs for improving their ability to provide quality instruction in science: (a) interaction with the science consultant and other resource personnel to enhance their instruction; (b) increased science preparation to enhance their confidence as science teachers; (c) additional activities that correlate to the content area using inexpensive materials.

To meet these needs, we conducted a Summer Institute and follow-up meetings during the succeeding academic year. These activities provided:

1. a deeper and practical understanding of, and skill at, application of the scientific method in life-science problem solving;

2. "hands-on" application of methods, including time to assemble the needed supplies;

3. increased knowledge of specific life science content;

4. opportunities for the teachers to develop a shared vision of the goals and science vocabulary for each grade level (vertical alignment awareness);

5. equipment (including a digital camera and color computer printer for each participating campus); and,

6. reading resources and manipulatives and materials for classroom science activities.

The Summer Institute focused on content mastery and application. Several guest speakers were utilized and teachers had opportunities for hands-on learning in how to teach science concepts.

Throughout the academic year project staff met with participating teachers at different school campuses. This promoted sharing in many areas, such as how labs were conducted, how to store and share equipment, how to implement the activities learned in the summer, how to schedule time for special interest clubs (such as a science club), and how to find financial resources for equipment. Project staff also shared innovative ways of utilizing technology for teaching science.

The Evaluation Process

A variety of sources and procedures were used to collect evaluation data for this project. For each of the topics addressed during the Summer Institute pretests and post tests were administered to the participants at the beginning and ending of each session. These tests addressed the content to be covered during that particular session. The differences in the pre- and post tests measured the increase in participants' knowledge of science content as a result of each session.

Also, at the end of each session participants were asked to complete a questionnaire regarding their perceptions of the effectiveness of that particular session. This instrument dealt with the quality of the presentation, of instructional materials, session format, etc. Instrument items were arranged in a Likert-type format and included some open-ended questions as well.

Approximately two weeks after the conclusion of the three-week Summer Institute structured interviews were held with participants. Questions were posed to elicit both knowledge of content and how the content would be integrated into the classroom. Although specific questions were developed for the structured interview, evaluators also asked follow-up questions based on participants' responses.

During the school year teachers were observed in their classrooms to determine to what extent they were integrating the information and skills addressed in the Summer Institute and in the Saturday sessions conducted during the academic year. A modified rubric developed for this purpose was used to collect information during the observation.

Two final avenues were used to collect data. Approximately six months after the conclusion of the Summer Institute questionnaires were sent to teachers who were project participants and to their principals. The teachers' instrument was designed to determine teachers' perception of how useful they felt the information, training and support provided by the project was over time and to determine how much, if any, of the information and skills addressed in the project they were integrating into their teaching of science.

At the same time principals at participants' schools were sent an evaluation instrument, as well. The principals' instrument addressed their perceptions of any changes in the quality of the teachers' science teaching as a result of their participation in the project. Principals were asked to report their perceptions based upon their own observations of the teachers.

Evaluation Results

As illustrated by Table 1, pre- and post test results on content knowledge showed a substantial growth, in general, in teachers' knowledge of science content. Gains ranged from 78 points (out of 100) on the Immune System to 20 points on Rubrics. The smallest gains in knowledge were in what might be called a "pedagogical area" (rubrics), a reflection possibly of the fact that participants were already fairly familiar with the content in that area. The low pretest scores on science content indicated participants' apparent lack of initial understanding of the science content covered by the Institute. The relatively high post test scores, though, demonstrate an impressive gain of the participants' short-term understanding of science content as a result of Institute sessions.

The perceived effectiveness of the sessions were also quite high. As can be seen in Table 2, overall the Summer Institute sessions were rated as "highly effective" with the highest rating on the organization of the sessions and the lowest on the pace of the sessions. In regard to individual Institute sessions, ratings were fairly high as well, as can be seen in Table 3. The sessions on Rubrics and on Immunology were rated particularly high. Perceived as less effective were the sessions on the cellular process and the heart. Since these were presented by guest lecturers, participants' responses may be more a reflection of the presenters than the session content.

Table 1

Content Knowledge Pretest and Post Test Averages

Session	Avg. Pretest Score	Avg. Post-Test Score
Cellular Processes	45	88
Exercise Physiology	42	85
The Heart	51	93
Immune System	11	89
Processing Skills	21	70
Rubrics	71	91

Table 2

Perceived Effectiveness of Summer Institute
("1" - Strongly Agree with the statement, "5" - Strongly Disagree with the statement)

Statement	Average Rating
1. The summer institute was well-organized.	2.1
2. The various presentations were scheduled in the appropriate sequence.	2.1
3. Presentations were paced appropriately (enough time was spent to cover the topic, but the pace was fast enough to maintain interest).	3.0
4. There was an effective mix of lecture, discussion, hands-on, and other types of activities.	2.1
5. Content presented was relevant and useful to me in my current position.	2.6

Table 3

Participants' Perceived Effectiveness of Individual Sessions of Summer Institute

Session	Statement 1	2	3	4	5	6	7	8
Rubrics	4.7	4.8	4.8	4.8	4.7	4.9	4.3	4.9
Immune System	4.3	4.3	4.0	4.0	4.3	4.3	4.3	4.0
Immunology	4.6	5.0	5.0	5.0	4.8	4.9	4.9	5.0
The Heart	3.9	3.6	3.6	3.6	4.1	4.1	3.7	3.4
Processing Skills	4.4	4.3	4.4	4.4	4.6	4.6	4.5	4.6
Pets	4.1	4.8	4.8	4.8	4.6	4.8	4.8	4.2
Exercise Physiology	4.6	4.7	4.3	4.6	3.9	4.5	4.5	4.8
Cellular Processes	3.9	4.0	3.9	3.8	4.7	4.2	4.0	3.5

To obtain more insight into the participants' reasoning in regard to their ratings two open-ended questions were also posed:

1. Which part of the presentation was most beneficial to you?
2. What would you change to make the presentation more effective?

Participants' responses to these two questions have been summarized in Table 4. As can be seen in this Table, for several of the sessions criticisms were given on the level of difficulty of the material with many teachers claiming it was too complex for them to adequately grasp and presented too quickly for them to absorb. There were also negative reactions to the format of the sessions. Teachers indicated a strong preference for activities that were more concrete and that involved their active participation.

Table 4

Participants' Responses to Open-Ended Questions

Please respond in more detail to any of the items above that would assist us in better understanding and interpreting your response.

Some of the things discussed are way over 4th graders' heads. The information needs to be geared way down so kids could understand better and I could teach the concepts better. I really like the books with the teachers guides and the AIM's activities.

More activities teaching us how to teach would have been great.

I think too much was covered in too little time.

A lot of the material is far too complex to teach in elementary school.

Some of the activities, information, etc. was on a much higher education level than what we teach but much of this was too advanced.

The information was good but it was too in depth. This material was too much to be taught at my particular grade level.

There needs to be more activities based for immediate use in the classroom.

If this class was related to my grade level. I can only use a few materials in my room.

I wish we could have done more "lesson type" things for lower grade levels. I really thought this was going to be an extended workshop type class. I didn't realize it would be so many tests and involve so much college level discussing.

Any suggestions for future Summer Institutes?

Don't make this session a "Class," make it more informational for each grade level.

I feel that more time is needed on actually developing plans for the classroom use.

Implementation plans need to be made. More grade level material is needed.

The information presented was valuable (if I were studying to be scientist). However, as an elementary teacher the information was much too detailed and high level. The information we were required to know for testing purposes was so intense, that the focus soon turned to only wanting to learn what I had to.

Material presented at times was fast paced. I needed more time to take in certain terms, especially those I had not heard since high school biology or college classes.

More hands on and sharing of lessons and materials to use in the classroom.

Opportunities to try out some more of the ideas would have been helpful.

More visuals, slower pace, information that is keyed lower towards the grade level that we are teaching. We felt that most of the information was over our heads and should have been modified for our classrooms. The vocabulary was hard and students will never understand it in these terms. We have little use for DNA, genes and etc. below 5th grade.

I really enjoyed this institute, even thought it was hard for me to study for tests again. I will use the information in my classroom, and I look forward to utilizing the materials.

More practical, hands-on activities for younger elementary school students.

Put the information into layman's terms so that we can teach it to students in K,1,2....

Approximately two weeks after the Summer Institute, structured interviews were held with project participants. Two groups were formed from the participants and a session conducted with each group. These sessions were intended to collect information regarding how well participants appeared to understand the information covered in the Institute and how well they might be able to integrate the content in their classrooms.

While one evaluator asked each question, another evaluator rated participants' responses using a rubric that rated responses based on five dimensions: Content, Terminology, Application, Clarity, and Integration. For each dimension the evaluator rated overall group responses from 0-2, (0-did not address, 1-addressed to some extent, 2-addressed to a great extent.) Table 5 displays the results of structured interviews held with project participants.

Table 5

Evaluator's Ratings of Participants' Responses to Interview Questions

	Content		Terminology		Application		Clarity		Integration	
Question	I	II	I	II	I	II	I	II	I	II
1	2	1	2	1	2	2	2	2	2	2
2	1	2	2	2	2	2	2	2	2	2
3	1	1	1	1	2	2	2	2	1	2
4	2	1	2	1	2	2	2	1	2	2
5	1	1	1	1	2	1	2	1	2	1
6	2	0	1	1	2	1	2	1	2	1
7	1	1	1	1	2	1	1	1	1	1
8	1	2	1	1	2	2	2	1	2	2
9	1	2	1	2	1	2	1	2	1	2
10	0	0	0	0	1	1	1	1	1	1

Comments:
GROUP I
Break down into grade levels, some things not appropriate for some grades
More activities and resources, Provide information on developing learning centers
Much of the content at too high a level, More application
GROUP II
Loved the brain and heart presentations, Loved part with the dog, Very hard work!

As can be seen in this Table, teachers appeared to be fairly adept at understanding and using the content and methodology addressed in the Summer Institute. Participants were familiar with the terminology, how to apply it to the classroom and integrate it into the curriculum, although they felt more comfortable with some of the content areas than with others. Comments again echoed those expressed on other evaluation instruments regarding the level and expectations of the content.

To evaluate how well participants integrated science content and methodology in their classrooms observations were conducted with selected project participants. The rubric designed for this purpose addressed both the content and teaching methodology addressed in the Summer Institute and rated teachers on both a qualitative (Q1) and a quantitative (Q2) scale. The results of these observations can be seen in Table 6. As indicated in this Table, teachers appeared to be utilizing appropriate teaching methodology, but there was little evidence that they were actively implementing and integrating science content from the Summer Institute in their classrooms.

Approximately six months after the beginning of the school year all participants were sent an instrument designed to collect information regarding participants' perceptions of the effectiveness of the project and the extent to which project activities had impacted classroom practice. Participants indicated that they were using the information on content, methodology and resources they had obtained through project activities. They also appeared to be much more comfortable with science content and more knowledgeable about how to teach it.

Responses to this instrument also indicated that respondents were participating in follow-up project activities and that they appreciated the opportunity to continue those activities and to interact with their colleagues. Their understanding and use of resources related to teaching science appears to have increased as a result of the project, and they indicated a comfort level with having resources and support available to them.

Table 6

In-Class Observations of Selected Project Participants

Observation 1

Rubrics: Q1-5 Q2-5
Children engaged in activity, although some not fully

Processing Skills: Q1-5 Q2-5
All children actively engaged at a fairly high level in cooperative learning

Observation 2

Rubrics: Q1-4 Q2-4
Children actively engaged

Processing Skills: Q1-4 Q2-5
Children were assigned a project presentation on a particular type of whale. Each child had a designated role on the project. When the project was complete and had been presented, children graded themselves on a rubric, as well as grading other students.

Observation 3

Rubrics: Q1-5 Q2-5
Children worked very well together to complete the project

Processing Skills: Q1-5 Q2-5
Used data collection, defining, predicting. The project involved properties of water and was very well-organized

Observation 4

Cooperative Learning: Q1-5 Q2-5
Students engaged in learning about cooperative learning and processing skills. The teacher assigned each student a specific duty on the project and they carried it out in an appropriate manner.

Processing Skills: Q1-5 Q2-5
The teacher set up centers designed to have the children infer, define operational, collect data, and predict. Excellent activity.

Discussion

The results of this evaluation process reveal a number of insights into effective professional development for teachers, particularly in regard to improving science instruction. Teachers appeared to substantially increase their knowledge of science content, particularly in those areas addressed by the Summer Institute. Despite their recurring complaints that the content was too difficult for the students they taught, teachers did feel more comfortable with the terminology and concepts of the science content after the Institute. This increased knowledge and comfort level contributed to teachers' improved ability to teach science to their students. This suggests that a focus on increasing knowledge and understanding of content, while uncomfortable, is translated into improved instruction in the classroom.

Participants indicated a strong preference for hands-on, practical type activities that they could immediately pick up and use in their classrooms. We also found that teachers used some of the techniques and strategies they had learned in regard to teaching science, but they tended not to use those that did not fit in with their particular teaching style or preference. Also, the longer teachers waited to use techniques and strategies the less likely they were to use them at all. In fact, without a specific plan to incorporate skills used during the Summer Institute some teachers failed to make significant changes in the way they taught science.

Implications for the Professional Development of Science Teachers

Our experience and study indicates that effective professional development activities for teachers include one or more of the following key characteristics: (a) planning that includes input from teachers, principals and other district personnel; (b) time with other teachers; (c) a combination of content and process topics; (d) a specific implementation goal; and (e) strengthened connections between teachers and a broad variety of instructional and community resources. Each of these key characteristics are described below.

Planning that Includes Input from Teachers, Principals and Other District Personnel

Classroom teachers have the most direct knowledge of their needs as teachers and of the needs of their students. Therefore, planning for professional development activities should include input from teachers to insure relevance of topics and a sense of ownership among the teachers (King, 2000). Professional development activity planning that includes significant teacher input will be more likely to produce activities that address the identified needs of teachers (Ramey-Gassert, 1997). During the design phase our project included input from the developers of state curriculum standards, district and educational service center curriculum specialists, and from classroom teachers.

Soliciting input from principals allowed proper consideration of teacher schedules and campus-wide needs that participants could address after the development activities. Input from district personnel allowed the development of activities to address existing problems and to prepare teachers for district-wide curriculum initiatives (National Science Foundation, 1998). Finally, as Allen (1998) noted, and as we also found, active support by principals and district administrators is critical to the success of any change effort.

Time with Other Teachers

Through both observation and participant feedback, we noted that activities designed to increase the amount of time teachers spend with other teachers supports innovation through (a) the sharing of practical means to implement good ideas, (b) development of formal/informal peer support structures which facilitate guided risk-taking, (c) vertical alignment of content topics and pedagogy, (d) increased sharing of development opportunities gained through workshops or grant activities experienced by part of a campus faculty and (e) renewal of the teacher's motivation for and interest in innovative teaching. Teachers who are considering innovation should be allowed time with other teachers who are experimenting (Hoewisch, 1998), or, more importantly, with teachers who have succeeded in classroom innovation (King, 2000).

Our experience suggests that effective professional development activities should include some unstructured time to allow teachers to raise questions about specific issues they are facing (National Science Foundation, 1998). Several sources cited the willingness of professional development instructors to adapt activities to address the current learning and situation of teachers (Dana, 1997; National Science Foundation, 1998). We found that meeting in the teachers' classrooms facilitated sharing among teachers and supported each of the key characteristics discussed here.

A Combination of Content and Process Topics

Both content and effective pedagogy are required for a teacher to effectively implement change in the classroom (Kubota, 1997). Lack of comfort with content is frequently cited as a reason that teachers fail to teach science effectively and as a major inhibitor to the risk-taking required for innovation (Allen & Lederman, 1998). Engagement with content and demonstrated mastery of content both renews teachers' interest in the content and increases teachers' comfort level with the content, thereby increasing the likelihood that they will experiment with innovation. Dana (1997) noted that "teaching science so that students learn with understanding requires that teachers understand child development, pedagogical and assessment alternatives, and scientific conceptual and procedural knowledge." (p. 427)

Dana further observed that "effective preservice and inservice professional development programs must not operate as a deficit model, trying to remediate deficiencies in elementary teachers' knowledge and skills associated with science and science pedagogy. A more productive model is one in which teachers are viewed as learners of science and science-related pedagogy." (p. 428) Teachers tend to teach in much the same way as they were taught (Kubota, 1997). This emphasizes that professional development instructors should model the pedagogical practices identified as effective in elementary science instruction. Pedagogical ideas will enhance teachers' creativity in instruction through helping teachers identify age-appropriate avenues to help students engage the content objectives (National Science Foundation, 1998).

A Specific Implementation Goal

Professional development activities should be designed to result in a specific product or a commitment to create and implement a specific product by a certain time. Workshop and other experiences often present a large quantity of material in a short period of time. Teachers then return to their normal daily duties with more knowledge but without an identified way of increasing teaching effectiveness based on this new knowledge. Teachers committed to produce a specific product are more likely to implement at least one innovation as a result of a development activity (Whitworth, 2000).

Products may include a lesson plan, a classroom activity, or other items. A complete goal should include at least four components: a product, a target date for implementation and/or experimentation in the classroom, an assessment of effectiveness, and a means of reflecting on the product and receiving feedback from other teachers. An effective program on our campus involved the use of letters teachers wrote to themselves which included a self-selected goal for a project. The workshop instructors collected the letters and then mailed them to the teachers at a later time as a personal reminder.

Teachers are pressed for time, so they seek a real product that is developed in the professional development experience and then implemented immediately in the classroom. Teachers tend to view professional development activities that result in such products as worthwhile and relevant. Teachers should also leave the professional development experience with the materials necessary for implementation of the product. Other features of easily implemented innovations include classroom sets to allow active learning strategies, efficient storage to allow the activity to be used more than once, and limited cost due to expendable supplies.

School and district administrators will value and encourage participation in professional development activities that result in products with clear connections to state, district and school initiatives (Allen & Lederman, 1998). In Texas, curriculum content is defined by the Texas Essential Knowledge and Skills (TEKS) and school effectiveness is determined, in part, based on student pass rates for exams over the TEKS. Therefore, administrators are more likely to endorse professional development activities which equip teachers to be more effective at teaching specific TEKS-defined topics.

Strengthened Connections Between Teachers and a Broad Variety of Instructional and Community Resources

Resources might include the curriculum specialists at educational service centers, faculty at universities, local resources (stores, fire stations, zoos, etc.) that provide field trip opportunities, local museum agencies and others (Allen & Lederman, 1998; Kubota, 1997; Ramey-Gassert, 1997; Dana, 1997). A goal of a long-term professional development program should be to create a support community committed to enhancing the effectiveness of both teaching and learning (O'Brien, 1992). In view of the turnover rate among early career teachers found in many schools and school districts (Recruiting New Teachers, Inc., 1999; Wolff, Cook, Rodriguez, and Colbert, 1997), long-term commitments to meaningful involvement in professional development activities will be needed from schools, districts and communities.

Conclusion

As we enter a new millennium, the quality of life in the decades to come will depend to a great extent on the quality of our schools. A hallmark of that quality will be our ability to provide effective science instruction for all students. Our success in achieving that objective will depend on teachers at every level who are well-equipped and well-prepared to teach science. Staffing our classrooms with teachers who are able to provide quality science instruction, though, will not be easy. It will require commitment and collaboration on the part of teachers, administrators, teacher educators, and many others. Nor can we assume that, once in the classroom, teachers will remain well-qualified and well-prepared. A clear understanding of effective professional development, and continuous implementation based on that understanding, will insure that we have the teachers that we, and our students, will need in the coming century.

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