DOCUMENT RESUME

ED 465 638 SE 066 361

AUTHOR	Bell, Glenda Love
TITLE	Elementary Science Teaching Enhancement through a Professional Development Schools Model.
PUB DATE	2002-01-00
NOTE	31p.; In: Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science (Charlotte, NC, January 10-13, 2002); see SE 066 324.
AVAILABLE FROM	For full text: http://aets.chem.pitt.edu.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	College School Cooperation; Elementary Education; *Elementary School Teachers; Higher Education; Models; National Standards; Partnerships in Education; *Preservice Teacher Education; *Professional Development Schools; *Science Education

ABSTRACT

This study on elementary science teaching enhancement was conducted in a program based on the professional development schools (PDS) model of teacher education and the National Science Education Standards. The premise being that if the PDS model can generally improve teacher preparation and P-12 education, perhaps, an integration of the PDS model with the National Science Education Standards can specifically guide improvement in elementary science teaching and science education. Through the Regents' Initiative, the Northeast Texas Science, Mathematics, Engineering, and Technology Collaborative (NETSMET), a school/university/agency partnership was formed to explore ways to improve science, mathematics, engineering, and technology education in the northeast Texas region. Members of the partnership include the university, two school districts, and an Area Health Education Center. (MVL)

Elementary Science Teaching Enhancement through a Professional Development Schools Model

by
Glenda Love Bell

ELEMENTARY SCIENCE TEACHING ENHANCEMENT THROUGH A PROFESSIONAL DEVELOPMENT SCHOOLS MODEL

Glenda Love Bell, Texas A&M University-Commerce

A Program of Elementary Science Teaching Enhancement

This study on elementary science teaching enhancement was conducted in a program based on the professional development schools (PDS) model of teacher education and the National Science Education Standards (NSES, 1996). The premise being that if the PDS model can generally improve teacher preparation and P-12 education, perhaps, an integration of the PDS model with the National Science Education Standards can specifically guide improvement in elementary science teaching and science education. Through the Regents' Initiative, which will be described more fully later, the Northeast Texas Science, Mathematics, Engineering, and Technology Collaborative (NETSMET), a schools/university/agency partnership, was formed to explore ways to improve science, mathematics, engineering, and technology education in our region. Members of the partnership include the university, two school districts, and an Area Health Education Center.

Our state, like many others, faces a formidable challenge. That challenge is to provide a sufficient number of qualified classroom teachers for P-12 who must demonstrate an unprecedented level of content knowledge, instructional proficiency, and instructional effectiveness (Sid W. Richardson Forum, 2001). This shortage is acute in science, mathematics, and technology (Institute for School-University Partnerships, 2000).

The NETSMET partnership assembled a group of targets to enhance science education. The partnership chose an inquiry-based approach to course design for an integrated science course, for a required science methods course, and for the curriculum and professional development education for an after-school program, and for a summer science institute with a science camp embedded in it. See Table 1 for the framework that directed development of the NETSMET model of science education enhancement.

Table 1.

Framework for NETSMET Model of Elementary Science Education Enhancement

Professional Development Schools Model	NETSMET Framework	National Science Education Standards
Maximize student achievement	Enhance scientific literacy and student achievement in science through inquiry learning	Scientific literacy for all students through inquiry learning
Rigorous professional development for pre-service and in-service teachers	On-going, rigorous professional development for primary through graduate school faculty and for participating pre-service teachers; an emphasis on inquiry learning, and integration with other content areas, especially with mathematics and technology.	On-going professional development for pre-service and in-service teachers: This includes science content, process skills, and pedagogy; and integration with other content areas, especially mathematics
University faculty is actively involved in a collaborative relationship of responsibility	Cultivate communication, networks, and active interrelationships among and between all collaborative members: P-12 schools, university, community, parents, and agencies.	Continuous dialogue and effort among all stakeholders to improve science literacy, including colleges and universities, nature centers, parks and museums, businesses, laboratories, community organizations and various media.
Provide opportunities for research	Provide opportunities for research	Provide opportunities for research
Provide challenging, equitable learning opportunities for a diversity of learners	Foster an appreciation of and active participation in mathematics, science, and technology by all participants: K-12 schools, university, community, parents, and agencies	Science learning excellence and equity for all students
Reflective learning regarding personal teaching practices	Focused reflection regarding, science, personal science learning experiences, and teaching practices	Structured reflection on science teaching practices
(NCATE, 2001)	(NETSMET, 2000)	(NSES, 1996)

All science learning experiences provided through this program for in-service, pre-service, and 2nd grade through 6th grade students were inquiry-based. Learning was couched in experiences based on constructivist tenets of active exploration with concrete objects, understanding through interaction with science concepts, and extension of cognitive constructs about science and science learning/teaching through mental manipulations. University faculty Provided additional science content through scaffolding. Scaffolding, or guided learning, was used to assist the participants in making connections among their prior understandings, their active learning experiences, and new understandings and articulation of science concepts congruent with the way the scientific community understands science. The purpose of this study was to determine if the extent to which pre-service and in-service teachers engaged in hands-on, inquiry-based science learning had significant influence on their teaching practices. The extent to which participants might have had the opportunity to learn science in an inquiry-based format provided in the framework of this study is shown in Table 2. Several factors affected the extent of involvement. Some pre-service teachers engaged in all aspects of the program. Some who taught in the "aka Science" program did not take IS351 because it was not required when they were at that sequence in their course work. Some in-service teachers taught in the "aka Science" program and participated in the summer Science Institute and Camp. Some only participated in one or the other of the two programs.

Professional Development Schools Model of School Improvement

In the 1980's, professional development schools emerged as a model with high potential for improving teacher education and pre-kindergarten – twelfth grade education. As the notion of professional development schools has grown, so have the names by which they are called such as

Table 2.

Possible Extent of Science Inquiry Learning Experiences

Types of Inquiry Learning Experiences	Pre-Service Teachers	In-Service Teachers
1. "aka Science" curriculum professional development	1 and 4	1 and 2
2. Teaching in the after-school program	1,4, and 5	3
3. Summer Science Institute and Camp	1,2,3, and 5	1,2, and 3
4. Completion of ElEd 437 Science Learning: Science Field-Based	3 and 4	
5. Completion of IS351 Integrated Science	3,4, and 5	

professional practice schools, clinical schools, and school-university partnerships. So, what are Professional Development Schools? They are partnerships dedicated to innovative, shared responsibilities among (P-12) schools, universities, and communities in teacher preparation and teaching enhancement for both pre-service and in-service teachers. They promote inquiry-based, student-centered teaching practices and improved student learning at all levels (NCATE, 2001).

The National Science Education Standards set forth by the National Research Council in 1996 and the National Standards for School Mathematics set forth by the National Council of Teachers of Mathematics in 1989, led the way for other academic groups to establish national standards as part of the national education reform effort. Education is still in the process of reform as we have stepped over the threshold from the industrial age into the information age and the 21st Century. In 2001, the National Council for Accreditation of Teacher Education (NCATE) set forth national Standards for Professional Development Schools (SPDS). Their purpose was to provide a framework of rigor in the development, progress, outcomes, and evaluation of these partnership professional development schools (NCATE, 2001). The education system has the task of improving all students' performance as learners, critical thinkers, and problem-solvers so that all have an equitable opportunity to participate as active, contributing citizens (AECT, 2000).

In response to this dilemma, in 1999 the Board of Regents of our university system approved The Regents' Initiative and garnered grant funding to support it. A concerted examination of the systemic structure of education, how all the parts are related and function together, revealed the need for innovative, non-traditional ways of addressing education and teacher preparation if the above-mentioned challenges are to be met. The requirements of productive change is outlined in change theory: It is multifaceted, will occur over time, involves change in attitude and practices, requires economic and emotional support, and requires collaboration among the different interested entities (Cuban, 1988, NSES, 1996, Stiegelbauer, 1994).

We are in the third year of the initial five-year plan to enhance and improve the quality and productivity of educator preparation programs and to address the shortage of science, mathematics, and technology teachers in particular. The Regents' Initiative promotes university-wide responsibility for teacher preparation and promotes school-university partnerships (Institute for School-University Partnerships, 2000). These efforts build upon the work of Centers for Professional Development and Technology (CPDT), field-based teacher preparation programs, established during the 1990's (Sid W. Richardson Forum, 2001).

In it's eighth year, the CPDT structure of elementary teacher preparation at our university is designed upon the professional development schools model. The CPDTs each represent a collaborative effort that places much of the decision making process within the Instructional Leadership Teams (the interns/residents, mentor teachers, campus contact persons, principals, and university liaisons, or faculty) and the school district Steering Committees (university faculty, school district faculty and administrators, community leaders, and university students). This year long, field-based teacher preparation program requires a 15-week internship semester and a 15-week resident semester during which the interns and residents teach with practicing mentor teachers. This environment of mutual cooperation and active participation of all partners in the teacher education process provides an environment in which practitioners and interns/residents can identify and refine their teaching knowledge and abilities. The interns/residents benefit from the seasoned experience and knowledge of the mentors and the mentors benefit from the academic experience of the interns/residents (Northeast Texas Center for Professional Development and Technology, 2000).

A Constructivist Approach to Teacher Preparation

The constructivist model of learning theory suggests that the learner develops a way of knowing or understanding new concepts based on prior knowledge. Knowledge is not simply transmitted from one knower to another. The learner must demonstrate a curiosity about and interact and grapple with the concept to be learned. The more experienced knower acts as a coach and guide in facilitating the conceptual understandings of the novice learner (Bell, 1999, Driver, Asoko, Leach, Mortimer, & Scott, 1994; Piaget, 1970; Vygotsky, 1962).

The professional development schools model embodies the constructivist approach in teacher preparation. The pre-service teachers learn in a real-work setting under the guidance of a team of mentor teachers, school administrators, and university faculty. They have the opportunity to connect theory and practice as they observe, practice, reflect, and are mentored

(Darling-Hammond, 1994, Loucks-Horsley, S., Hewson, P.W., Love, N., & Stiles, K.E., 1998). These experiences contribute to their professional growth as reflective, child-centered practitioners, collaborative team players, who are more confident in their knowledge and skills and of their ability to function in the culture of schools and teaching (Book, 1996; Darling-Hammond, 1994; Levine, 1997, Loucks-Horsley, S., Hewson, P.W., Love, N., & Stiles, K.E., 1998, Tell, 1998). Since these experiences influence what they believe about teaching and their ability to teach, their beliefs may be a major factor in science education reform (Beck, J., Czerniak, C.M., and Lumpe, A.T., 2000).

The Dynamic Nature of a Small World System

A systems approach to education change directed development of this program. Upon analysis and evaluation of how this program might function within the larger education system, it was determined that implementation could not be linear, neither a top-down approach, nor a bottom-up approach. The interrelationships of the various entities required a dynamic model so that the best perspectives of each entity could be brought to the table. The model that seemed to best represent the dynamic relationships was the Small World Effect, a mathematical model, developed by Steven Strogatz and Duncan Watts (1998). They used a ring graph to demonstrate how a network comprised of elements with no obvious direct connections are related by six or fewer degrees of separation. In their quest for networks allowing the shortest path between any two points, they found that on a ring graph, if 1% or less of the total number of elements have long distance connections, then the average degrees of separation are about four. This is similar to a random network, but with more clustering, or direct, near connections. Strogatz and Watts examined three networks of which all connections were known: the neural network of Caenorhabditis elegans, a nematode worm, the grid of power stations in the western United

States, and a database of everyone who has ever acted in a feature film. They suggest this idea may be used for analysis of other neural networks, tracking contagious diseases, marketing on the Internet, and many other such applications. It seems credible as a tool for examining systems in education.

Sixteen elements that included people, programs, and policy were included as the most salient factors in the network, or partnership, that provided the environment for this study. They are listed in Figure 1. Small World Effect of Program Constituents and Elements. According to the 1% factor, only two distance connections would be necessary in this network to achieve the average of about four degrees of separation. However, three were used to emphasize the importance of the Regents' Initiative, the CPDT relationships, and the after-school and summer programs. This model demonstrates how closely connected unseeming elements are to teacher preparation and to P-12 student achievement in science. The varied perspectives on science education and teacher preparation, brought into the process by members of the partnership, formed the basis for problem analysis, implementation, and evaluation.

Planting Seeds of Vision in an Elementary Program of Enhancement

Elementary science education was targeted for these reasons: (a) Lack of attention to science at the elementary level; (b) Limited preparation of elementary teachers in science and inquiry-based pedagogy; (c) Current emphasis on problem-solving and critical thinking in all areas of education for all children; (d) Planting a vision of science as a route of choice and achievement for all children; (e) Scientific literacy that enhances daily living and eventual career choices; and, (f) Resultant longitudinal effects.

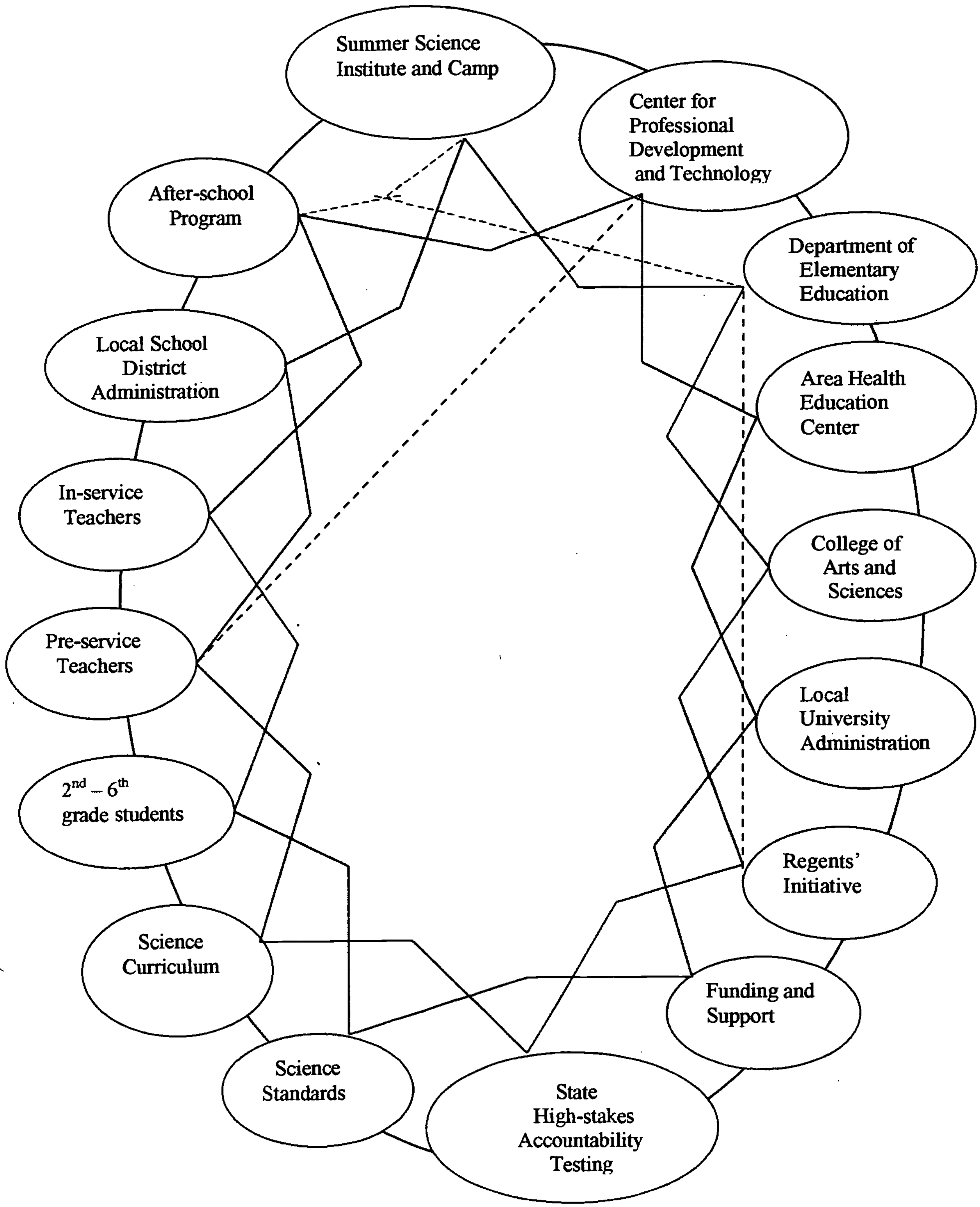

Figure 1. Small World Effect of Program Constituents and Elements

In response to and with support of the Regent's Initiative, a pilot program of science teaching enhancement was put into place in two elementary schools and one intermediate school located in two of the CPDTs. In addition, a summer science institute for college credit with a science camp for 2nd through 6th grade students embedded in the course was funded by an Eisenhower Professional Development grant and by a Regent's Initiative research grant. Interns and residents (students in the last two semesters of their professional development sequence), newly graduated students, and in-service teachers participated in both enhancement programs. University faculty provided instruction in the two programs. In addition, science methods instruction for interns was provided in a seminar/field-based setting. A small number of the interns completed a hands-on, inquiry-based integrated science course that relatively recently was added as a requirement of their individual degree plans. A Family Science Fun Night culminated the after-school science program.

The relationships already established through the field-based CPDT teacher preparation program facilitated the expediency with which the after-school programs were implemented and with recruitment for the summer science institute and the follow-through professional development education. The planning team for this cluster of enhancement programs consisted of university faculty and department chairs from the College of Education and the College of Arts and Sciences, an assistant dean, the campus director of the Regent's Initiative, local school district curriculum directors and principals, and the CEO and a program director from a health education agency.

Changing Professional Development to Change Teaching Practices

The purpose of this study was to determine if the extent to which pre-service and in-service teachers engaged in hands-on, inquiry-based science learning had significant influence on their teaching practices. Professional development with a cohesive group of participants, over time, has been found to engender the most effective results (Stiegelbauer, 1994). The context within which most learning took place was a model that closely resembled the professional development schools model. Pre-service teachers were paired with mentor teachers experienced in classroom practice. All kept reflection journals and received professional development education in science content and pedagogy. Their experiences in teaching children were considered a valuable part of their own learning experiences. University faculty acted as facilitators and consultants.

Participant Beliefs, Attitudes and Performance

Several measures were used to assess participant beliefs, attitudes, and performance. An adaptation of the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs & Enoch, 1990) was used to measure general beliefs and attitudes about science and science teaching. Scores on the science domain of the test for state teacher certification and content pre and post tests were used. Journal responses, course evaluations, and survey data were used.

The "aka Science" After-School Program

The initial after-school program was an after-school inquiry-based, hands-on science program for nine groups of second grade through sixth grade students. A team comprised of a practicing teacher and an intern or resident taught each group of 12 students. Each segment, consisting of 8 one-hour sessions taught over an eight-week period, focused on one topic of science such as anatomy or chemistry. Prior to teaching in the after-school program, hands-on exploration of the science content, materials, activities, and teaching skills was provided for the instructional teams through professional development education taught by a university professor. "aka Science", a hands-on, inquiry-based curriculum developed by Hands On Science Outreach, Inc. was the curriculum chosen for the after-school program. This curriculum, with a strong emphasis on critical, probing questioning, manipulation of concrete objects and ideas, model building, and integration of mathematics, was comprised of kits that contain essentially all of the supplies and equipment needed by the children. A lesson plan booklet, provided for the teacher's use, guided the lessons and provided content background.

Decisions about participant recruitment and implementation of the after-school program were placed mainly with the cooperating schools. The only proviso, required by the planning team, was that the participants in the after-school program reflect the demographics of the school in which the program was implemented and that there be no participation fee. All schools met this proviso by including heterogeneous groups of students that highly correlated to each school's make-up by gender, ethnicity, socio-economic status, special education, English as a Second Language, and Gifted and Talented. No school charged a fee for participation.

At the beginning of the professional development education, prior to each 8-week student segment, a science content pre-test was administered to each teacher participant. After the participants had completed the professional development and had taught the 8 classes to the students a posttest was administered. In addition, a pre/post STEBI was administered to the participants. A pre/post content test was administered to the elementary students.

Elementary Education 437 Science Learning Field-Based

The nine pre-service teachers in this study completed the Elementary Education 437 Science Learning Field-Based course. This hand-on, inquiry-based course was designed to assist students in their understanding of how to teach science to elementary students using hands-on, inquiry based methods to inspire investigations, higher-order thinking, confidence, and an appreciation for science. Since most of these teachers were destined to teach in self-contained classrooms where they are responsible of all content matter, integration across content areas was an important component of this course. In addition to regular instruction by a university professor, the course included six and one hours of hands-on, inquiry-based instruction by a National Aeronautics and Space Administration (NASA) professional development specialist and six hours of hands-on, integrated, inquiry-based instruction by two Project Learning Tree (PLT) professional development specialists.

The pre-service teachers were administered a pre/post STEBI, generated weekly reflection journals, did a course evaluation, and completed a survey about inquiry-based teaching/learning. University faculty, whose regular assignments included acting as liaisons in the field-based teacher preparation program, mentored the pre-service teachers.

Integrated Science 351

In 1999 a required Integrated Science 351 course, taught in the College of Arts and Sciences, was implemented to enhance elementary education majors' science content knowledge and to help prepare them for the science domain of the state teaching certification test. A minimum of 85% of the course content was focused on science content. About 15% of the course content was based on professional development. Several studies suggest the most successful teacher education students are those who reflect upon their own current learning experiences, develop an image of themselves in their future roles as teachers, and make connections between present and future experiences (Centre for Academic Practice, 2000; Chambers & Stacey, 1999; Key, 1998; Swafford, Jones, Thornton, Stump, & Miller, 1999). A substantial effort was made through course assignments and class discussions to cause the students to reflect upon their personal image of their future roles as teachers. Seven of the pre-service teachers had taken this upper division course that is, generally, completed shortly before the internship (first) semester of field experience.

Summer Science Institute and Science Camp

In a three- week, Eisenhower and Regents' Initiative funded summer science institute, there were 17 in-service participants and 5 pre-service participants. The course was cross-listed so that those participants who had graduated could receive graduate credit for the course and those who had not graduated could receive undergraduate credit. Forty-three second grade through sixth grade students participated in a seven-day summer science camp that was embedded in the course. The 22 adult participants were divided into 10 teaching teams of two or three. Pre-service teachers were paired with in-service teachers. While five of the teaching teams were in class, the other five teams were teaching the elementary students who were divided into groups of eight or nine. The course design included content instruction, hands on learning of the activities that would later be taught to the students, a component on teaching children who represent diverse socioeconomic and cultural commitments, a component on teaching children with diverse learning abilities and needs, and a component on cross curricular integration with an emphasis on reading, writing, and mathematics. The camp activities for the students were completely hands-on, inquiry based.

The adult participants were administered pre/post content and content tests and pre/post STEBI assessments. Each individual generated a background survey, an end-of-course evaluation, and daily reflection journals. Four in-service teachers participated in the after-school program and in the summer science institute.

Classroom Observations

Classroom observations occurred in several different settings. The interns were observed in their intern program a minimum of six times per semester, at least once by their university liaison with the balance by their mentor teachers. The evaluator for the Eisenhower program observed the in-service teachers. During the after-school program visits were made to observe each team with their students and observations were made of the summer institute participants teaching their groups of elementary students.

Program Analysis and Findings

Pre-Service Teachers

In any one of the learning situations, isolated from the others, there was often no significant gain in confidence and attitude toward science and science teaching. However, pooled data using a modification of the STEBI, surveys, journals, and observations, with increased participation in these learning situations significant gains began to emerge. The more exposure and active involvement with inquiry-based learning the more significant gains were established. Pre-service teachers who taught in the after-school program and/or participated in the Summer Science Institute were more likely to choose to teach science lessons or integrate science in other content area lessons for formal observations by their liaisons or mentor teachers. On course evaluations students' comments that will follow indicated that they perceived inquiry learning was valuable to them.

I really learned a lot from the inquiry learning lessons.

I think it reflected on the ExCET.

I really enjoyed the science content. They were hands-on and very fun.

Journal reflections and interviews indicated that, as a result of increased confidence in science content and teaching skills, the students intend to incorporate more inquiry-based science teaching into their practices when they have their own classrooms.

My teacher doesn't teach science, but when I get my own classroom I'm going to teach hands-on science because it is fun.

My teacher doesn't teach much science, but she let me include science in my observation lesson.

"aka" helped me to see that science is not something to be scared of. It also gave me a few ideas as to how to bring science into my classroom.

I have learned many new lessons that I plan on using in my classes next year. (First contract teaching position.)

I can see how the students learn much more from this approach rather than a lecture approach.

As an eventual first semester teacher, one of the students had completed the IS351 course, the ElEd437 course, and had participated as a pre-service teacher in the after-school program. During her first semester as a certified teacher she received praise from both her school principal and her team members regarding her knowledge and willingness to suggest and bring ideas for integrating content across the curricula and for integrating science into regular teaching practices.

Thirty pre-service teachers' scores on the science domain of the state test for teaching certification were analyzed. Many had completed the IS351 course and all had been taught ELED437 by one or the other of the two elementary education faculty who also provided instruction in the professional development education for the after-school program and in the summer science institute. First a comparison was made between each individual's total score and the score made on the science domain. Then, the total score was subtracted from the science domain score. An average difference for the group was ascertained. Then the average difference scores of 10 pre-service teachers, who had participated on some level in the after-school program and/or the summer science institute, were compared against the average difference scores of the whole group. The average difference scores of a random sample of 10 pre-service students who were not taught by the two instructors were ascertained. A comparison was made across the three samples. For the group of thirty, it was found that on average their science domain scores were 2.56 points higher than their total score. For the group of program participants, on average their science domain scores were 3.44 points higher than their total score. For the random sample of 10, on average their science domain scores were about .5 points less than their total score. See Table 3 for a comparison of Average Difference Scores.

Table 3.

Average Difference Scores on Science Domain of the ExCET

Group of 30 mixed program participants and non-participants taught by two program administrators	Group of 9 program participants taught by two program administrators	Random Sample of 10 Others Non-program participants and none taught by either of the two program administrators

A point of interest is that students in the group of 30 who failed the state test for certification maintained a 2.5 average difference score in the science domain of the test. Their average difference score matched the average difference score of the whole group. Further research is needed to verify whether there is an authentic relationship between extensive inquiry-learning experiences and science scores on the state accountability test.

Six of the nine pre-service teachers had completed the IS 351 course. Of these, the final semester grade was a B for four of them and an A for two of them. The normal sequence of participation in inquiry learning provided in this study and completion of the state test for certification is as follows: IS 351 before internship/residency, ElEd 437 during internship, professional development education for the after-school program, completion of the state test for certification, and professional development education/course work in the summer science institute.

In-Service Teachers

Surveys, journal responses, evaluations of the summer science institute and of the professional development education for the after-school program, and observations indicated significant gains in improvement in beliefs and attitudes toward science and inquiry-based science teaching. Findings were similar to those of the pre-service teachers. The more exposure and active involvement with inquiry-based learning, the more significant gains were established. The in-service teachers were more likely to indicate intent to teach inquiry-based science and to actually implement inquiry-based science into their teaching practices.

Comments on evaluations of the professional development education and the teaching experiences in the after-school program indicated that some of the teachers concerns had been mitigated by their own learning experiences.

We had a minimum of student behavior problems. (Note that the demographics of the elementary student participants closely matched the demographics of the school.)

I was happy to see students love doing science.

The fast pace of the lessons and the amount of material to cover made me stay structured and focused on the objective.

It helped me to know that science can be fun and isn't too difficult.

It gave me ideas on how to bring experiments into the classroom.

At least half of the in-service respondents indicated that they incorporate more science in their regular classroom teaching practices. All respondents indicated that one of the most important benefits was an increase in science knowledge.

Journal responses from some of the in-service teachers indicated concerns about inquiry-based teaching, raised confidence, and increased knowledge.

This science camp has presented many challenges for me as a seasoned teacher.

I have begun to see new ways of motivating and teaching my students in the classroom that will correlate all subjects.

The inquiry method causes the students as well as the teachers to become higher order thinkers.

(Pre summer institute journal.) *I was a little nervous about this class. When I was in school, science wasn't "fun". It was a lot of bookwork without much hands-on. I grew up believing that science and experimenting were dangerous.* (Post summer institute journal.) *I do not feel the (content) test showed how much I learned. It didn't have a place to put what I now know about cabbage juice indicators, pH, bubbles, roller coasters, and bouncing balls. I never would have believed all the things I would get (ideas) from these 2 weeks. I am much more comfortable with science.*

Combined Pre-Service and In-Service Data

A modification of the STEBI was administered to both pre-service teachers and in-service teachers. All original questions of the STEBI-B were included. Four additional questions on comfort with open-ended questioning, open-ended student assignments, and assessment of open-ended assignments were added. A comparison of total pre and post assessment scores on the modified STEBI indicated an important improvement in beliefs and attitudes toward science and science teaching. See Figure 2 for Modified STEBI Results.

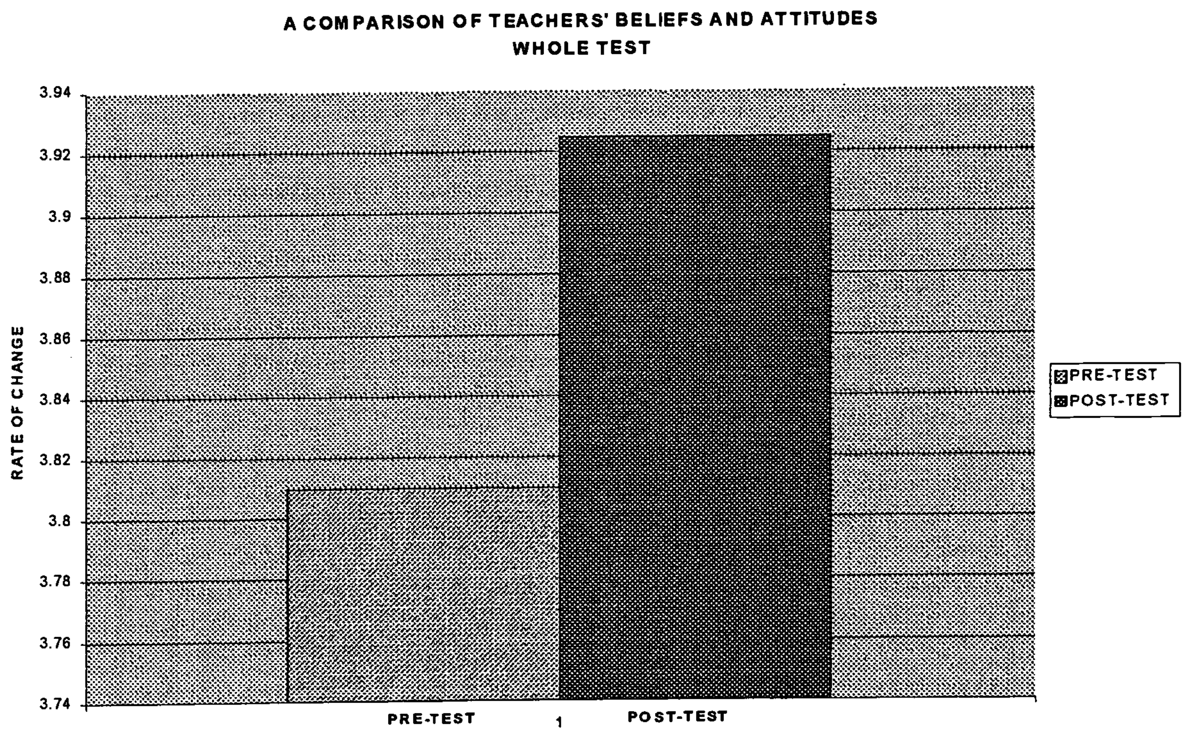

Figure 2. Modified STEBI Results

Results on the pre/post content tests administered to the after-school teachers and the pre/post content tests administered to the summer science institute teachers indicated a significant increase in science content knowledge See Figure 3 and Figure 4).

All of the teachers in this study, both pre-service and in-service, were representative of most elementary teachers in that most had taken only three or fewer laboratory courses in their undergraduate work. Only a few had taken more. Five of the in-service teachers taught science in a departmentalized setting, meaning they taught only science or taught all science with one class of social studies. Most of the teachers taught in self-contained settings where they taught all content subjects. Two were reading specialists. There was no significant difference between the ways the pre-service teachers scored on the content tests compared to the in-service teachers.

However, as noted earlier, there was a considerable difference between the scores of the pre-service teachers in this study ad those not in this study on the science domain of the state accountability test.

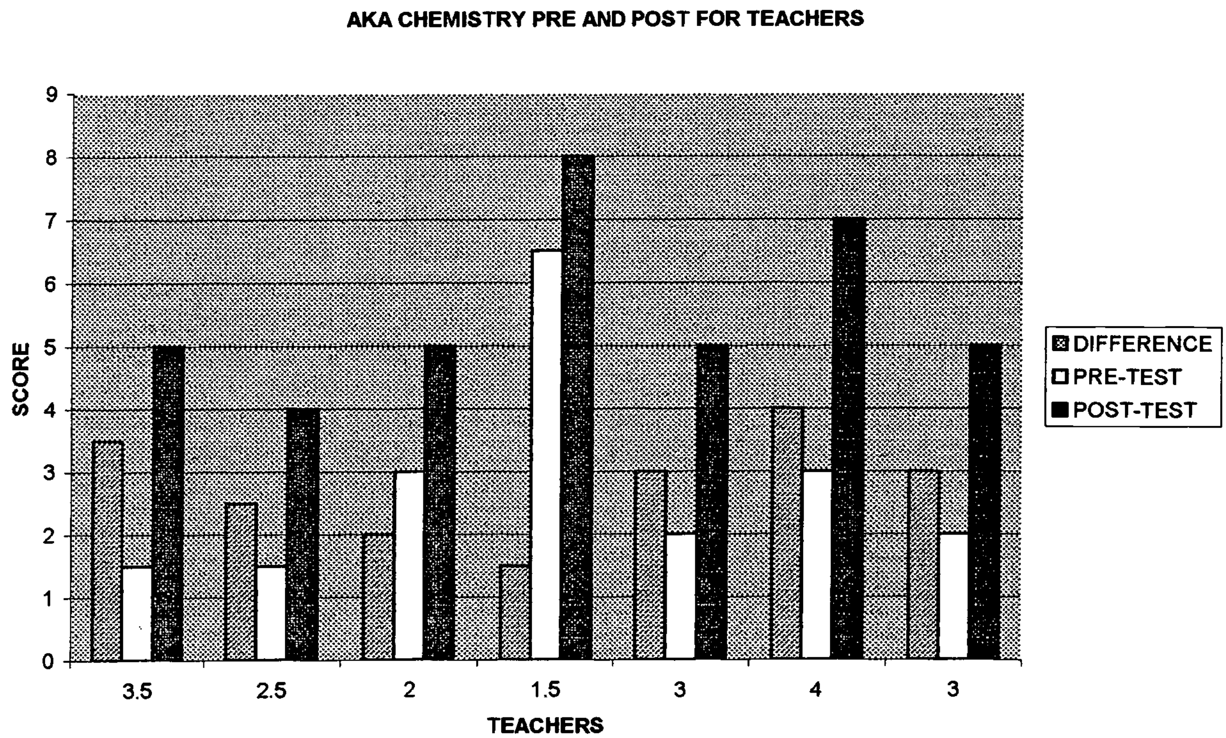

Figure 3. After-School Teachers' Content Test Results

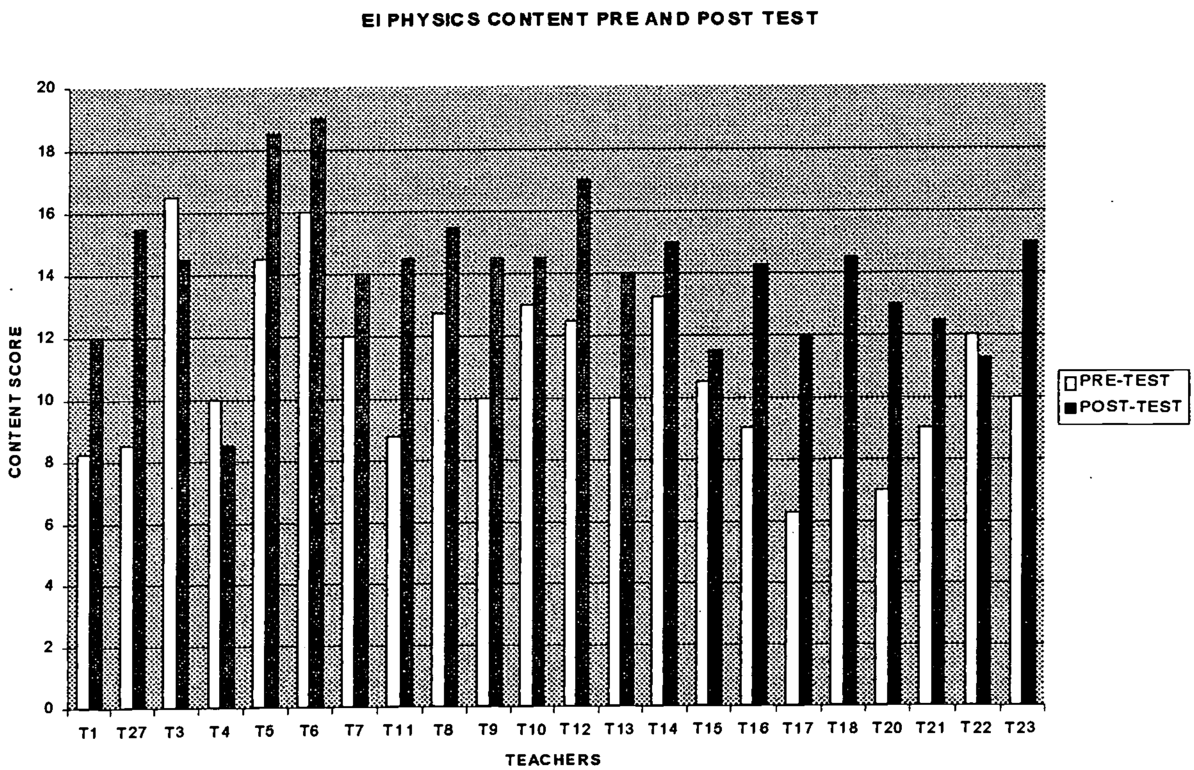

Figure 4. Summer Science Institute and Camp Teachers' Content Test

Participant evaluations of the summer science institute indicated that their expectations of learning science activities to motivate their students and how to manage and implement inquiry-based science in their teaching practices were more than adequately met.

I learned new ideas and extension activities for teaching science.

Learning new things to interest kids in science was invaluable.

The institute went well beyond what I hoped it would be.

Overwhelmingly, the participants indicated that the greatest benefits of the institute were the opportunity to work in partners and to try the experiments and lessons with small groups of children.

...being able to try ideas/experiments with children so I could make modifications and anticipate behaviors...

Collaborating with a partner, the exchange of ideas, and shared responsibility helped me to be more confident and made the experience more interesting.

I witnessed first-hand how children enjoy this way of learning.

The participants' views of science and science teaching were affected appreciably by their experiences.

The institute has given me an increased understanding and appreciation of how science can be taught.

Science seems less complex and fearsome. I have more confidence.

Teaching science is feasible, even in a class of 30.

It opened my eyes. There's not just one correct way to achieve a goal.

I am less fearful and more confident.

I was apprehensive before, now I look forward to teaching science.

I'm more open and feel more comfortable teaching using inquiry techniques.

Inquiry will cause me to use questions that cause students to think.

The participants indicated that their summer institute experiences influenced their views of how their students' understand and learn science.

They will remember what they have learned with hands-on learning.

Students can apply what they learn, not just spit out facts.

Students use a higher level of thinking than with worksheets.

The more than can "do" it, the more than can understand it.

The camp experiences showed me that students are smarter than I thought; they come up with ingenious ideas.

Hands-on will motivate students.

After working with the students, it is obvious to me that even lower achieving students can gain an understanding by using inquiry.

Safety and structure creates a deeper learning environment that fully engages students in learning.

Inquiry teaching/learning is not easy. My mouth wants to tell all, but I see students learn more and understand best if I allow them to discover. I have learned to ask questions leading to the answer rather than giving the answer.

All hands-on learning is not inquiry.

The teachers were asked to compare their perceptions of teaching and learning science through inquiry and note any changes from the beginning of the institute to the end of the institute.

I dreaded science before, now I see how much fun it can be.

Our experiences of using inquiry eased my concerns.

Implementing inquiry in my classroom may not be so difficult.

I feel more comfortable letting students do a lot of the learning process themselves.

I feel more comfortable about teaching by inquiry because we were shown how inquiry works and then we practiced what we learned.

All measures used to evaluate the pre-service and in-service teachers' beliefs and attitudes showed that they experienced improved confidence and attitudes toward teaching inquiry-based science and perceived its value for their elementary students' learning. Indicators also showed one of two things: (a) They were more likely to teach active, inquiry-based science lessons in their classrooms; or, (b) They indicated an intent to teach active, inquiry-based science lessons more frequently in their classrooms.

Discussion

The results of this study support the notion that the more experiences pre-service and in-service teachers have engaging in inquiry-based learning, the more positive the influence on their attitudes toward science and on their science teaching practices. Both the pre-service teachers and the in-service teachers indicated that their inquiry-based learning experiences raised their confidence to teach inquiry-based science and indicated an intent to teach more science by inquiry. Lesson observations revealed that the teachers were actually teaching more science by inquiry. This was likely influenced by their improved attitudes toward science and science teaching. Both groups of teachers indicated a discovery that teaching science is a viable and important endeavor in their elementary classrooms.

Journal reflections and course evaluations indicated that learning experiences were enhanced for both the pre-service and in-service teachers as they engaged in mentor/mentee situations. The pre-service teachers' knowledge of teaching was heightened by the relationships with the more knowledgeable, seasoned teachers. The in-service teachers benefited from the willingness of the pre-service teachers' risk-taking and openness toward inquiry-based teaching/learning, which was more closely aligned with the pre-service teachers' college learning experiences.

Among the implications of this study the three most important ones follow. This study suggests that open communication between faculty from departments of elementary education and faculty from the departments of science can have a strong influence on course development and scaffolding pre-service teachers' science content learning to their science methods courses in education and eventually to their pre-service field experiences and future teaching experiences. Early science learning experiences have long-term effects how elementary teachers perceive and teach science. In addition, partnerships between universities and school districts can enrich and continue education for in-service teachers. The shared responsibilities and the relationships developed through the professional development schools model of teacher preparation can have positive effects on science education in P-12 schools.

The systems within the larger system of education are complex, have a different character and appearance from one school to the next, and thus each requires communication, planning, and preparation by all entities involved. There is not a one-model-fits all systemic framework (Rodriquez, 2002). The nature of the professional development schools model, which is contingent upon partnerships, communication, and shared responsibility, can provide an environment in which unique and innovative decisions that advance systemic reform can be made on a school district by school district basis. Shared decision-making and responsibility has the potential for identification of needs and development of a system that will deliver equitable access to quality learning in science.

Further examination of this program and other similar programs will provide insight into their effectiveness to positively influence elementary student learning in science, into the sustainability of apparent changes in teacher beliefs, attitudes, and practices regarding science and science teaching, sustainability of institutional and public commitment to such programs, and into the long range effects of these programs on students' eventual choices and participation in challenging science courses in secondary and higher education.

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Organization: Association for the Education of Teachers in Science

Publication Date: June 2002

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Signature: Peter A. Rubba

Printed Name/Position/Title: Peter A. Rubba, DAP, World Campus

Organization/Address: Dr. Jon Pederson, AETS Exec. Secretary
College of Education, University of Oklahoma
820 Van Velet Oval ECH114
Norman, OK 73019

Telephone: 814-863-3248
FAX: 814-865-3290
E-Mail Address: par4@psu.edu
Date: 6/24/02

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