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ABSTRACT

This study examined elementary school students', parents', and teachers' reactions to instruction implemented by teachers participating in a special professional development program called Science: Parents, Activities and Literature (Science PALs). Specifically, this paper focuses on students' perceptions of their science instruction and attitudes toward science learning, and parents' and teachers' perceptions about science instruction as a function of their experience with an interactive-constructivist teaching approach designed to focus on student ideas, utilization of literature connections, and incorporation of parents as partners. Findings indicate that the Science PALs project successfully improved teachers' content-pedagogical knowledge in specific science units, pedagogical skills and attitudes toward teaching science, increased parental involvement and support of elementary school science, and developed a cadre of leaders and a district-wide infrastructure to support elementary school science. (Contains 23 references.) (WRM)

SCIENCE, PARENTS, ACTIVITIES, AND LITERATURE: OVERVIEW, RESULTS, AND REFLECTIONS

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Research Questions

This study examined elementary school students', parents', and teachers' reactions to instruction implemented by teachers participating in a special professional development program — Science: Parents, Activities and Literature (Science PALs). Specifically, this paper focuses on students' perceptions of their science instruction and attitudes toward science learning and parents' and teachers' perceptions about science instruction as a function of their experience with an interactive-constructivist teaching approach designed to focus on student ideas, utilization of literature connections, and incorporation of parents as partners. The following questions were addressed:

- Do perceptions and attitudes differ between students in Science PALs and non-Science PALs classrooms?
- Are students' perceptions and attitudes within Science PALs classrooms influenced by grade-level and gender?

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- What do parents' and teachers' comments reveal about Science PALs?

The Science PALs Project was a four-year systemic reform effort collaboratively undertaken by the Science Education Center at the University of Iowa and the Iowa City Community School District. The overarching goal of the project was to move teachers towards a middle-of-the-road, interactive-constructivist model of teaching and learning (sometimes referred to as soft-constructivism). This model differs from the extreme interpretations of social constructivism, which assumes understanding is constructed at the group level, and radical constructivism, which assumes all ideas are of equal veracity. As many of the teachers in the project had little or no experience with constructivist classrooms, the project leaders sought to promote teaching strategies consistent with interactive-constructivist views of learning by modeling these strategies in the teacher inservice activities.

Background

Constructivism, an old epistemic theory (not an instructional theory), has many interpretations (faces) in education (Good, Wandersee, & St. Julien, 1993; Phillips, 1995). The faces of constructivism provide a "range of accounts of the processes by which knowledge construction takes place. Some clarification of these distinct perspectives and how they may interrelate" is needed as this epistemic theory is used to construct compatible teaching and assessment approaches (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5). Without such clarification, teachers and researchers have little predictive potential and nearly any form of instruction can be justified.

The individual faces of constructivism do have some common basic assumptions and important differences. Accounts of the various interpretations of constructivism agree that understanding is actively made out of, invented from, or imposed on personal experiences (Fosnot, 1996). The construction processes and the resulting constructs are influenced by the learners' prior knowledge, memory, cognitive abilities, metacognition, interpretative framework, and sociocultural context. Each interpretation encourages meaningful learning of integrated knowledge networks through active debate and reflection, and each has discounted rote learning and drill-practice. Furthermore, each interpretation agrees that people have misconceptions within their prior knowledge and that these misconceptions are not indications of stupidity; are found across age groupings, content areas, cultures, and national boundaries; and are resistant to change. Replacement of misconceptions with more scientifically acceptable conceptions requires that the new concept be sensible, rational, usable, and powerful.

The individual faces of constructivism, however, also differ in their philosophical, psychological, epistemic, and pedagogical profiles (Table 1, Yore & Shymansky, 1997).

(**World view** involves ways of thinking about how the world works — mechanistic, organistic, contextualistic and hybrid (Prawat & Floden, 1994). **Mechanistic** views stress the important role of antecedent events as influence on behavior. **Contextualistic** views stress the importance of situation and environment where the meaning of an act may have situation-specific features, may undergo changes as it unfolds in a dynamic environment, and the pattern of events in a sociocultural context have low predictability. **Organistic** views stress the importance of the organism as a whole. Reality is only what the organism subjectively perceives; knowing is an individualistic event. **Hybrid** views stress the importance of interactions with the physical world (natural and people-built) as well as the sociocultural context and recognize that interpretations reflect lived experiences and cultural beliefs of the knowers.

- **Epistemic view of science** represents the structure of knowledge and ways of knowing (Hofer & Pintrich, 1997; Kuhn, 1993) — **absolutist** (a single right answer is proven), **evaluatist** (multiple interpretations are tested and supported or disconfirmed), and **relativist** (multiple interpretations are equally valid).
- **Locus of mental activity** represents the beliefs about where understanding is created — **privately**, deep within the mind and brain of the individual (activity flows from periphery to core where irrelevant stimuli are discarded leaving abstract representations of critical and essential information or activity focuses on subjective experiences, extracting internal coherence and where rightness is seen as the fit with personally established order); **publicly** within the dynamics of the group (activity is on the interface between the individual and the environment where the collective wisdom of the group and craft knowledge of the group construct understanding); and **publicly and privately** in which possibilities are surfaced, clarified, and narrowed by group negotiations but actual meaning is made privately by individuals reflecting on these possibilities (Hennessey, 1994; Prawat & Floden, 1994).
- **Locus of structure/control** represents a pedagogical feature and the pragmatics of classroom teaching dealing with who sets the agenda for study within a specific epistemology — **teachers**, **students**, or **shared**. An implicit source of structure imposed

on the learning comes from the content area under consideration: physical sciences or biological sciences (Yore, 1984; 1986).

〈 **Discourse** represents the combined psychological-pedagogical feature of type and purpose of communications in the classroom — **one-way interpersonal** communications of expert to novice, **one-way intrapersonal** communications of person to self (inner speech the language tool of thinking and spontaneous conception), and **two-way interpersonal** communications among people to negotiate clarity or consensus (Fosnot, 1996; Prawat & Floden, 1994).

Table 1
Philosophical, Psychological, Epistemic, and Pedagogical Features of Information Processing, Interactive-Constructivist, Social Constructivist, and Radical Constructivist Approaches (Yore & Shymansky, 1997).

Feature	Information Processing	Interactive-Constructivist	Social Constructivist	Radical Constructivist
World View	Mechanistic	Hybrid	Contextualistic	Organistic
Epistemic View of Science	Absolutist (traditional) Nature as Judge	Evaluative (modern) Nature as Judge	Evaluative (postmodern) Social Agreement as Judge	Relativist (postmodern) Self as Judge
Locus of Mental Activity	Private	Public and Private	Public	Private
Locus of Structure/Control	Teacher	Shared: Teacher and Individuals	Group	Individual
Discourse	One-Way: Teacher to Student	Two-Way: Negotiations to Surface Alternatives and to Clarify	Two-Way: Negotiations Leading to Consensus	One-Way: Individual to Self (inner speech)

Henriques (1997) established a comparative framework for four faces of constructivism — information processing, social constructivist, radical constructivist, and interactive-constructivist. She provided parallel descriptions of the approaches and their implications for teaching elementary school science:

1. **Information processing** utilizes a computer metaphor to illustrate learning in which a series of micro-processes generates ideas and analyzes errors, which lead to closer and closer approximations of the right answer. Learning is a process of identifying causal relationships between antecedents and outcome, establishing critical (essential, necessary,

and sufficient) attributes of a concept, and acquiring accurate understanding of fixed entities and relationships that exist independent of human activity.

2. **Social constructivism** utilizes a context metaphor to illustrate learning in which group dynamics lead to multiple interpretations that are resolved by social negotiations resulting in consensus and common understanding at the group level. Knowledge is perceived as a social artifact, not as a representation of reality.

3. **Radical constructivism** utilizes an organism metaphor to illustrate learning in which intrapersonal deliberations and inner speech lead to equally valid unique interpretations that are internally assessed for personal consistency. Knowledge is perceived as an individualistic snapshot of a multiple reality.

4. The **interactive-constructive model** utilizes a ecology metaphor to illustrate learning in which dynamic interactions of prior knowledge, concurrent sensory experiences, belief systems, and other people in a sociocultural context lead to multiple interpretations that are verified against evidence and privately integrated (assimilated or accommodated) into the person's knowledge network. Knowledge is perceived as individualistic conceptions that have been verified by the epistemic traditions of a community of learners.

The vision described in the *National Science Education Standards* (NRC, 1996) is of science teaching that engages all students in a quest for science literacy involving the abilities and habits-of-mind to construct understanding of the big ideas and unifying concepts of science and the communications to share with and persuade other people about these ideas (Ford, Yore, & Anthony, 1997). The science teaching standards envision changes in emphasis (NRC, 1996, p. 52):

Less Emphasis on	More Emphasis on
Treating all students alike and responding to the group as a whole	Understanding and responding to individual students' interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

When these changing emphases in teaching (children's attributes, rigidity of curriculum, relevant learning outcomes, active quest, alternative assessment, locus of control, and collaboration) are considered in the context of science and technology standards (science as inquiry and technology as design) and the epistemology described by the nature of scientific knowledge standards ("Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for best possible explanations about the natural world"), it becomes apparent that an interactive-constructivist perspective is supported by the *National Science Education Standards* (NRC, 1996, p. 201).

Treatment

At the beginning of the Science PALs Project, the Iowa City Community School District had an extensive hands-on, kit-based elementary school science curriculum in place. This kit-based curriculum was supported by a district science coordinator and a material distribution center. The kits contained exemplary National Science Foundation (NSF) supported materials, such as FOSS (Full Option Science System), NSRC/STC (National Science Resource Center/Science and Technology for Children), and the INSIGHTS series (Educational Development Center). The kits were delivered to the teacher on a rotating basis with minimal professional development focused mainly on mechanics and activity deployment. While the students enjoyed the kits and curriculum, there was a strong sense among the teachers that students were not developing meaningful science understandings from the experience. A primary reason for this belief was that the typical elementary school teacher in the district had little understanding of the science concepts the kits explored and was uncomfortable teaching science.

It was determined that, in order for teachers to become more effective, a comprehensive professional development program to increase science content knowledge and science content-pedagogical knowledge, to enrich the cross-curricular connections of the science units, and to promote meaningful parental involvement was needed.

The first year (1994-95) of the Science PALs Project began with 16 elementary school teachers designated as science advocates — one from each elementary school in the district. These teachers were selected in part for their willingness to serve as science leaders in their schools as well as their interest in participating in the teacher enhancement project. Around these common attributes, the science advocates had diverse demographics, teaching experiences, and academic backgrounds (Henriques, 1997).

The science advocates began the project by attending a special, problem-centered summer workshop similar to the Focus on Children's Ideas in Science project (FOCIS) (Shymansky, Woodworth, Norman, Dunkhase, Matthews, & Liu, 1993). The FOCIS project utilized middle school science teachers' interest in children's misconceptions and their sincere desire to promote conceptual change in their students as an authentic problem focus for the summer workshop and multiyear collaboration with a science content mentor. The focus on children's ideas served as the "straw man" in the FOCIS project, since enhancement of the teachers' science content knowledge and content-pedagogical knowledge were the actual goals of the project. The FOCIS project was effective in achieving meaningful science and science pedagogical learning among the middle school teachers on science topics of their choice.

The Science PALs workshop was designed to help participants explore selected curriculum units (NSF-supported versions), and activities using students' ideas again as the "straw man". The workshop matched science content consultants with small groups of science advocates to explore the science concepts in specific units and to promote interactive-constructivist teaching strategies among the teachers. The Science PALs activities attempted "to create optimal, collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers" (NRC, 1996, p. 58). In the workshop and the ensuing school year inservice sessions, various strategies were employed to have the science advocates articulate their alternative frameworks for the science concepts related to the school district's science units, and additional extension activities to challenge these understandings were implemented. The ultimate objective was to address the teachers' personal misconceptions and have them rethink their understandings to develop more accurate scientific conceptions critical to teaching the unit. These science advocates then supplemented the specific FOSS, INSIGHTS, and NSRC units with understandings of the science reforms, misconception literature, additional science activities, children's literature, and interdisciplinary connections to produce teacher resource binders (TRBs) for each science unit.

They field-tested the enriched units (field-test versions) in their own classrooms in the fall and attended three one-day workshops during and after teaching the units. The field-test experiences were shared with colleagues and science content consultants to further clarify science understandings and explore other activities to challenge additional student misconceptions they had uncovered while teaching the unit. These insights were used to revise the TRBs for each science unit (final version) and to develop home science activity bags. The activity bags consisted of a children's literature selection related to the central science topic of the unit, simple science equipment, and a parent interview and activity guide. The activity bags were used by parents to assess their children's prior science conceptions and to provide this information to their children's teachers. Parents and children read the story together and explored various science challenges in the story as they occurred, using the activity guide and equipment provided in the activity bags. The feedback from parents was used to make adjustments to the science instruction that more accurately reflected their students' prior knowledge. Parent orientation meetings were developed to introduce parents to the Science PALs project and activity bags. A Science PALs project newsletter was published to keep the community informed about the project's progress and to maintain contact with students' families.

The cascading leadership design of Science PALs involves a progression of participating teachers and an evolution of their specific leadership roles. April 1994-April 1995 focused on recruiting and working with the 16 science advocates. Fourteen of these original advocates remained active in the project during the 1995-96 cycle. Thirteen of the original advocates continue to serve in the advocate capacity, while one is active in the project but no longer as an advocate and two have left the school district. April 1995-May 1996 activities focused on recruiting and working with 24 lead teachers to complement and share leadership responsibilities with the advocates in a school. Eighteen of the original lead teachers remained active as of December 1996; four are still affiliated with the project but are not actively teaching Science PALs units during the 1996-97 school year and two have left the project. May-December 1996 activities focused on 37 additional teachers recruited as Year 3 (1996-97) cohort teachers to increase the cadre of Science PALs teachers in each school. One hundred forty teachers were recruited as the Year 4 (1997-98) cohort, but these teachers are not considered as part of this study.

The summer workshop with follow-up inservice cycle was repeated in subsequent years with approximately 40 teachers in the second year, 80 teachers in the third, and 140 teachers in the fourth year (Table 2). These numbers represent about 70% of the elementary teachers in the school district and about 90% of those that taught science on a regular basis. The cascading leadership model used meant that the advocates and lead teachers progressively assumed greater responsibility for the summer workshop, professional development activities, and science decisions.

One professional development activity worthy of specific note is the collaborative development of the Professional Development System (PDS). This activity was critical in defining the science teaching model associated with the Science PALs project. Science advocates, project staff, and external consultants progressively refined the fundamental dimensions of the project (planning, implementation, leadership), the artifacts (points of evidence) used to inform each

Table 2
Science PALs Professional Development Activities

Dates (month, day, year)	Focus
5-18-94 & 5-19-94	2-day retreat of science advocates, project staff, and district administrators to clarify project goals and introduce critical features
6-10-94 to 7-9-94	Select and explore science units: Light and Shadow (1-2), Floating and Sinking (3-4), and Experiments with Plants (5-6)
8-16-94	Share unit plans and organize implementation
9-20-94	Clarify Science PALs model and constructivism
10-17-94	Cross-curricular connections and assessment
11-29-94	Share implementation results and start on spring units: Growing Things (1-2), Earth Materials (3-4), Magnets and Motors (5-6), and Optics (5-6)
12-16-94	Continue work on spring units
1-24-95	Continue work on spring units and discuss teacher portfolios
1-31-95	Initiate scoring rubric for artifacts—Professional Development System (PDS)
2-28-95	Discuss PDS and literature component
4-18-95	Continue work on spring unit and analyze stories
5-11-95	Introduce lead teachers and establish focus for summer workshop
5-18-95 & 5-19-95	Multiple intelligences, planned change, and reflections on year 1
6-12-95 to 6-23-95	Revise fall and spring units (all but Optics) and develop new units: Balls and Ramps (1), Life Cycle of Butterflies (2), Lifting Heavy Things (3), Crawling Creatures (4), and Levers and Pulleys (5)
9-25-95 & 9-26-95	Parent components: Activity bags and orientation meetings
10-16-95 & 10-17-95	Language Arts connections and continue work on new science units
12-4-95 & 12-5-95	Alternative assessment
2-13-96	Follow-up on Parent Orientation Guide and assessment ideas
3-12-96	Children's literature and science
4-22-96	Technology applications in science
5-19-96 & 5-20-96	Science advocates' retreat—Leadership responsibilities
6-10-96 to 6-19-96	Introduce 65 new teachers and develop new science units: Living Things (1), Pebbles, Sand and Dirt (1), Habitats (2),

	Water (3), and Microworlds (5)
9-23-96 & 9-24-96	National Science Education Standards
10-16-96	Iowa State Science Teachers Conference
10-24-96 & 10-25-96	Statewide Dissemination Conference

dimension, and the four categorical examples for each dimension (Figure 1). This system provided the definition and catalyst for much of the inservice activities (Shymansky, Henriques, Chidsey, Dunkhase, Jorgensen, & Yore, 1997). The categorical examples for each dimension served as analytical scoring rubrics for any point of evidence (lesson plans, field notes, videotapes, teacher journals, peer interactions, students' work, etc.) used to inform the dimension. The PDS was used to assess instructional planning artifacts, examples of classroom teaching, and leadership

Figure 1
Science PALs Professional Development System

	POINTS OF EVIDENCE						LEVEL
	Lesson Material	Participant Observations	Lesson Video Tapes	Teacher Journals	Other Interactions	Classroom Documents (student work, etc.)	
Organizes Instruction							
Goals							
Materials							
Strategies							
Time							
Connection							
Evaluation							

BEST COPY AVAILABLE

Resources							
Reflective Planning							
Science Component							
Implements Instruction							
Student Differences							
Student Understanding							
Students as Self-Directed Learners							
Parent Involvement							
Reflective Teaching							
Science Component							
Time							
Leadership							
Communications							
Networking							
Attitudes							
Mentoring							

evidence on a 4-point scale (1 = low-level of Science PALs to 4 = high-level of Science PALs). The "student differences" dimension was evaluated according to the following ordinal categories (traditional to constructivist):

1. The teacher demonstrates a lack of interest in understanding why it is important to become familiar with students' backgrounds or misuses information such that there is interference with effective high-quality learning.
2. The teacher demonstrates interest in understanding why it is important to become familiar with students' backgrounds but does not use this information to enhance the quality of learning for all students.
3. The teacher demonstrates interest in understanding why it is important to become familiar with students' backgrounds and uses this information to enhance the quality of learning for some students.
4. The teacher demonstrates interest in understanding why it is important to become familiar with students' backgrounds and uses this information to enhance the quality of the learning experiences for all students. (Shymansky, et al., 1997, p. 37)

Collectively, the level 4 exemplars for the 9 planning dimensions, the 7 teaching dimensions, and the 4 leadership dimensions describe the prototypical Science PALs teacher (Henriques, 1997).

The Prototypical Science PALs Teacher

The prototypical Science PALs teacher is one who has a working knowledge about inquiry, the nature of science, and science topics in elementary school science. The teacher's content knowledge is married with age-appropriate and topic-specific pedagogical knowledge (content-pedagogical knowledge) that informs instructional planning, classroom teaching, and assessment. "Learning science thus involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at the individual level" (Driver, et al., 1994, p. 6). Science PALs teachers, as more experienced members of the scientific learning community, collaborate with the less experienced members (students, others teachers) to seek problems, ask questions, set tasks, structure experiences, and scaffold performances such that the less experienced persons can internalize and assume control of the processes. Science PALs teachers, as interlocutor, constantly seek to understand what the students know; to support, stimulate, question, and monitor conceptual growth and changes; and to provide just-in-time expertise. The interlocutor role involves a balancing act of being a co-investigator at times and a mentor who demonstrates, guides, and directs at other times. They are encouraged to be spontaneous, flexible, and anticipate learners' interests, questions, and problems. They use holistic teaching strategies that emphasize contextual learning and well-defined concept goals. They plan interactions with literature, activities, and prior experiences (including misconceptions) in a sociocultural context in which learners are encouraged to talk science, share alternative interpretations, and negotiate clarity. They focus on the value of children's ideas and how to utilize those ideas to plan, modify, and design concrete experiences to help children consolidate and integrate new ideas with prior knowledge structures. They involve parents in assessing their children's science ideas, promoting science education and supporting classroom learning as an instructional resource. Finally, the prototypical Science PALs teacher is a professional who is responsible for their continued growth as a teacher of children and science.

Design

The research questions were addressed using a multiple-source survey approach. Students from classrooms with teachers having Science PALs project experience and students from classrooms with teachers having no project experience were given surveys constructed expressly for this project to assess their perceptions of science teaching and attitudes toward science learning (Dunkhase, Hand, Shymansky, & Yore, 1997). Parents' and teachers' comments about specific features of Science PALs were collected with a variety of questionnaires and informal surveys. Analyses of instructional artifacts (TRBs) were used to document changes in planning for science teaching.

Instruments

Students' Perceptions of Science Teaching and Attitudes toward Science Learning

Students' perceptions of science teaching was composed of: (a) view of constructivist approach, (b) parents' interest, (c) teacher's use of children's literature in science, and (d) relevance of science. Students' attitudes toward science learning was composed of: (a) attitudes towards school science, (b) self confidence, (c) nature of science, and (d) science careers. These eight factors were established using factor analyses techniques. Original items were scored as disagree (1), do not know (2), and agree (3) and were assigned to factors using a varimax approach with minimum loading weights of 0.30. Items not meeting this condition or items not fitting the factor were deleted. This screening process resulted in a final Grade 1-2 survey of 37 items, a Grade 3-4 survey of 57 items, and a Grade 5-6 survey of 72 items. Table 3 provides the number of items in each factor and the internal consistency based on data collected for Grades 1-2 (N = 831), 3-4 (N = 722), and 5-6 (N = 999) in the spring of 1996. Internal consistencies ranged from marginal (0.45-0.60) on 9 data sets to reasonable (0.61-0.88) on 21 data sets. Generally, the instrument has reasonable validity and reliability for exploratory research, but further verification is planned to explore construct and predictive validities (Yore, Shymansky, Henriques, Hand, Dunkhase, & Lewis, 1998).

Parents' Comments

Parental perceptions were assessed using an 8-item questionnaire included by the 16 science advocates in the activity bags sent home. The 5-point Likert items were designed to assess parents' strong disagreement (1) to strong agreement (5) on the value of the activity bags and related activities, parent orientation meetings, need for additional information, and the transfer to other content areas. One hundred eighty-six completed questionnaires were returned

Table 3

Internal Consistencies of and Number of Items in the Likert Item Factors used to Assess Students' Perceptions and Attitudes

Scale and Factors	Grade-Level Groupings		
	1-2	3-4	5-6
Perceptions of Science Teaching	0.83(20)	0.85(34)	0.88(35)
Constructivist Approach	0.67(8)	0.81(21)	0.85(17)
Parental Interest	0.70(6)	0.68(5)	0.72(7)
Use of Literature in Science	0.52(3)	0.49(3)	0.61(5)
Relevance of Science	0.50(3)	0.56(5)	0.74(6)
Attitudes toward Science Learning	0.71(17)	0.79(23)	0.84(37)
Attitudes toward School Science	0.58(6)	0.74(5)	0.81(21)
Self-concept	0.54(3)	0.64(6)	0.63(6)
Nature of Science	0.60(4)	0.53(9)	0.51(7)
Careers in Science	0.68(4)	0.72(3)	0.79(4)

(46.5% response rate). The respondents indicated that 66% had attended a Science PALs orientation meeting.

Teachers' Comments

Teachers' comments were obtained by informal surveys as part of the 1995 and 1996 professional development activities and program evaluations. The comments were collected on specific features of an inservice activity at the end of each activity and about general features of Science PALs at retreats and at the end of the summer workshops. These comments were recorded retaining general category of the respondent (advocate, lead teacher, year 3 teacher) and date.

Analysis of Instructional Artifacts

Teacher Resource Binders (TRBs) developed by the teachers were evaluated on the 9 organizing instruction dimensions of the PDS. The three versions (NSF-supported version, field-test version, and final version) of the 1995 TRBs were evaluated to determine the impact of inservice activities and field testing. The final versions of the 1996 TRBs were evaluated to determine the impact of the increased science advocates' leadership and of the 1995-96 Science PALs activities on the curriculum development component. Collectively, the TRBs provide evidence about Science PALs teachers' planning for science teaching.

Data Analyses

The primary research focus of this study was to explore the influence of Science PALs teacher enhancement activities on students' perceptions of science teaching and attitudes toward science learning. The analyses provide descriptive data for students in classrooms in which the teachers were or were not involved in the Science PALs project. Since the perceptions and attitudes were assessed by different but similar items, the average perception and attitude for each factor was used to allow cross-grade comparisons. Differences in perceptions and attitudes were tested using a 3-way Analyses of Variance (ANOVA). Survey data and comments from parents and teachers were summarized using descriptive and qualitative techniques in an attempt to detect strengths and weaknesses and to establish general patterns. Percentage responses for each category of agreement/disagreement were calculated, and common patterns of comments were determined using constant comparison and expressed as assertions. The TRBs data were compared to the desired goals of the PDS (1 denotes traditional/low Science PALs alignment and 4 denotes constructivist/high Science PALs alignment).

Results

Students' Perceptions and Attitudes

Dunkhase, et al. (1997) provided a comprehensive report of the descriptive statistics and ANOVA results, while the general results are reported here. The treatment effects (Table 4) generally favored the Science PALs teachers over the non-Science PALs teachers for perceptions of science teaching (except "parental involvement") and for attitudes toward science learning (except "attitude toward school science" and "careers in science"). The Science PALs approach appeared to be more influential at the Grades 3-4 and 5-6 levels than at the Grades 1-2 level, but only the treatment effect for "using literature in science" was significant ($p \leq 0.05$). The treatment by grade level interaction for "using literature in science" was significant. There were no significant treatment by gender interactions, but females' perceptions were more positive than males' perceptions about science teaching while males' attitudes were more positive than females' attitudes toward science learning within the Science PALs treatment. These results appear to indicate that the strategies utilized in Science PALs are similar to those used by most

Grades 1-2 teachers, (i.e., using literature-based instruction, listening to children's ideas, using small-groups discussion, promoting self-directed inquiries, etc.) but different from the standard approaches in Grades 3-6.

The impact of the Science PALs approach may not be fully realized until the compound effects are explored as children have multiple exposures to the treatment over their elementary school years. Furthermore, the Science PALs approach involves the common basics of constructivism and the unique features of the interactive-constructivist approach — using literature in science, parental involvement, shared control, critically positioned teacher

Table 4
Means and Standard Deviations of Science PALs and Non-Science PALs Students' Perceptions and Attitudes

Dimensions	Science PALs X SD	Non-Science PALs X SD
<u>Perceptions of Science Teaching</u>	2.44, 0.33	2.43, 0.34
Constructivist Approach	2.62, 0.35	2.61, 0.36
Parental Interest	2.15, 0.53	2.16, 0.56
Use of Literature in Science	2.31, 0.66	2.24, 0.66
Relevance of Science	2.50, 0.54	2.38, 0.60
<u>Attitudes toward Science Learning</u>	2.40, 0.33	2.38, 0.34
Attitude toward School Science	2.32, 0.53	2.37, 0.54
Self-concept	2.62, 0.44	2.59, 0.45
Nature of Science	2.40, 0.56	2.23, 0.62
Careers in Science	2.13, 0.65	2.16, 0.66

interventions, etc. It is likely that these unique features will become more influential with repeated teacher use.

Parents' Responses

A survey of parent participants in the Science PALs project revealed overwhelming support (>70% agree to strongly agree) from the 186 respondents. Table 5 summarizes the respondents' belief about the Science PALs experience, activity bags, literature as springboards into science inquiry, parent-child involvement, parent orientation meetings, and transferability to other subject areas. The response patterns were consistent except for the usefulness of parent orientation meetings (likely caused by the fact that 34% of the respondents had not attended the scheduled meetings). Written comments indicated that parents had concerns about time requirements, advance notice, and lead time; that activity bags were more effective with younger children; that some literature selections were not explicitly connected to science ideas; and

Table 5
Parent Participation Survey

	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
1. This experience is valuable for your child.	0%	2%	8%	64%	26%
2. The science bag activities lead to more discussions of science at home.	0%	7%	20%	59%	14%
3. Story reading is a good introduction to the activities.	1%	2%	9%	55%	33%
4. The science activity bag is	1%	1%	17%	62%	19%

useful in helping your child learn science at school.					
5. Parent training sessions are useful in helping you work with your child.	1%	4%	25%	49%	21%
6. No additional information or explanation sessions are required.	2%	8%	18%	57%	15%
7. The science activity bag helps you have a better awareness of the science your child is studying.	1%	3%	2%	59%	35%
8. Home connection activities should be used in other subjects like mathematics.	1%	1%	11%	49%	38%

clarity and value of parent directions and training sessions. Several parents expressed a willingness to help develop activity bags, orient new parents, and participate in workshops for new teachers.

Parental involvement and the activity bags have been the most positive aspects of the Science PALs project. These components have been significant public relations successes, but their actual educational impact has not been fully documented. The feedback provided by parents about their children's prior knowledge at best allows teachers to make adjustments to their planning due to timing. Students' perceptions of their parents' interest in Science PALs classrooms is less positive than for students not involved in Science PALs classrooms at the Grades 1-2 level, while students for Grades 3-6 perceive their parents' interest more positively.

Teachers' Comments

Teachers' comments were examined using key ideas and constant comparison techniques to establish assertions. Source (advocate, lead teacher, year 3 teacher), date, and professional development activity's purpose (unit development, leadership, parental involvement, etc.) were used to help cluster comments and analyze the comments' message. Five assertions were detected, which are provided with some of the supporting teacher comments.

Assertion 1: Understanding the science concepts embedded in and the practical reform ideas related to selected science units in an authentic classroom-centered context, focusing on children's ideas and developing TRBs, allowed teachers to construct their own content-pedagogical knowledge about specific science topics.

Science Content and Reform Ideas

An especially effective part of the school year inservices was to be able to learn new science.

The most beneficial part of the inservice was working through the lessons and science concepts; developing/working on concept maps; sharing ideas/activities with peers.

Especially effective part of the summer inservice was finding ***Benchmarks*** *and key concepts. You know what and why you are doing the activities with the students.*

Children's Ideas and TRBs

By focusing on the science concepts I can better focus on the student ideas and understand how they relate to the KEY concepts of the unit.

The focus on student thinking encourages concept development in language that kids generate as they investigate rather than just receive information from the teacher.

Addressing student preconceptions starts the unit at the students' developmental level and their ideas are direct starting points for unit activities.

Starting with what the student already knows allows the student to build a more sophisticated understanding of the concept.

I feel very strongly about having the opportunity to learn more science and also having the opportunity to change and improve units.

The most beneficial part of the inservice was learning the science content and fixing the parts of the unit that didn't work before.

The TRBs are an excellent resource to refer back to and pull from. However, it will take me a few times through the unit to be able to utilize all it offers and to make good "pick and choose" decisions.

The TRBs will be useful to a new teacher but this will require that the teacher take more initiative since he/she won't have created it.

Clearly the teachers' comments assign priority to their concerns about content knowledge and practicality. Elementary teachers were comfortable learning science content since it was linked to real issues regarding their teaching responsibility and their students. Children's misconceptions and improving the science units addressed these concerns. They also realized that the process was likely as important as the product.

<u>Assertion 2:</u> Planning science instruction involved focusing on a few important concepts, identifying cross-curricular connections and developing multiple forms of assessment.

The focus on the "big ideas" encourages students to mental map several experiences that are hooked to one concept.

It was very beneficial to go through each activity and write ways of connecting them to other areas.

Having time to collaborate with colleagues and to have specialists available to answer science questions was very helpful. Also, having time to go through the unit activities and to discuss ideas and extensions to make it most meaningful for students.

I think that the task of creating an assessment will help me focus on specific concepts and I will assess throughout the unit instead of just assessing at the end of the unit. This should improve my teaching – it definitely raised my awareness.

My understanding of assessment has been quite broadened. I will look at methods of assessing students and evaluate these more critically.

Students can demonstrate their knowledge in creative, hands-on tests and need not be restricted to paper-pencil tests.

Teachers' comments regarding planning demonstrate concern for some of the content and assessment standards (NRC, 1996). Some teachers recognize the need to be focused and to provide in-depth instruction, relevant applications, and compatible assessments. The cross-curricular aspects of planning appear to be a priority of the self-contained elementary school classroom culture and a feature of generalist elementary teachers.

<u>Assertion 3:</u> Using children's literature as a springboard into science teachings required selection that reflects potential challenges, inquiry as well as content, and impact on students and thoughtful planning and guidance.

Selection

There are good picture books for the 5/6 level. They're not always written for inquiry, length is a problem.

We had evaluated books for science only. Now we (as a result of inservice) will look for skills and processes.

We should reserve judgment before dismissing a piece of literature. It may be more useful than immediately evident.

Planning and Guidance

Literature is great for increasing student interest and motivation.

It is important not to overemphasize the literature.

I don't use literature for a rigid 50-minute science period.

Literature provides examples of explaining science in narrative.

When they respond to literature, kids are reacting to the story, not the science.

If we give our students literature and let them immerse themselves in it, we need to give them time to investigate their questions.

Teachers recognize that the purposes of the children's literature are to challenge prior conceptions and to motivate students; it is not necessarily a source of information. Selection is critical in that the literature has to resonate with the children. Furthermore, when the literature is used in the activity bags, parents must be informed of the anticipated connection since it might be based on children's interest, inquiry skills, or other subtle features.

Assertion 4: Parents were perceived by teachers as parents and resources, and the Science PALs activity bags as quality parent-child experiences.

[Activity bags are effective] at keeping parents involved in the curriculum.

[Parent involvement is especially effective] as an opportunity for parent and child to interact academically.

[Activity bags provide] an opportunity for parent and teacher interaction and to promote science with parents.

Parent involvement is effective for discussing student understanding prior to the start of the unit and previewing kids' thinking.

Teachers' comments suggest that they value parents as partners. Clearly, the comments indicate that parental support increased when parents understood what the science instruction was trying to do, how difficult it was, and how they could be meaningfully involved. The Science PALs' parent component was viewed positively by teachers and parents, and it establishes a foundation for continued involvement in their children's later schooling (Hoover-Dempsey & Sandler, 1997).

Assertion 5: Science advocates defined their leadership roles as being an exemplary model of science teaching and as a consultant to help enhance other teachers' science knowledge and classroom practices.

Exemplary Model

One of my roles as an Advocate is to become more knowledgeable of constructivist structure and practice.

Part of my role as an Advocate is to focus on the identification of preconceptions of my students and work on them (ideas) during activities.

To develop a greater understanding of the science in the units I teach.

To learn more about the big concepts in our science units.

Part of my role as an Advocate is to develop appropriate assessment tools to assess student growth in science literacy.

No longer do I measure "success" as a whole class activity or achievement; but rather daily/weekly formative assessment to show current understanding, student discussion topics, problems, etc.

<u>Consultant</u>

Part of my role as an Advocate is to work with science teachers at other grade levels to enhance science teaching in our building.

Part of my role as an Advocate is to better able to support more individuals in the building. This year was spent trying to get more discussions going about science and children.

To continue to work with my building team to develop an all-school interest in science among all students.

To grow more in my own understanding of science concepts, issues, and reform recommendations – then to be able to help my staff in this area.

Although little explicit effort was devoted to developing leadership roles and skills in the first two years, science advocates appeared to develop an operational definition of their responsibilities from the actions of the project staff and science consultants. They believed that leadership by example would have the greatest impact on their fellow elementary teachers. Therefore, they planned to develop the classroom expertise in interactive-constructivist approaches, science reform, children's ideas, and assessment. Furthermore, once this expertise was realized, they would direct their leadership efforts to helping other teachers enhance their science teaching.

Teacher Resource Binders

The teacher resource binders (TRBs) represent a point-of-evidence for content-pedagogical knowledge. Teachers utilized their content insights and instructional insights on specific topics to revise, elaborate, and enhance the NSF-supported science units. The resulting effectiveness of the Science PALs project was indirectly assessed by evaluating the TRBs against predetermined planning attributes referenced to the "desired image" of teaching described by the project goals and specified in the PDS (1 denotes low Science PALs alignment and 4 denotes high Science PALs alignment).

The three versions (NSF-supported, field test, and final) of the target science units for the 1994-95 phase were assessed according to the 9 organizes instructions dimensions of the PDS. The original NSF-funded versions served as the basic reference frame, while the field test versions served as examples of the 1994 summer workshops' effectiveness, and the final versions served as examples of the first complete professional development cycle's effectiveness. The three versions of *Growing Things* (Grade 2), *Floating and Sinking* (Grade 4), and *Experiments with Plants* (Grade 6) were evaluated.

Growth in the direction of the Science PALs "desired image" became progressively more evident across the versions. The original versions were evaluated as 0-2 on the 4-point scale, while the final versions were evaluated as 3-4 on the same scale. Only the resources dimension did not reach acceptable levels in the final versions. The following trends were found:

1. Connections to the misconception literature are apparent in the later versions but these ideas do not appear to have influenced lesson design and actual instructional recommendations of the original units. The final versions provide additional activities but do not explicitly provide teachers with suggestions for addressing predictable misconceptions.
2. Connections to the science reform documents are apparent in the final versions and frequently are illustrated in activities, but critical ideas do not seem to be assigned greatest influence. Key concepts are identified but are not expanded or connected to other related or generalized cases.
3. All versions contain evidence of a strong hands-on experience, but the final versions are weak in specific strategies for scaffolding the construction of understanding.
4. As judged from the ultimate user's perspective of a generalist classroom teacher, the unit modifications to date still have work to be done. Comprehensive lesson plans that illustrate the Science PALs desired image should be provided.

Five new science units were identified for development during the 1996 summer workshop: *Pebbles, Sand & Silt* (Grade 1), *Living Things* (Grade 1), *Habitats* (Grade 2), *Water* (Grade 3), *Microworlds* (Grade 5). These five units were again evaluated using the PDS organizing instruction dimensions, and scoring rubrics. The results of the 1995 and 1996 evaluations are provided in Table 6.

The TRBs provided evidence that Science PALs teachers were using the content standards (NRC, 1996). The unit goals, activities, and resources represent a balance between the inquiry, physical science, life science, earth and space science, technology, personal perspective and society, and nature of science. The hands-on inquiry activities are question-initiated.

Students

Table 6

Evaluation of 1995 and 1996 TRBs based on 2 or 3 Evaluators' Judgments

Dimension	1995 Final TRBs			1996 Final TRBs				
	Growing Things	Floating and Sinking	Experi-menting with Plants	Living Things	Habitats	Pebbles, Sand & Silt	Water	Micro-world
Goals	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0
Materials	3.5	3.0	3.0	3.5	3.5	3.5	3.5	3.5
Strategies	3.0	3.0	2.5	3.5	3.0	3.5	3.5	3.5
Time	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Connections	3.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0
Evaluation	3.0	3.0	3.0	4.0	3.0	4.0	4.0	4.0
Resources	2.0	0.0	1.0	3.0	3.5	3.5	3.5	3.5
Reflective Planning	3.0	3.0	3.0	3.5	3.5	3.5	3.5	3.5
Science Component	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5

conduct investigations, gather data, use tools to extend their senses, and share their results and findings to other students.

The 1996 TRBs also provided evidence of marked improvement over the 1995 TRBs. The Science PALs teachers were incorporating a larger variety of materials and encouraging students to add different materials to expand their explorations and to aid in the formulation of reasonable explanations. External human resources provided another means to check and confirm their results and explanations.

The 1996 TRBs identified explicitly a variety of strategies to engage, explore, and consolidate students' ideas. Students used the coordinated skills of mathematics and science to collect and manipulate data from observations, draw conclusions, share these in pair/share groups, and predict what they will find in new situations.

Cross-curricular connections made to mathematics, arts, social studies, and language arts are also evident in the TRBs. Students explored examples as to why people derive pleasure from science (nature of science) when they experience art and music. Curricular connections with social studies, geography, mathematics, literature, writing, research skills, or reading, and real-world connections to home, family, or local community can be found in the 1996 units.

Reflecting planning is also evidenced in the TRBs, as teachers discussed lesson goals, salient science concepts, and common students ideas from the *Benchmarks for Science Literary*

(AAAS, 1993) and *National Science Education Standards* (NRC, 1996). Teachers reflected on integrated resources, activity bags and story analyses, and systematic data collection.

Reflections

The Science PALs project has successfully improved teachers' content-pedagogical knowledge about specific science units, pedagogical skills, and attitudes toward teaching science; increased parental involvement and support of elementary school science; and developed a cadre of leaders and a district-wide infrastructure to support elementary school science. The analyses of the TRBs and teachers' comments consistently indicate that teachers have improved understanding of science concepts embedded in the selected science units, children's misconceptions about these topics, the science reform and science education standards, and the potential of specific teaching strategies, assessment techniques, and cross-curricular connections. The Science PALs teachers' implementation of these planning ideas into actual classroom teaching and assessment practices are not fully documented. The overwhelming belief that more hands-on activities as the singular solution to the science literacy issue appears to be under question. The importance of certain reflective activities designed to get students to consolidate their new ideas and prior knowledge networks, to monitor and regulate learning, and to seek real-world applications has increased. Science PALs teachers are using children's ideas as the focus for their questions and activities and using children's incomplete and incorrect responses to guide discussion and group interactions. They are refocusing their assessment on understanding and knowledge production rather than recall of shallow ideas. Science PALs teachers are talking about science and are demonstrating a more relaxed and positive disposition toward teaching science.

Orchestrating effective and worthwhile parental involvement in children's science education has become more difficult with both parents working, single parents working two or more jobs, lack of extended families, and school environments with constant tension among schools, governments, and taxpayers. The Science PALs Project has demonstrated that family involvement can be achieved by designing meaningful, time-efficient, and worthwhile take-home science activities. The activity bags provide a natural, safe, inquiry context by using science-related literature to establish a challenge from which the parent can obtain worthwhile preassessment information to help the teacher, gain insights into how their children think, and demonstrate their honest interest in their children's learning. Children do not see these opportunities as "work"; rather they truly enjoy this context as an opportunity to demonstrate their knowledge and skills. Teachers also view these opportunities as positive chances to establish working relationships, rapport, and lines of communication with parents that might be utilized to address much more difficult tasks at a later time. These features are in agreement with the National Parent and Teacher Association recently released handbook of standards for parent involvement in children's education (NSTA, 1997):

〈 regular, two-way, meaningful communications;

- promotion and support of parenting skills;
- active parental participation in students' learning;
- open, welcome acceptance of parent volunteers;
- full parent partnership in school-related discussions about their children and family;
- community outreach for resources.

Incorporating parents as partners to share cultural insights, customs, and traditions, and to enrich and connect school learning and family life experiences will ensure relevance. Developing effective interfaces between schools and families is critical for minority, non-English speaking parents.

Science PALs has produced a group of science advocates and lead teachers who have demonstrated leadership for the 16 elementary schools in Iowa City. They have collaborated with their colleagues on science education projects and professional development activities. They have presented workshops at regional science teachers conferences and promoted the needs of elementary school science reform within the school system and community. Likewise, Science PALs has improved the kit distribution and maintenance facility. The school district has redesigned and staffed a resource center to support classroom teaching.

Science PALs successes are numerous, but effort needs to be given to the less successful aspects of the project. Likewise, steps need to be taken to maintain and improve the inservice activities. Teachers suggested:

Greater focus on research trends in science education would be useful (or maybe just handouts). You guys know all this which means YOU understand why constructivism or assessment, etc. is critical. We don't always know that.

I look forward to inservices to continue to get regular infusions of focus and energy.

Some objectives were more valuable earlier and have become less so as I feel more competent to do them independently. The new participants need to go through the development process themselves.

I feel this inservice was a valuable source for me. I feel confident about this unit and that all the ***Benchmarks*** *and concepts will be met fully. I also feel there are wonderful connections made that will provide real-life learning.*

I always enjoy the collaborative work of small groups of teachers working together and the wealth of teaching ideas rendered in the process.

The opportunity to develop meaningful curriculum in a wonderful professional atmosphere and to talk with colleagues about the ideas, concepts, issues, and pedagogy that really matters in what we do with children made this worthwhile.

The Iowa City Community School District superintendent summarized the effects of Science PALs as "one of the most important and successful programs in our schools" (Grohe, 1996, p. 1). She suggested that the success is due to the power of partnerships – university and schools, parents and teachers, secondary science teachers and elementary teachers, interdisciplinary, school and real world. These partnerships are based on collaboration, respect, and trust where the agenda was jointly set by all groups involved (Dunkhase, 1996).

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