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A Study of the Impact of a Long-Term Local Systemic Reform on the Perceptions, Attitudes, and Achievement of Grade 3/4 Students.

James Shymansky

Larry Yore

John Anderson

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ABSTRACT

This study reports on the effects of a major reform initiative which was implemented in the Iowa City Community Schools District. The Science: Parents, Activities, and Literature (Science PALs) Project was launched in 1994 to reform the district's elementary science program. It was designed to increase teacher effectiveness by providing a comprehensive professional development program for improving science content knowledge and science content-pedagogical knowledge, to enrich the cross-curricular connections of the science units, and to promote meaningful parental involvement in science learning. Another goal of Science PALs was to move teachers towards an interactive-constructive model of teaching and learning that reflected a "middle-of-the-road" interpretation of constructivism. Data indicated that teachers involved in Science PALs used many constructivist and cross-curricular strategies that were detected by the science supervisor and perceived by the students. Parents also positively responded to their new roles as partners in learning. The program did not seem to consistently develop positive attitudes in students about science learning or improve student achievement in science. (Contains 17 references and 12 tables.) (WRM)

A Study of the Impact of a Long-Term Local Systemic Reform on the Perceptions, Attitudes, and Achievement of Grade 3/4 Students

JAMES A. SHYMANSKY
E. Desmond Lee Professor of Science Education
University of Missouri, St. Louis, Missouri, USA

LARRY D. YORE
Department of Social and Natural Sciences
University of Victoria, Victoria, British Columbia, Canada

JOHN O. ANDERSON
Department of Psychological Foundations
University of Victoria, Victoria, British Columbia, Canada

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A Study of the Impact of a Long-Term Local Systemic Reform on the Perceptions, Attitudes, and Achievement of Grade 3/4 Students

Introduction

This paper is about the Iowa City Community Schools District's (ICCSD) effort to effect a major reform of its elementary science curriculum. The district had an extensive hands-on, kit-based elementary school science curriculum in place. The kit-based curriculum was supported by a district science coordinator and a materials 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 district teachers on a rotating basis. The minimal professional development provided focused mainly on mechanics and activity deployment. While the students enjoyed the kits and curriculum, there was a strong sense among the teachers and curriculum supervisors that students were not developing meaningful science understandings from the experience. The primary reason for this belief was that the typical elementary school teacher in the district had little understanding of the science concepts explored in the kits and was uncomfortable teaching science. The Science: Parents, Activities, and Literature (Science PALs) Project was launched in 1994 to reform the district's elementary science program.

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. It was also decided that these intentions needed to be addressed in a professional development context that provided teachers with first-hand experience with interactive-constructivist learning and a problem-centered, inquiry approach. The project's overarching goal was to increase elementary school teachers' content-pedagogical knowledge and move teachers towards an interactive-constructive model of teaching and learning that reflected a "middle-of-the-road" interpretation of constructivism (Shymansky, Yore, Dunkhase, & Hand, 1998a).

Problem

Science PALs stressed the importance of children's ideas about science, strategies for challenging children's prior knowledge to stimulate conceptual growth and change, connections to other content disciplines in the children's school day, and parents as partners in their children's science education. Since all these elements ultimately play out in the classroom, it was decided that the program's impact on the children's perceptions of science teaching, attitudes about learning science, and achievement in science should be considered as prime measures of the project's success. But project staff also recognized that any teacher could embrace and exhibit Science PALs-type philosophies and teaching strategies. Moreover, it was recognized that not all teachers receiving Science PALs training would be equally effective in implementing the project's practices and principles. To study the impact of the Science PALs project, it was decided that analyses of student performance as a function of "teacher exposure" to Science PALs training (0-4 years) and the degree to which teachers embraced and exhibited Science PALs practices and principles or their Science PALs "implementation quality" factor would be conducted.

This study took advantage of the Third International Mathematics and Science Study (TIMSS) in assessing student achievement. Thus, even though the Science PALs project involved Grade 1-6 teachers, this study focused only on Grade 3/4 students' perceptions of science teaching, attitudes toward science learning, and science achievement as a function of their exposure to a Science PALs brand of instruction. Specifically, this paper focuses on the following research questions:

- Are students' perceptions, attitudes, and achievement influenced by the level of teacher exposure to Science PALs enhancement activities?
- Are students' perceptions, attitudes, and achievement influenced by the implementation quality of the current-year Science PALs instruction?

Background

Science teaching, science learning, and science teacher education research has enjoyed increasing popularity in recent years with the publication of the *National Research Council's National Science Education Standards* (NRC, 1996), the *National Board for Professional Teaching Standards* (NBPTS, 1994), and the *Report of the National Commission on Teaching and America's Future* (Darling-Hammond, 1996). These reform documents reaffirm the importance of teachers, teaching, and hands-on/minds-on learning as primary influences on students' thinking, achievement, and science literacy. Collectively, the documents provide a vision of what we should teach, how we should teach, and how we should teach teachers to teach. Furthermore, an analysis of the reform documents for English language arts, mathematics, science, social studies, and technology revealed a common focus on "all" students, common learning outcomes of literacy and critical thinking, and common instructional intentions regarding constructivism and authentic assessment (Ford, Yore, & Anthony, 1997). Unfortunately, little attention has been given to developing a concise, clear definition of constructivism and of associated classroom practices. The National Science Teachers Association (1997) encouraged teachers to increase their professional awareness of the science standards for teaching, professional development, assessment, content, program, and education system. Clearly, the current science reform believes it is not enough to specify learning outcomes without emphasizing the quality of the learning experience, the authenticity of the evaluation, and the availability of learning opportunities.

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, critical thinking, 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 questioning, 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). An interactive-constructive model utilizes an 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 (Shymansky, et al., 1997b). Knowledge is perceived as individualistic conceptions that have been verified by the epistemic traditions of a community of learners.

The Science PALs Project

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 (Shymansky, et al., 1993). 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 science concepts in specific units the group selected 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; additional extension activities were utilized to challenge these understandings. 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. The 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 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. Using the parental feedback, adjustments were made to the science instruction that more accurately reflected 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. Fourteen of the original 16 advocates (1994-95) remained active in this study, now having 4 years of experience with Science PALs. Thirteen teachers 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. Second year (1995-96) activities focused on recruiting and working with 24 lead teachers to complement and share leadership responsibilities with the advocates. Eighteen of the original lead teachers remained active in this study; four are still affiliated with the project but are not actively teaching Science PALs units and two have left the project. This cadre of active lead teachers now has 3 years experience with Science PALs. Third year (1996-97) activities focused on 37 additional teachers recruited as Year 3 cohort teachers to increase the cadre of Science PALs teachers in each school; these teachers now have 2 years of experience with Science PALs. One hundred forty teachers were recruited as the Year 4 (1997-98) cohort; these teachers have 1 year of Science PALs experience in this study. The 1997-98 numbers represent about 70% of the elementary teachers in the school district and about 90% of those who 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 curriculum decisions.

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. The inservice cycle focused on authentic problems, using activities to challenge teachers' ideas and social interaction and private reflections to get the teachers to rethink their ideas. A similar cycle was then used by the teachers to challenge their students' ideas and to promote conceptual growth and change in science.

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 dimension, and the four categorical examples for each dimension. The PDS system provided the definition and catalyst for much of the inservice activities (Shymansky, et al., 1997a). 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 (Henriques, 1997).

The prototypical Science PALS teacher was defined as 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, other 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 function as interlocutor, constantly seeking to understand what the students know; supporting, stimulating, questioning, and monitoring conceptual growth and changes, and providing 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. Science PALs teachers are spontaneous and 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 continued growth as a teacher of children and science.

Vital Statistics

The Science PALs project was funded as a teacher enhancement project in March 1994 by the National Science Foundation and the Howard Hughes Medical Foundation. In the four years (1994-98) of the project, 235 K-6 teachers and 15 Grade 7-12 teachers from the ICCSD participated in summer and school year inservice activities. In addition to the teachers, approximately 3400 parents participated in special training sessions designed to integrate them into the K-6 science instruction. Across the four years of Science PALs, teachers received an average of 110 hours of inservice education designed to enhance their content and content-pedagogical knowledge.

Design

The research questions for this study were addressed using a comparative groups design that utilized all Grade 3-4 teachers and their 1998 students in the school district—both those participating in Science PALs and those electing not to participate. Two different independent variables were utilized in the study: (1) level of teacher exposure to Science PALs enhancement activities (0-4 years), and (2) implementation quality of the Science PALs brand of instruction as measured by supervisor ratings of all teachers on critical elements of basic constructivist teaching, Science PALs practices and principles, and interactive-constructivist teaching. Scores from a specially constructed student perceptions and attitudes survey and a battery of Grade 3-4 TIMSS items served as the measures of the dependent variables for this study.

Years of exposure to Science PALs enhancement activities was defined in terms of a teacher's participation in both a summer workshop and a full year of follow-up inservice activity, not in terms of the number of years of using Science PALs materials and strategies after the first year of involvement. Thus, a teacher who attended a Science PALs workshop in project years one and four would be considered to have only two years of Science PALs exposure.

Implementation quality of Science PALs-type instruction was defined by supervisor ratings. The science coordinator rated each teacher (Science PALs and Non-Science PALs) on an 8-dimension rubric developed to assess the basics of constructivism, the unique features of the Science PALs approach, and the global features of the interactive-constructivist approach (Shymansky, Yore, Henriques, Dunkhase, & Bancroft, 1998). These ratings facilitated the study of student performance as a function of implementation quality of constructivist instruction by their current year teacher regardless of the number of years their teacher was involved with Science PALs. The rubric required the rater to assess the degree of compliance (1-very weak, 2-weak, 3-satisfactory, 4-strong, 5-very strong) with the following dimensions:

1. Depth of content knowledge and content-pedagogical knowledge on science topics taught.
2. Knowledge of the reform standards and focus on fewer, big ideas as part of connected whole rather than on coverage of isolated ideas.
3. Use of strategies to access and utilize information on student ideas in planning instruction.
4. Use of strategies to challenge student ideas and to have them reflect on and integrate those ideas into their thinking.
5. Use of strategies that routinely and continuously incorporate children's literature and personal experiences as context for learning science.
6. Use of strategies that promote ongoing, substantive parent involvement in the science instruction.
7. Use of strategies that promote development of reading, writing, and speaking skills in the context of science instruction.

8. Overall ratings as a constructivist teacher, as defined in the goals of the Science PALS program.

Dimensions 1-4 represent common basic features across several interpretations of constructivism, while dimensions 5-7 represent unique features of the Science PALs approach and dimension 8 represents a holistic assessment of the interactive-constructivist approach.

Instruments

The Student Perceptions Of Constructivist Climates (SPOCC) instrument contained Likert items designed to assess students' agreement, absence of opinion, or disagreement on a five-position response scale to statements describing aspects of the Science PALs teaching elements and statements describing students' attitudes about science learning (Dunkhase, Hand, Shymansky & Yore, 1997; Shymansky, Yore, Dunkhase & Hand, 1998b; Yore, Shymansky, Henriques, Hand, Dunkhase & Lewis, 1998). The original survey had 191 items and was administered during the spring of 1996 to 721 Grade 3-4 students. Eight factors were established using factor analyses of these data. Original items were scored as strongly disagree (1), disagree (2), do not know (2.5), agree (3), and strongly agree (4), and were assigned to factors using a varimax approach with minimum loading weights of 0.30. Items not meeting this condition were deleted, resulting in a final survey of 79 items. Internal consistencies ranged from marginal (0.49-0.60) to reasonable (0.61-0.85). Based on the collective information about reliability and validity, the following dimensions were used in this study: students' perception of their teacher as a constructivist, students' perception of parental involvement, students' perception of the use of stories in science, students' perception of relevance, students' attitudes toward school science, students' self-concept in science, students' attitudes about the nature of science, and students' attitudes toward careers in science. The revised SPOCC was given to 456

Grade 3-4 students in 1997. These responses revealed reliabilities of 0.74, 0.61, 0.40, 0.41, 0.74, 0.54, 0.56, and 0.69 for the 8 factors.

The released items from TIMSS Grades 3-4 were collected into 6 tests to assess science achievement (IEA, 1997). Each form of the science achievement test consisted of 32 items: 25 multiple choice and 7 student-generated response items (5 short-answer and 2 extended-response). All forms of the test had 10 common multiple choice items and 3 common student-generated short-response items. Various combinations of the forms had other common student-generated (extended-response) items. The 6 forms were randomly distributed across students in each classroom tested. Therefore, every teachers' students were assessed by all 6 forms of the TIMSS test.

Data Analysis

Correlational analysis of the supervisor's rating on each of the eight dimensions of implementation quality, the basics of constructivist teaching (sum of dimensions 1-4), the Science PALs teaching (sum of dimensions 5-7), the global interactive-constructivist teaching (dimension 8), and the composite interactive-constructivist teaching (sum of dimensions 1-7) revealed that the rating dimensions were acting as a unified factor. Based on these results, it was decided to use the basics of constructivism rating (dimensions 1-4), Science PALs rating (dimensions 5-7), and the global interactive-constructivist rating (dimension 8) in all further analyses involving implementation quality. The basics of constructivist teaching and Science PALs teaching ratings were clustered into 3 categories (low, middle, high). The low category consisted of ratings of 1 or 2 on each dimension and the high category consisted of ratings of 4 or 5 on each dimension. The middle category represented ratings of 3 on each dimension or combinations of high and low ratings on different dimensions.

Preliminary analysis (one-way ANOVA) of the results on the common items across the 6 forms of the TIMSS test revealed that the performance for the groups of students taking each form were not significantly different ($p \leq 0.05$). Therefore, the results for each form were converted to standard scores and the science achievement results were treated as if they came from a single test for all further analyses in this study.

The students' perceptions of science teaching, attitudes toward science learning, and science achievement results were analyzed by a series of one-way ANOVAs using Science PALs exposure and implementation quality as the main dimension. Science PALs exposure was determined by the teachers' full participation in the project and was categorized as 0, 1, 2, 3, or 4 years. Implementation quality was determined by the supervisors' rating of the teachers' implementation of the basics of constructivist teaching (low, middle, high), the unique features of Science PALs teaching (low, middle, high), and interactive-constructivist teaching (1, 2, 3, 4, 5).

Results

Tables 1-12 provide descriptive statistics for students' perceptions of science teaching (N=843), attitudes towards science learning (N=843), and science achievement (N=976). The raw scores were analyzed using a series of one-way ANOVAs using measures of the independent variables as the main dimension. The actual sample sizes for these analyses vary slightly from the sample sizes reported for the descriptive data because of missing responses on some measures. Significant results of these ANOVAs are also indicated in the tables.

[INSERT TABLES 1-12 ABOUT HERE]

The ANOVAs revealed significant years of exposure main effects for students' perceptions of constructivist view of teacher ($F=26.03$, $df=4,834$, $p \leq 0.001$), parental involvement ($F=11.12$, $df=4,833$, $p \leq 0.001$), and use of stories ($F=13.15$, $df=4,839$, $p \leq 0.001$) and students' attitudes toward school science ($F=4.12$, $df=4,837$, $p=0.003$), self-concept in science ($F=2.99$, $df=4,837$, $p=0.018$), nature of science ($F=8.33$, $df=4,838$, $p \leq 0.001$), and science careers ($F=3.23$, $df=4,836$, $p=0.012$). No significant years of exposure effect was found for science achievement. The pattern of students' perceptions of constructivist view of their teacher was positive, with the major differences occurring between students with teachers having 0 and 4 years and 2 and 4 years of Science PALs experience. The pattern of students' perceptions of parental involvement was positive, with the most positive perceptions being from students with teachers having 4 years of Science PALs experience. The pattern for students' perceptions of use of stories revealed consistently more positive perceptions across years of exposure. Student attitudes toward school science generally declined for teachers with more Science PALs experience with some recovery for teachers with 4 years of experience. Likewise, students' self-concept in science demonstrated a similar pattern. Students' attitudes toward the nature of science generally increased across the years of Science PALs experience. The students' attitudes toward science careers were relatively consistent except for an increase for students having teachers with 2 years of experience followed by a decline for students having teachers with 3 years of Science PALs experience.

The ANOVAs revealed significant implementation quality of basic constructivism main effects for students' perceptions of parental involvement ($F=8.60$, $df=2,842$, $p \leq 0.001$) and use of stories ($F=15.29$, $df=2,848$, $p \leq 0.001$) and students' attitudes towards school science ($F=9.19$, $df=2,846$, $p \leq 0.001$), self-concept in science ($F=3.71$, $df=2,845$, $p=0.25$) and nature of science ($F=7.14$, $df=2,847$, $p=0.0001$). No significant implementation quality of basic constructivism effect was found for science achievement. Students' perceptions of parents' involvement in their science instruction consistently decreased across the supervisor ratings of basic constructivism. Conversely, students' perceptions of the use of stories in their science instruction consistently increased across the supervisor's rating categories. Students' attitudes toward school science decreased and then leveled off with the major decreases being between students whose teachers received a low basic constructivism rating and those receiving middle and higher ratings. A similar pattern was found for students' self-concept in science. Students' attitudes toward the nature of science consistently improved across the low, middle, and high categories for implementation qualify of basic constructivism.

The ANOVAs revealed significant implementation quality of Science PALs teaching main effects for students' perceptions of constructivist view of teacher ($F=8.27$, $df=2,843$, $p \leq 0.001$), parental involvement ($F=7.70$, $df=2,842$, $p \leq 0.001$) and use of stories ($F=14.79$, $df=2,848$, $p \leq 0.001$) and attitude toward the nature of science ($F=9.86$, $df=2,847$, $p \leq 0.001$). No significant main effect was found for science achievement. Each of the significant main effects results from patterns of consistently improving perceptions and attitudes across the low, middle, and high supervisors' ratings of implementation quality of Science PALs teaching principles and practices.

The ANOVAs revealed significant interactive-constructivist implementation quality main effects for students' perceptions of constructivist view of teacher ($F=7.40$, $df=3,836$, $p \leq 0.001$) and use of stories ($F=11.96$, $df=3,841$, $p \leq 0.001$) and attitudes toward school science ($F=5.49$, $df=3,839$, $p=0.001$), nature of science ($F=6.83$, $df=3,840$, $p=0.001$) and science careers ($F=3.73$, $df=3,838$, $p=0.01$). No significant interactive-constructivist main effect was found for science achievement. The major differences in students' view of teachers were between teachers with an interactive-constructivist implementation rating of 2 and those with ratings of 3, 4, and 5. Again, the major differences in students' perceptions of the use of stories were between teachers with a rating of 2 and the other ratings. The pattern in attitudes toward school science was negative, with negative differences between 2 and 5 ratings and 4 and 5 ratings accounting for most of the variance. The differences in nature of science were positive across the ratings, with most of the variance being contributed by the differences between students with teachers' ratings of 2 and those with ratings of 4 and 5. The pattern in science careers was negative, with the declines between 2 and 5 ratings and 4 and 5 ratings contributing most of the variance.

Discussion

The Science PALs reform effort was successful in many ways in the Iowa City Community School District: elementary school science teachers moved toward an interactive-constructive approach; parents positively responded to their new roles as partners; and, most importantly, students saw a change in their science instruction. But, unfortunately, this effort did not consistently develop a more positive attitude about science learning or improve students' achievement in science. Science PALs teachers utilize students' ideas to plan instruction; they challenge these ideas with activities and questions; they use a variety of assessment techniques; they connect science to other areas of the elementary school curriculum; and they involve parents in meaningful ways. Supervisors' ratings for the basics of constructivism, Science PALs practices, and interactive-constructivist teaching correlated significantly with years of experience in the Science PALs project. This finding needs to be viewed with skepticism, since the rater may have unknowingly expressed vested interest. Henriques (1997) found similar results using somewhat more distant observers and objective instruments. There is little doubt that instruction in Science PALs teachers utilized many constructivist and cross-curricular strategies that were detected by the science supervisor and perceived by the students. But whether these changes impact students' perceptions, attitudes, and achievement still must be questioned.

A survey of parent participants in the Science PALs project revealed overwhelming support (70% agree to strongly agree) from the 186 respondents for the Science PALs experience, activity bags, literature as springboards into science inquiry, parent-child involvement, parent orientation meetings, and transferability to other subject areas (Shymansky, Yore & Hand, 1999). 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 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.

Public awareness of elementary school science instruction has increased in the Iowa City Community School District. The central administration and school principals have consistently promoted science and the Science PALs project won a 1998 First in the Nation Education Award. The science education climate in Iowa City elementary schools is much more positive with each school having strong advocacy for hands-on/minds-on science teaching and learning and the school district supporting a science resource center with staff and materials during times of difficult budget constraints.

This study has demonstrated that students' perceptions about science teaching improve when their current teacher has been involved in Science PALs and when their current teacher has been rated higher on implementation quality. Unfortunately, the same is not true about students' attitudes toward science learning (except nature of science) and science achievement. Students' attitudes toward school science, self-concept in science, and science careers significantly decreased in some cases, while science achievement stayed relatively constant for increased exposure and implementation quality. The positive finding was that students' attitudes toward the nature of science were much more in keeping with the National Science Education Standards (NRC, 1997) about science as inquiry and on evidence-based epistemology.

There is evidence to suggest two or more years of experience are required to implement complex constructivist practices that students will detect and will impact science learning. But reform efforts are not always uniform in their effects (Henriques, 1997). This pattern was apparent in the 1998 data. Evidence indicated that some non-participating teachers were utilizing many general principles of constructivist teaching. In some limited cases, these teachers were more effective constructivist teachers than some Science PALs teachers who were struggling to change their teaching approach. But, when exposure is reduced to Science PALs teachers with high implementation quality compared to non-Science PALs teachers with low implementation quality, the students of Science PALs teachers have more positive perceptions and attitudes and have higher scores on the TIMSS tests.

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Table 1. Means and Standard Deviations of Students' Perceptions of Science Teaching for Teachers with Different Years of Science PALs Exposure.

Dimension	Years of Science PALs Exposure (Number of Students Responding)				
	0 (N=226)	1 (N=259)	2 (N=151)	3 (N=183)	4 (N=23)
Constructivist View of Teacher***	2.90(0.72)	3.16(0.38)	2.64(0.76)	3.05(0.43)	3.51(0.44)
Parental Involvement***	2.43(0.91)	2.65(0.65)	2.38(1.00)	2.65(0.65)	3.39(0.54)
Use of Stories***	2.49(0.48)	2.71(0.45)	2.75(0.51)	2.79(0.54)	2.84(0.40)
Relevance	3.19(0.50)	3.24(0.46)	3.18(0.52)	3.16(0.52)	3.23(0.45)

Table 2. Means and Standard Deviations of Students' Attitudes toward Science Learning for Teachers with Different Years of Science PALs Exposure.

Dimension	Years of Science PALs Exposure (Number of Students Responding)				
	0 (N=226)	1 (N=259)	2 (N=151)	3 (N=183)	4 (N=23)
School Science**	3.05(0.68)	2.96(0.63)	2.85(0.70)	2.81(0.67)	3.00(0.60)
Self-concept in Science*	3.13(0.59)	3.20(0.45)	3.15(0.52)	3.03(0.51)	3.16(0.50)
Nature of Science***	2.99(0.36)	3.05(0.30)	2.91(0.46)	3.04(0.34)	3.31(0.24)
Science Careers*	2.68(0.72)	2.65(0.73)	2.79(0.75)	2.50(0.83)	2.64(0.62)

Table 3. Means and Standard Deviations of Students' Science Achievement for Teachers with Different Years of Science PALs Exposure.

Dimension	Years of Science PALs Exposure (Number of Students Responding)				
	0 (N=265)	1 (N=344)	2 (N=142)	3 (N=201)	4 (N=24)
TIMSS	15.83(4.09)	15.47(4.22)	15.09(4.26)	15.15(4.11)	14.54(5.01)

Table 4. Means and Standard Deviations of Students' Perceptions of Science Teaching for Specific Supervisor's Ratings of Teachers' Implementation Quality—Basic Constructivism.

Dimension	Supervisor Ratings (Number of Students Responding)		
	Low (N=81)	Mid (N=527)	High (N=238)
Constructivist View of Teacher	3.03(0.43)	2.99(0.60)	2.93(0.66)
Parental Involvement***	2.77(0.62)	2.61(0.80)	2.40(0.87)
Use of Stories***	2.50(0.46)	2.64(0.51)	2.81(0.47)
Relevance	3.19(0.39)	3.18(0.53)	3.23(0.48)

Table 5. Means and Standard Deviations of Students' Perceptions of Science Teaching for Specific Supervisor's Ratings of Teacher s' Implementation Quality—Basic Constructivism.

Dimension	Supervisor Ratings (Number of Students Responding)		
	Low (N=81)	Mid (N=527)	High (N=238)
School Science***	3.22(0.51)	2.88(0.72)	2.93(0.59)
Self-concept in Science*	3.27(0.40)	3.11(0.56)	3.15(0.45)
Nature of Science***	2.96(0.29)	2.98(0.40)	3.08(0.32)
Science Careers	2.80(0.65)	2.62(0.78)	2.65(0.75)

Table 6. Means and Standard Deviations of Students' Science Achievement for Specific Supervisor's Ratings of Teachers' Implementation Quality—Basic Constructivism.

Dimension	Supervisor Ratings (Number of Students Responding)		
	Low (N=73)	Mid (N=700)	High (N=263)
TIMSS***	17.04(3.32)	14.97(4.23)	15.69(4.18)

*** denotes significant main effect ($p \leq 0.001$)

** denotes significant main effect ($p \leq 0.01$)

* denotes significant main effect ($p \leq 0.05$)

Table 7. Means and Standard Deviations of Students' Perceptions of Science Teaching for Specific Supervisor's Ratings of Teachers' Implementation Quality—Science PALs.

Dimension	Supervisor Ratings (Number of Students Responding)		
	Low (N=181)	Mid (N=405)	High (N=263)
Constructivist View of Teacher***	2.76(0.68)	2.96(0.65)	3.15(0.42)
Parental Involvement***	2.38(0.92)	2.57(0.84)	2.68(0.67)
Use of Stories***	2.54(0.49)	2.66(0.51)	2.80(0.49)
Relevance	3.15(0.49)	3.22(0.51)	3.18(0.50)

Table 8. Means and Standard Deviations of Students' Attitudes toward Science Learning for Specific Supervisor's Ratings of Teachers' Implementation Quality—Science PALs.

Dimension	Supervisor Ratings (Number of Students Responding)		
	Low (N=181)	Mid (N=405)	High (N=263)
School Science	2.93(0.76)	2.94(0.68)	2.91(0.60)
Self-concept in Science	3.11(0.55)	3.14(0.54)	3.15(0.46)
Nature of Science***	2.93(0.34)	2.99(0.39)	3.08(0.36)
Science Careers	2.70(0.74)	2.66(0.79)	2.59(0.72)

Table 9. Means and Standard Deviations of Students' Science Achievement for Specific Supervisor's Ratings of Teachers' Implementation Quality—Science PALs.

Dimension	Supervisor Ratings (Number of Students Responding)		
	Low (N=294)	Mid (N=428)	High (N=314)
TIMSS	15.36(4.12)	15.08(4.18)	15.54(4.28)

Table 10. Means and Standard Deviations of Students' Perceptions of Science Teaching for Specific Supervisor's Ratings of Teachers' Implementation Quality—Interactive-Constructivist Teaching.

Dimension	Supervisor Ratings (Number of Students Responding)				
	1 (N=0)	2 (N=153)	3 (N=368)	4 (N=253)	5 (N=69)
Constructivist View of Teacher***	–	2.78(0.73)	3.05(0.50)	2.99(0.70)	3.04(0.37)
Parental Involvement	–	2.43(0.96)	2.64(0.70)	2.53(0.90)	2.56(0.67)
Use of Stories***	–	2.55(0.48)	2.62(0.52)	2.82(0.46)	2.75(0.47)
Relevance	–	3.19(0.48)	3.18(0.50)	3.26(0.49)	3.09(0.48)

Table 11. Means and Standard Deviations of Students' Perceptions of Science Teaching for Specific Supervisor's Ratings of Teachers' Implementation Quality—Interactive-Constructivist Teaching.

Dimension	Supervisor Ratings (Number of Students Responding)				
	1 (N=0)	2 (N=153)	3 (N=368)	4 (N=253)	5 (N=69)
School Science***	–	3.07(0.67)	2.87(0.71)	2.99(0.63)	2.77(0.52)
Self-concept in Science	–	3.12(0.54)	3.14(0.54)	3.15(0.50)	3.05(0.43)
Nature of Science***	–	2.93(0.35)	2.99(0.39)	3.08(0.33)	3.05(0.33)
Science Careers**	–	2.76(0.70)	2.62(0.77)	2.69(0.74)	2.43(0.79)

Table 12. Means and Standard Deviations of Students' Perceptions of Science Teaching for Specific Supervisor's Ratings of Teachers' Implementation Quality—Interactive-Constructivist Teaching.

Dimension	Supervisor Ratings (Number of Students Responding)				
	1 (N=0)	2 (N=233)	3 (N=390)	4 (N=285)	5 (N=68)
TIMSS	–	15.76(3.90)	15.15(4.26)	15.54(4.29)	15.38(4.31)

*** denotes significant main effect ($p \leq 0.001$)

** denotes significant main effect ($p \leq 0.01$)

* denotes significant main effect ($p \leq 0.05$)

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Organization/Address: UMSL- 8001 Natural Bridge Rd St. Louis, MO 63121	Telephone: 314 516 5046	FAX: 314 516 7025
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