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ABSTRACT

This study explored the cumulative effect of three years of exposure to teaching strategies being promoted in a local school district's systemic reform on elementary students' attitudes towards school science, awareness of science careers, and science achievement. The reform effort, referred to as the "Science: Parents, Activities, and Literature" (Science PALs) program focused on incorporating children's literature and parent partners using an interactive-constructivist epistemology as its base. Individual teachers were rated by the school district's science coordinator on their use of specific Science PALs strategies. Student attitudes and awareness were assessed with a paper and pencil survey developed for this research. Student achievement was assessed with multiple choice and constructed response items taken from the released item pool of the Third International Mathematics and Science Study (TIMSS). Student attitude, awareness, and achievement data were analyzed in terms of the cumulative ratings of teachers across the last three years of the reform effort. Results indicate that students receiving three years of instruction from teachers with different ratings on their use of Science PALs strategies did not show significantly different attitude, awareness, or achievement. These results are discussed in terms of school district characteristics, research design factors, and challenges of systemic reform goals. (Contains 19 references.) (Author/CCM)

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Abstract

This study explored the cumulative effect of three years of exposure to teaching strategies being promoted in a local school district systemic reform on elementary students' attitudes toward school science, awareness of science careers, and science achievement. The reform effort, referred to as the Science: Parents, Activities and Literature (Science PALs) program focused on incorporating children's literature and parent partners using an interactive-constructivist epistemology as its base. Individual teachers were rated by the school district's science coordinator on their use of specific Science PALs strategies. Student attitudes and awareness were assessed with a paper and pencil survey developed for this research. Student achievement was assessed with multiple choice and constructed response items taken from the released item pool of the Third International Mathematics and Science Study (TIMSS). Student attitude, awareness, and achievement data were analyzed in terms of the cumulative ratings of teachers across the last three years of the reform effort. Results indicate that students receiving three years of instruction from teachers with different ratings on their use of Science PALs strategies did not show significantly different attitude, awareness, or achievement. These results are discussed in terms of school district characteristics, research design factors, and challenges of systemic reform goals.

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Introduction

This paper is about one school district's 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 curriculum was supported by a district science coordinator and a materials distribution center. The kits contained exemplary National Science Foundation (NSF) supported materials from recent curriculum projects and others based on the 1960s projects. The kits were delivered to the district teachers on a rotating basis. While the students enjoyed doing activities, there was a strong sense among the teachers and district staff that students were not developing meaningful science understandings from the experiences. It was generally acknowledged that the typical elementary school teacher in the district had little understanding of the science concepts explored in the kits, was uncomfortable teaching science, and believed that simply doing activities would enhance students' science process and thinking skills. There was little or no attention paid to developing specific conceptual knowledge or to addressing students' mis-conceptual knowledge. The Science: Parents, Activities and Literature (Science PALs) project was launched in 1994 to address the district's concerns with its elementary science program.

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 students should be considered as the primary measure of the project's success. But since Science PALs was a multi-year project, it was further decided to explore the cumulative impact of the reformed science program on the relatively untainted student population of the early elementary school grades. Thus, this study focused on students' science learning over a three-year period using Grade 3 and Grade 4 students who were in Kindergarten and Grade 1 at the outset of this study. Students' attitudes toward science, awareness of science careers, and science achievement were explored as a function of the quality of the implementation of a Science PALs brand of instruction over three years. Quality of implementation was measured by the science coordinator's ratings of teachers using a four-dimension rubric. Science attitudes and science career awareness were measured with Likert-type items developed specifically for this study and science achievement was measured by a TIMSS-based instrument using released items for Grades 3 and 4.

Background

Science teaching, science learning, and science teacher education research has attracted increased attention and funding 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 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). Science literacy, like the other contemporary literacies, involves critical thinking, cognitive abilities and habits-of-mind to construct understanding in the specific disciplines, the big ideas or the unifying concepts of the disciplines and the communication skills to share these understandings and to persuade others to take informed action.

Unfortunately, little attention has been given to developing a concise, clear definition of constructivism and of the associated classroom practices (NRC, 1996, p. 52). The National Science Teachers Association (1997) encourages teachers to increase their awareness of the emerging standards for teaching, professional development, assessment, content, program, and the full education system. Clearly, proponents of 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 interactive-constructivist brand of science teaching promoted in the Science PALs project is a middle-of-the-road interpretation of constructivism (Shymansky, et al, 1997). Interactive-constructivist teaching recognizes a specific worldview of thinking, the epistemological and ontological nature of science, the locus of mental activity in the learner, the socio-cultural aspects of the classroom, the multiple purposes of language, and the realities of public education and schools (Yore & Shymansky, 1997). Interactive-constructivist science teaching assumes that contemporary science is based on a hybrid view of knowing that stresses the importance of interactions with the physical world and the sociocultural context in which interpretations of these experiences reflect the lived experiences and cultural beliefs of the knowers (Prawat & Floden, 1994).

An interactive-constructivist perspective also assumes an epistemological and ontological view of science that stresses evaluation of knowledge. This evaluation requires that explanations and interpretations are judged against the available data and canonical theories using evidence from Nature and scientific warrants to justify claims about reality (Hofer & Pintrich, 1997; Kuhn, 1993). The locus of mental activity and construction of understanding in interactive-constructivism involves both a private and public component, unlike social constructivism which defines understanding as a group consensus building or radical constructivism which defines understanding as a uniquely individual decision (Hennessey, 1994; Prawat & Floden, 1994). An interactive-constructivist perspective assumes that discourse reveals the variety of alternative interpretations but that consensus need not be reached. It is evidence from Nature that supports or rejects the interpretations, not consensus (Fosnot, 1996; Prawat & Floden, 1994). The locus of control for learning in an interactive-constructive model is shared by the learner and the teacher. The basic assumptions about the role of prior knowledge, the plausibility of alternative ideas, and the resiliency of these ideas are preserved in an interactive-constructivist perspective; but professional wisdom, the accountability of public education, and the priorities of elementary schools mediate decisions about what to teach and how to teach in the science classroom.

The Science PALs Project

The Science PALs project is an on-going local systemic reform effort that was originally funded by the National Science Foundation and the Howard Hughes Medical Institute between 1994 and 1998. During the funded period K-6 teachers and Grades 7-12 science teachers participated in summer workshops 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 to enhance their pedagogical-content knowledge.

The first year of the Science PALs Project began with 16 elementary school teachers designated as science advocates—one from each elementary school in the district. The science advocates began the project by attending a special, problem-centered summer workshop. That workshop was designed to help participants explore selected NSF-sponsored curriculum units and activities using students' ideas as "straw men". The workshop matched science content consultants with small groups of science advocates to explore science concepts in the units selected by grade level groups. Interactive-constructivist teaching strategies focusing on the use of students' ideas, literature, and parent partners were modeled and taught in the workshop.

The summer workshop with the follow-up inservice cycle was expanded in the next three project years involving approximately 40 teachers in the second year, 80 teachers in the third year, and 140 teachers in the fourth year. The inservice cycle focused on authentic problems of curriculum adaptation, using activities to challenge teachers' ideas, and social interactions and private reflections to get the teachers to rethink their ideas about both the science content of the units and how to teach the units. A similar instructional cycle was then used by the teachers to challenge their students' ideas and to promote conceptual growth and change in science.

Design

The research questions for this study were addressed using a comparative groups design that utilized attitude, awareness, and achievement data collected on all 1998 Grade 3 and Grade 4 students as dependent variables and cumulative ratings of their 1998, 1997, and 1996 teachers on their use of specific Science PALs strategies as the independent variable. The independent variable in the study effectively represented a measure of the "three-year implementation quality" of district teachers' use of student ideas, children's literature, and parent partners in teaching science. Scores from a specially constructed student attitudes and awareness survey and a modified TIMSS provided data on the dependent variables—attitudes toward school science, awareness of science careers, and science achievement.

Independent Variable

Implementation quality of the Science PALs brand of interactive-constructivist instruction was rated by the school district science coordinator. All K-6 teachers with a science teaching responsibility were rated on an 4-dimension rubric developed to assess the unique features of the Science PALs interactive-constructivist approach. The rubric required the coordinator to assess (1-very weak, 2-weak, 3-satisfactory, 4-strong, 5-very strong) the degree of compliance on dimensions stressed in the reform effort:

1. Use of strategies to access and utilize information on student ideas in planning instruction.
2. Use of strategies to challenge student ideas and to have them reflect on and integrate those ideas into their thinking.
3. Use of strategies that routinely and continuously incorporate children's literature and personal experiences as context for learning science.
4. Use of strategies that promote ongoing, substantive parent involvement in the science instruction.

The substantive validity, external validity, structural validity, and reliability of the rubric were established by a series of inquiries (Messick, 1989). First, the substantive validity was established by examining the degree to which dimensions in the rating scale matched both the theoretical and practical assumptions and goals of the project. This match was verified further with correlation studies on the rubric dimensions 1, 2, 3, and 4. Correlations between the individual pairs of items were between 0.68 and 0.95 for the 1997 ratings and between 0.78 and 0.95 for the 1998 ratings.

The external validity was explored by t-test analyses of 128 teachers' ratings over a complete Science PALs cycle. Comparisons of the 1996 and the 1997 clustered Science PALs dimension revealed statistically significant predicted improvement ($t=5.0$, p-value <0.001).

The structural validity was checked by a series of factor analyses. The one-factor solution was supportive (component loadings of 0.80 to 0.97) indicating that the 4 dimensions were acting as a unified factor.

Reliability was established by the correlation results and by a rate/re-rate analysis of a random sample of teachers. Measures of internal consistency for the 4-dimension cluster were 0.96 (1997 ratings) and 0.97 (1998 ratings). The science coordinator's rating consistency was explored by asking her to rate 235 teachers who teach science in the 16 elementary schools. One week later a random sample of 20 teachers were re-rated by the science coordinator on the ploy that their rating results were lost. The correlations of these paired ratings was 0.95.

Dependent Variables

An five-position Likert scale survey designed to assess students' strong agreement (4.0), agreement (3.0), absence of opinion (2.5), agreement (2.0), or strong disagreement (1.0) on statements describing students' affective stance toward school science and science careers was used to measure students' attitudes and awareness (Dunkhase, et al, 1997; Shymansky, et al, 1998; Yore, et al, 1998). Validity and reliability of this survey were explored using expert analysis, factor analyses, and internal consistency. The construct validity of the instrument was investigated by having experts examine the items selected from established item pools or constructed by science educators for the project. Factor analyses were conducted on the 1996 results from 722 Grade 3 and Grade 4 students taking the original pool of items. The final version of the instrument was then constructed using only items that had factor loadings of greater than 0.30. The items retained were analyzed again to insure the resulting factors matched the design features of the instrument. The 2 factors in the attitudes toward science scale were identified as attitudes toward school science and awareness of science careers. Internal consistency of the combined scale was 0.79, of the 5-item school science sub-scale, 0.74, and of the 3-item science careers sub-scale, 0.72. The same instrument administered to 456 students the next year revealed internal consistencies of 0.75, 0.74, and 0.69 for the overall survey and the two sub-scales.

Released items from the TIMSS Grades 3-4 were collected into 6 tests to assess science achievement (IEA, 1997). Each form of the science achievement test contained 29 items: 22 multiple-choice and 7 constructed-response (short-answer and extended-response). All forms of the test had 9 common multiple choice items and 3 common short-answer items. Various combinations of the forms had other common short-answer items.

The validity of the special TIMSS forms was assumed to be reasonable since the items were selected from those used in the international study. The internal consistency of the 6 forms ranged from 0.73-0.77 (average of 0.75). The 6 forms were randomly distributed across students in each classroom tested. Statistical analysis of the results on the common items across the 6 subgroups revealed no significant differences. Based on this evidence, it was assumed that the results across all forms of the test could be combined using standard scores (Z = 50 + 10z-score, SD = 10sd) to adjust results for the uncommon composition. The scores for the multiple-choice and open-end (short-answer and extended-response) sub-scales might be considered as measures of lower-level and higher-level knowledge.

Students were asked to identify their current year science teacher and their science teachers from the previous two years. Knowing a student's teachers for three consecutive years provided the opportunity to examine links between the cumulative quality of science instruction and student performance over three years. The district coordinator ratings of the teachers allowed linkage of the current year teacher to his/her students directly. The coordinator ratings of all three teachers were combined to yield a cumulative quality of Science PALs instruction (QOSPI) rating score for each student. The QOSPI allowed examination the cumulative effect of different qualities of science teaching across a three-year period on student performance. The three-year QOSPI scores could range from 12 to 60. QOSPI scores of 46-60 were categorized as "high" (HQOSPI), total ratings of 30-45 were categorized as "medium" (MQOSPI), and total ratings of 12-29 were categorized as "low" (LQOSPI).

Results

Table 1 contains summary descriptive statistics of student attitudes, awareness, and achievement grouped by quality of Science PALs instruction (QOSPI). Table 2 provides the summary ANOVA results of student attitudes, awareness, and achievement in science as a function of QOSPI across three years.

Table 1: Descriptive Statistics for Students' Attitudes, Awareness and Achievement Grouped by HQOSPI (High), MQOSPI (Middle), and LQOSPI (Low) Ratings

Teaching Experience	Attitude toward School Science	Science Careers Awareness	TIMSS Multiple Choice	TIMSS Constructed-Response
High	2.89(0.64)	2.55(0.87)	50.8(10.3)	49.2(10.18)
	N = 62	N = 62	N = 90	N = 52
Middle	2.98(0.65)	2.65(0.73)	51.0(9.69)	50.1(9.94)

	N = 477	N = 477	N = 487	N = 453
Low	3.09(0.64)	2.65(0.87)	50.4(9.46)	51.6(9.17)
	N = 35	N = 35	N = 105	N = 50

Table 2: One-way ANOVA Results for HQOSPI, MQOSPI, and LQOSPI Student Attitudes, Awareness and Achievement Scores

Main Effect	F ratio	Degrees of Freedom	P value
Attitude toward School Science	1.15	2,571	0.316
Science Careers Awareness	0.46	2,571	0.630
TIMSS Multiple Choice	0.19	2,681	0.826
TIMSS Open-ended	0.76	2,552	0.466

The analyses yielded no significant differences in student attitudes, awareness or achievement among students experiencing different qualities of instruction as defined by the teachers' use of student ideas, children's literature, and parent partners.

Discussion

Results from earlier studies suggest that the Science PALs reform effort was successful in several ways. Teachers seemed to embrace the key element of interactive-constructivist teaching—they paid more attention to student ideas in science—the district science coordinator noted this and so did the students. Teachers also began utilizing children's literature in their science classrooms—again, both the science coordinator and the students noticed this. Finally, parents responded extremely positively to their new roles as partners and students sensed this increased involvement (Shymansky, Yore & Anderson, 1999; Shymansky, Yore & Hand, 2000). These positive results of the earlier studies make the non-significant results of the current study seem almost anomalous. All the conditions seemed to be in place to yield positive student performance results—more positive student attitudes toward science, greater student awareness of and positive dispositions toward careers in science, and higher student science achievement scores. So why the non-significant student outcomes?

First, an examination of the student achievement results. One explanation for the non-significant results is that the elements critical to Science PALs (focus on student ideas, use of children's literature, and parent partners), though positively viewed by students, parents, the science coordinator and the teachers themselves, have little to do with how well students learn science. While there was good "cardiac" evidence that the Science PALs reform effort was effective (i.e., in their hearts, everyone in the district knew the program was good), student achievement data simply did not support that good feeling.

There are, however, at least two other explanations for the non-significant student achievement results. The variation of the TIMSS instrument used to assess achievement may not have been tuned sufficiently to the school district's science curriculum to serve as a valid measure of achievement. The TIMSS instrument was chosen for its visibility and the existence of national and international norms against which the school district could gauge its own students. It was also thought that the instrument did not favor students whose teachers were differentially effective at embracing and implementing the elements critical to Science PALs. It is interesting to note, however, that teachers in the school district did not have any input into the selection of items for the instrument constructed from the released TIMSS item pool. We are planning to involve a number of the district teachers in a retrospective "item-fitting" activity in which teachers will be asked to match TIMSS items on the test with the district's science units. To ensure that this item-fitting is done without bias, student scores on the TIMSS items will not be revealed.

Another explanation for the non-significant achievement results is that student achievement in this particular small, university-dominated district are positively influenced by forces and factors outside the formal school program. Home and community support for education and involvement in the schools are very high. As a result, students in this district traditionally score very well on standardized test. For example, students in this district routinely rank in the top three on the Iowa Tests of Basic Skills and Iowa Test of Educational Development. The district also traditionally produces about 20-25 national merit scholars each year—more than some states. This combination of supportive parents and an above-average student population could account for the smaller variance in the TIMSS scores, making differences more difficult to detect among the target groups in this study.

Yet a third explanation for the non-significant achievement results could be the quality of the district teaching staff and/or the strength of the science program that was in place before the Science PALs reform was launched. As mentioned in the introduction, the district did have in place a full contingent of hands-on units prior to any inservice instruction on interactive-constructivist or Science PALs strategies. It may well be that the district's elementary science program generally and the teachers' pedagogical content knowledge specifically were sufficiently developed to make any improvements in either of these areas small relative to the quality of the existing program (a homogenizing effect more than a ceiling effect since there still room for improvement in student scores on both the SPOCC and the TIMSS). Since the basic science units and supporting kit materials did not change substantially across the four years of the Science PALs reform effort and may have been already functioning better than teachers and leaders in the district realized, perhaps it should be no surprise that there was no difference in student achievement across the groups of teachers.

The lack of significant results in the student attitudes toward science scores is a little more puzzling given the fact that parents were enthusiastic about the Science PALs developments and that students saw teachers using their ideas more in class and saw their parents more involved in their science instruction. One would think that students receiving three years of science instruction from teachers rated the highest on the use of student ideas, children's literature, and parent partners would exhibit the most positive attitudes towards their school science. But the results of this study do not show this. Could it again be that we are dealing with such small differences between strategies promoted in the Science PALs effort and an already effective and positive district hands-on science program that the non-significant differences in student attitudes toward science might be expected? After all, the overall mean for student attitude toward school science across teacher ratings was just about 3.0 with 4.0 being unanimous strong agreement.

There is one more alternative explanation for the non-significant results in attitude, achievement, and career awareness that warrants recognition. It is the time and timing factor. This study focuses on the cumulative impact of instruction across the earliest three years of school in which science is seen as part of the formal curriculum (at least in the district studied). Perhaps the cumulative effect of any set of teaching strategies deemed critical to achievement, attitudes, career awareness, etc. does not begin to manifest itself in three years; maybe it simply takes more time-- four years, five years, or even more? Or perhaps it is a timing thing; younger school children may see any hands-on activity in a uniformly positive light, making the impact of strategies such as using student ideas and parent partners less remarkable with younger students. Perhaps these strategies would be far more powerful with middle school or even high school students?

Concluding Remarks

The idea of "systemic reform" has been promoted by numerous groups for a little more than ten years now. The summer and academic year "institute" models of the 1960s and 1970s were seen as too costly and ineffective. It is fairly safe to say that we will not see externally funded, one-shot inservice programs targeting single teachers for a long time, if ever again. But long-term "systemic reform projects" are no panacea either. State and urban systemic projects of the 1990s have produced very little evidence of enhanced teacher knowledge and skills or improved student performance. "Local systemic reforms" such as Science PALs likely hold the most promise for major, efficient reform of science education, if for no other reason that the process of the efforts can be monitored and adjusted relatively easilty and the fruits of the effort can be weighed with reasonable accuracy. With a curriculum framework in which to set goals, a clear procedure for assessing outcomes and a baseline against which to measure success, local systemic reform projects have the potential to produce major, cost-effective improvements in how science is taught in our schools.

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