What’s Happening in the Elementary Inquiry Science Classroom and Why? Examining Patterns of Practice and District Factors Affecting Science Reforms

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Paper presented at AERA, New Orleans
Session #39.62, April 4, 2002
Policy Levers for Urban Systemic Mathematics and Science Reform: Impact Studies from Four Sites

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This paper is based on data collected during a project supported by a grant from the National Science Foundation (REC:9805078). Any opinions, findings, conclusions or recommendations expressed herein are those of the authors and do not necessarily reflect the views of NSF or the Education Development Center’s Center for Science Education, the primary grant recipient.
Introduction

Millions of dollars have been invested in science education reforms to improve practice so that all students will be able to achieve scientific literacy goals. The rationale is clear and compelling:

The terms and conditions of human existence can be expected to change radically during the next human life span. Science, math, and technology will be at the center of that change – causing it, shaping it, responding to it. Therefore, they will be essential to the education of today’s children for tomorrow’s world (American Association for the Advancement of Science, 1993).

Taking stock of how well we are achieving our goal to educate students in science is crucial. It grows more so as high stakes testing in literacy and math drives the elementary curriculum away from science. It remains to be seen whether there will be similar testing in science in future, and if so, what the nature of those tests will be and their effect on the science curriculum. This paper is a very modest attempt to take stock. It examines the current state of practice in selected elementary science classrooms in three districts long committed to science reforms. It identifies specific areas of challenge for teachers, describes existing support for their professional growth, and identifies additional district factors that help explain what’s happening in these inquiry science classrooms and why.

What is an “inquiry” approach to science education and why should we care about it? Inquiry science involves a process of exploring the natural or material world that leads to asking questions and making discoveries in the search for new understanding. Students come to understand the nature of scientific problem solving as the pursuit of meaningful questions through the use of procedures that are thoughtfully generated and evaluated (Magnusson & Palincsar, 1995). Contemporary learning theories support this approach to science education and argue that the development of deep understanding requires that students be actively engaged in and have some direction over this inquiry process (Palincsar, 1998). Reformers believe that an inquiry approach to learning science helps students build rigorous ways of understanding the world around them and of gaining and organizing information to test their ideas (AAAS, 1989; AAAS, 1993; Harlen, 1985; NRC, 1996.) It prepares them to deal more effectively with wider decision making and problem solving in their lives. It’s enabling – students realize they can find things out for themselves – and it’s also enjoyable and exciting -- they are more likely to see the value of lifelong learning.

But why elementary science? Reformers point out that learning science in elementary grades is important because the longer unscientific ideas are held, the harder they are to change. It’s clear that many adults persist in unscientific thinking and that such views affect everything from popular culture to important political and societal issues. Attitudes toward science are formed early. Students will be more inclined to appreciate the value of scientific thinking and reasoning if given a chance to develop it themselves early on.

The central importance of scientific thinking and attitudes to development of scientific literacy means that the teacher plays a critical role. It is not so much choice of science content but how it is taught that allows these reasoning skills and habits of mind to develop. So how a teacher teaches the science curriculum is crucial. Furthermore, research suggests that quality of teaching is the single most important school factor in determining student success (Tharp & Gallimore, 1988).
We agree with Spillane and Zeuli (1999) that it is essential to develop some systematic understanding of patterns of practice in classrooms where teachers are trying to enact reform. This paper includes an analysis of teaching practice as an essential component of policy implementation research. How we look at practice can have a powerful impact on what inferences we make. Indicators of practice can direct attention towards certain facets of education and away from others (Porter, 1988). We believe it is useful to identify the challenges that science reforms pose for practitioners in order to improve teacher preparation and professional development. This research also explores other factors affecting success that have implications for educational administrators and boards of education, state and national policymakers, and funding agencies.

Our research questions included:

- How much elementary science is being taught in districts with well-established hands-on inquiry science curriculum?
- What factors influence classroom practice?
- What support is provided for science instruction?
- What patterns of practice exist?
- What reform practices are most challenging for teachers?

**Method**

This study utilizes data from three school districts that were part of a larger study of the sustainability of elementary science reforms (Century & Levy, 2002). In this paper we use quantitative and qualitative data from multiple sources collected during numerous visits to the districts over three years. The data came primarily from observations of K-6 classrooms and professional development sessions, with additional data from a teacher survey and interviews of teachers and other educators.

**Districts**

The districts were selected for having well established, elementary hands-on inquiry science programs. The programs varied in age from about 15 to 30 years. Thus all three districts’ science programs were established prior to the national science standards, but their program goals are well aligned with these standards and the goals of other key science reform documents (AAAS 1989, 1993; NRC, 1996). The hands-on inquiry science programs in these districts all utilize a core curriculum consisting of a mix of commercial and locally developed science kits. Typically, four units (science kits) are taught per grade. Over the elementary grades, students encounter units on physics, biology, earth science, chemistry, and science methodology (e.g. measurement and variables). None of the districts had incorporated science textbooks in the elementary science curriculum at the time of the study although many of the commercial kits include brief booklets and/or worksheets.

The three districts vary considerably in the amount of external funding they have had. One has had virtually continuous grants from the National Science Foundation (NSF) since the inception of the inquiry science program; one has had NSF funding for about 5 years; and one has had no NSF funds. In the first two districts, much of this external funding was used for teacher professional development activities. Each district expects
teachers to be trained on a kit before teaching it, but in reality, teachers sometimes teach kits without prior training.

The districts in this analysis vary somewhat in size and demographics, with two of them in suburban areas and one in an urban area. Two of them have over 50,000 students; the other district is smaller, just under 20,000. The proportion of their students who qualify for free or reduced price lunches ranges from approximately two-fifths to two-thirds, and the percentage of students who are minority ranges from about 30% to 90%.

Each district is in a different state, but each state has a statewide testing program that heavily emphasizes literacy and math and did not test elementary science at the time of the study.

**Teachers surveyed**

In each district, approximately 100 elementary teachers were randomly selected and sent a written survey about their background, teaching practices, professional development experiences, work context, and other influences on instruction. Response rates varied across districts from 55% to 81%, and the overall response rate was 68%.

**Teachers and Classes Observed**

This paper analyzes data from 40 classroom observations in kindergarten through sixth grade across three districts, with a nearly equal number of classes observed in each district. Teachers and their classes were selected for observation by the district science coordinators and/or their principals to represent good science teaching within a sample of schools representing the range of student SES levels and geographic areas in each district.

We observed one science lesson in each classroom, which typically lasted about an hour, although the range was 30 to 90 minutes, and one was cut short by a fire drill. Science is usually taught twice a week, but the schedule varies so we had to schedule our observations with the teachers. Since they knew when we were coming, we assume they tried to show us what they considered to be at least average or good classroom practice. An indicator that a number of these teachers were considered by science coordinators to be quite good at teaching science was the fact that they were involved in conducting some of the districts’ professional development sessions in science for their colleagues. Narrative field notes, supplemented by audio tapes, were used to provide a descriptive summary and time log of activities in each classroom.

The conceptual scheme we used to examine classroom practice reflects recent science reforms as well as general principles of sound practice (cf. Aschbacher, 1999; Clare & Aschbacher, 2001; Harlen, 1985; Newmann, Lopez & Bryk, 1998; NRC, 1996). One of our goals is to improve practice by focusing attention on critical dimensions of good teaching potentially under the control of teachers, program coordinators, principals, and professional development staff. We were interested in practices that seemed to support learning to view and investigate the world scientifically at a level that is developmentally appropriate for elementary students, such as appreciating careful observation and expression, reasoning logically and appreciating fair comparisons, distinguishing observations from speculations, and supporting claims with evidence. We looked at the classroom discourse patterns, particularly the cognitive interaction between students and teachers throughout the lesson and among students during small group learning activities. The curricula specify hands-on investigations, so we were interested in how the teachers used them and what opportunities they provided for students to learn desired outcomes.
Based on earlier classroom observations, we developed a rubric for rating several dimensions of the learning environment. Raters applied the rubric at the time of the observations, and researchers later reviewed the notes and ratings to arrive at a final analysis of the classes. The rubric addresses specific instructional strategies that might be expected to facilitate learning, including: general classroom management and focus; linking new learning in science to students’ prior knowledge; linking science to other subjects in and beyond school; helping students to see how their investigative activities approximate those of real scientists; asking conceptual and scientific process questions that facilitate deep thinking and require more than rote learning; expecting students to support their scientific claims with evidence obtained during their inquiries; having students represent their data and ideas in writing and/or drawing as well as orally; and allowing students’ own interests to drive some of the inquiry activities.

Interviews and Focus Groups

We conducted separate focus groups with experienced, inexperienced and resource teachers in each of the districts. We also interviewed observed teachers about their lesson and typical practice, their interpretation of “inquiry science,” professional development history, and factors that affect the success of the science program. We also interviewed the science coordinators and numerous other administrators in each district about the history and nature of the program, professional development and other support for instruction, teacher recruitment and turnover, and other factors affecting the science program. Most interviews were audio taped.

Observations of Professional Development

We attended several different types of professional development sessions for elementary science teachers in each district. District offerings varied quite a lot and addressed different subgroups of teachers: experienced, novice, trainers of other teachers, and teachers who were the science teacher-leaders at their schools. The types of training we observed included:

- one-day workshops on basic kit training;
- an after school meeting of a school-based study group on science instruction;
- a one-day workshop on the use of writing in science;
- a two-day institute on inquiry instruction and science content knowledge;
- a one-week institute for selected “teacher-leaders” on inquiry methods not tied to a particular kit;
- a two-week institute on inquiry instruction with basic training on one kit;
- a one-week scoring institute in which teachers received training and then scored student work on science tests; and
- a workshop for local scientist volunteers to help them learn how to support and work with teachers during training and in the classroom.

Results

How much elementary science is being taught?

Most of the teachers who responded to our survey said they teach science at least an hour a week. See Figure 1. Only 10-20% said they teach less than half an hour a week. The number teaching more than two hours is greatest (36%) in the district (A) with lowest teacher turnover and moderate professional development, and it is lowest (17%) in the district (C) with the least professional development and instructional support. We do not know the extent to which teachers who chose not to return the survey are teaching
science. The clerks in the district materials centers who refurbish the kits after use said that typically a fifth to a third of the kits are sent back unused, and that some kits are better used than others.

Teachers are expected to teach 3-5 kits per year in these districts depending on grade and district. In two of the three districts, teachers said they typically teach one less kit per year than they are expected to. In the third district, they claimed they are teaching what is expected. The vast majority of teachers surveyed (about 80%) said they use the district curriculum kits when they teach science, and about 20% of them supplement kits with science-related literature or non-fiction. They tend to pick and choose parts of the kits to teach. Only 16-25% of teachers said they teach the full kit, start to finish. Most teachers said they spend 8 to 12 weeks on a science unit, but this may vary a great deal, depending in part on how comfortable they are with the kit concepts and investigations and on whether they link science to math, language arts and/or social studies.

![Figure 1. Percent of Teachers Teaching Science](image)

What factors influence classroom practice?

All three districts in our study spent a fair amount of time in the last several years clarifying their district standards for teachers. Not surprisingly, the teachers we surveyed said that those standards and the district science curriculum were the two factors they most frequently considered when planning their science instruction. Other important influences on instruction were the districts’ focus on literacy and expectations of school and district administrators. The districts varied considerably in the extent to which teachers saw the superintendent’s priorities and principals’ lack of support for science as problems affecting their science teaching. In one district, teachers felt these were serious concerns; in one they were moderately problematic; and in the third they were much less an issue because there has been far less turnover of administrators and a more consistent vision.
The extent to which science is a priority is reflected in the lack of accountability for teaching science in these districts despite their long history of hands-on science programs. Teachers said that principals almost never observed their science teaching (88% said “never”). And although data on kit use (and non-use) obtained by kit refurbishers is provided to principals, there are no requirements that principals act on this data, and principals and teachers we interviewed said the information was very seldom if ever used to counsel teachers. Despite the kit use data, coordinators and resource teachers say they are too busy running the program to monitor who is implementing the curriculum, to what extent, and with what level of quality. Perhaps more importantly, there were no consequences for teachers who are not teaching science or doing it poorly, even if coordinators or administrators had this information. A few teachers told us that some principals are reacting to high stakes literacy testing by requiring such a strong focus on language arts that science is being largely ignored in those schools.

Teachers in all three districts said their teaching of science was negatively affected by the lack of three things: adequate time for preparation, teacher training, and opportunities to share ideas with colleagues. Teachers often stressed the value of “talking shop” or gaining “hands-on management tips” from their peers and would like to do more of it. But interestingly, they did not mention wanting to learn more science content knowledge. Teachers complained that they often did not know what training was available, and coordinators and resource teachers admitted they sometimes had difficulties getting the word out to everyone.

**What support is provided for science instruction?**

In the most stable district, two thirds of the teachers have had some kit training, but in the other two districts with higher teacher turnover, less than half have had it. Substantial numbers of teachers (varying across districts from 50% to 80%) say they have not yet been trained on all of the 3 to 5 kits they are expected to teach at their grade level. From 20 to 40% of the teachers who responded to our survey, depending on district, said they have not been trained on any kits yet. A fourth to a third of teachers said they had gone beyond basic kit training with workshops on science content knowledge, inquiry instruction, and/or integration of language arts with science.

Training teachers on the 3 to 5 kits they are to use is a significant challenge for a number of reasons. Among these are: increasing teacher turnover as baby boomer teachers reach retirement age, even more new teachers in recent years due to lowering of class size, normal changing of grade taught, and increases in district enrollment in two districts. Underscoring these concerns are the actual numbers. About 45% of the teachers surveyed have taught their current grade for less than 3 years, and 38% of them have been in the district for only five years or less. District administrators estimated the teacher turnover rates for their districts varied from about 10% to 30%. Two of the coordinators said they are tired of training teachers only to lose them to neighboring districts within a couple of years due to higher pay, lower living costs, and/or student populations “who are easier to teach.” With so many teachers to train, the districts find it difficult to keep up with the need for basic training, let alone provide or require more advanced training throughout the district.

The challenge of teacher training in science is not just in addressing the numbers of teachers who need it but also in how to change their practice effectively. Elementary teachers typically feel less comfortable teaching science than other subjects. Teachers in professional development sessions often express relief when told that “it’s ok to tell children that teachers don’t have all the answers.” Effective training must help them
overcome their misconceptions and teach them the basic concepts they are to teach (e.g. gravity, density, and photosynthesis) that many have never learned in any depth. In addition, teachers need to learn to teach in a way (inquiry) that many have never experienced themselves when they were students and that puts more pressure on the teacher to be able to handle students’ questions. Furthermore, good science teaching asks that teachers focus on different learning goals (experimental methods and scientific reasoning) than that given priority on high stakes tests (spelling, grammar, reading comprehension, arithmetic problems, and memorized facts).

The amount of professional development available varies widely across the three districts and was directly related to the amount of external funding for science education. In one, a massive effort to focus on literacy has reduced resources for science in the last few years, and there has been no large external funding for the science program. Thus, in the two years prior to the survey, teachers there said they had had an average of 39 hours of professional development in language arts, 21 in math, but only 6 in science. By contrast, in another district, also emphasizing literacy but with considerable funding from NSF over most of the life of the program, teachers had had 27 hours in language arts, 15 in math, and 21 in science over 2 years. In the third district, which had had some NSF money for about five years, teachers had had 21 hours in math, 16 in language arts, and 12 in science. Thus, average training in science teaching varied from 6 to 21 hours over 2 years, and this represented from 9% to 33% of the training taken across these three subject areas.

The amount of external funding also had a major impact on how many science resource teachers were available. In the three districts in order of funding there were 6, 3, and 0 resource teachers at the time of our data collection. The presence of funding and resource teachers allowed two of the districts to provide an array of professional development opportunities not possible in the third. In the district with the most funding and staff, the district science team seemed particularly knowledgeable about inquiry science education. They also had opportunities for professional growth that resource teachers in other districts seldom had (e.g. participating in regional or national conferences, helping to develop performance assessments, working with district partners from local universities and museums).

Despite differences in resources for the science programs in these districts, just over half of the teachers in each district said they almost never received help for their science teaching from resource teachers or colleagues at their schools. As noted, one district has no resource teachers due to lack of resources. But even in the other two, teachers said they did not get much support despite there being three or more resource teachers at the time of the survey, a science liaison teacher at each school, and the existence of other teachers with special training in science. Resource teachers told us that they simply did not have enough time to help everyone in the district. The largest district did in fact have a plan to focus most of its attention on about a third of the schools in the district before scaling up some aspects of the program (such as teacher study groups) to the rest of the schools. However, now much of its elementary resources have been shifted to secondary, leaving the other schools’ faculties less well prepared.

Even though there are many teachers who need training, most of the professional development sessions we observed were not fully attended. For example, in the district with the assessment scoring institute, the coordinator encouraged each school to send someone to attend, but in fact, there were only a dozen elementary teachers there and they were from only two or three schools. However, many principals now tell teachers to focus almost totally on literacy; the teachers are typically not very comfortable teaching science; and training is typically held on Saturdays or during summer vacation. It is not
surprising, therefore, that many teachers do not want to give up free or family time for science training even if they get a small stipend or salary point credit.

In a couple of districts some local scientists were involved in the professional development efforts, several teachers praised their usefulness in deepening teachers’ science content knowledge. Interestingly, the program leaders involved the scientists more for their expertise in scientific methods and reasoning than their content knowledge, but it is the latter that teachers more readily acknowledged they lacked.

The quality of professional development we observed also varied widely. The widest array of training opportunities and the deepest professional development on inquiry methods was in the district with the most external funding and the strongest partnerships with local universities and museums. The science staff collected data on teacher implementation and student performance after the first two years of district-wide professional development. It revealed that there had been significant improvement in the amount of time science was being taught and in students’ interest in science. However, students had not learned how to analyze and make inferences about data from science investigations. The science staff observed teachers in the classroom and noted that they did not know how to use questioning strategies effectively to promote student thinking and investigation skills. Teachers used cooperative learning techniques more to manage materials than to facilitate content learning. Since then district science staff have been working to provide continuing and deep professional development on best practices, and the professional development sessions we observed there were quite good. However, our classroom observations suggest that they still have much to work on. Unfortunately, they no longer have sufficient external resources to maintain this effort to improve and maintain strong elementary practice throughout the district. Grants are typically for developing new programs, not sustaining existing ones. Hence, the latest grant focuses more on secondary than elementary science. As a consequence, the number of elementary resource teachers was cut back as were the stipends for teachers to participate in the well-liked teacher study groups, the extended training on inquiry methods, the money to pay parents to coordinate the reordering of consumable science materials, and so forth. They have recently made efforts to shift the locus for maintaining quality practice from the district to the schools, but schools, like district offices, lack the incentives, time, money, and expertise to achieve this illusive goal.

This same district was the only one in our sample to provide regular training for principals on science education. They realized that principals can greatly influence what is taught, so they provided practical training for all principals to help them see how science can support literacy, and they gave examples of school objectives that they could incorporate in their required site plans. Principals we interviewed said that this training helped them understand why good science instruction is important, what they could do to support teachers, and what they should expect teachers to do in their science lessons. It is unclear whether reduced funding for elementary science will undermine this good effort as well.

In one of the districts, there has been somewhat less incentive to deepen the professional development offered to teachers or to worry about moving beyond mechanical use of the kits since their students typically do well on standardized tests. A strong, stable team of excellent resource teachers in the program’s early days helped build it from a small effort to a strongly supported, district-wide program. Currently, most teachers are teaching most of the curriculum there; students seem to like science, and they do well on tests. With an influx of new teachers, their attention is focused on giving these teachers basic training to maintain the status quo. There were no threats to scuttle the hands-on program; thus,
administrators’ attentions were directed to other concerns, and science was not receiving serious scrutiny.

In the third district, declining resources, an aging infrastructure in serious need of repair, changing student demographics, and a strong concern with literacy have left the science program to operate on a shoestring with no resource teachers to help run the program. The district science staff has been devoted and inventive. Despite few resources, they managed to offer a strong professional development session on writing in science. Still, they struggle to meet the needs of their teachers.

All three programs now face uncertainties due to recent changes of superintendents, other key administrators, and/or program coordinators in addition to reduced resources for elementary science. Fewer resources available for science typically means less training and oversight, and thus less quantity and quality in the teaching of science. In particular, the loss of key administrative leadership and support is a serious concern for these programs.

**What patterns of practice exist?**

Although we were only able to observe each classroom once and therefore cannot reliably characterize individual teachers, grades or districts, the collected observations provide a window on implementation of reforms in districts that have been strongly committed to hands-on inquiry science programs for quite a few years. As Spillane and Zeuli noted (1999, p.2), “…looking carefully within practice seems critical to understanding the progress of recent reforms.” We were not the only ones interested in what is happening in the science classroom. District administrators, science coordinators, principals, resource teachers, and classroom teachers in these districts told us that they do not have much solid information about how science is being taught behind the classroom doors. Below is a brief overview followed by more detail about the patterns of practice we observed.

In general, the vast majority of the science lessons observed for this study were taught with knowledgeable mechanical use of science kits. Across all observed elementary classrooms, the science instruction followed a fairly typical sequence. Most science lessons consisted of approximately 20 minutes of initial direction from the teacher with a few questions posed to students in a whole-class setting, such as asking them to predict what would likely happen in the day’s activity. This introduction was followed by about 20–30 minutes in pairs or small groups doing prescribed hands-on activities, such as observing objects or phenomena and recording observations in a notebook or other data record sheet. By the end of the lesson, many teachers “ran out of time” and simply closed with directions to clean up. Some included a very brief and superficial opportunity for students to recite their activities or findings but with little or no discussion of patterns in students’ observations or links between observations and claims that might help students develop ideas, concepts or generalizations.

While there was some disruptive student behavior in almost every class, it was usually quite minor (e.g. students talking out of turn or not following directions during small group work), and most teachers had reasonable control of their classes. Most teachers assigned roles to students for small group work. Many of the teachers used well-developed strategies for controlling students’ behavior and sharing responsibilities and opportunities to learn. For example, one created four roles for students to play in their small groups, and students each wore a colored-coded rubber band on their wrists to remind them of which role they were assigned that day in science. It was clear from students’ behavior that they understood and accepted their role assignments.
In general, students tended to really enjoy the science lessons. They were eager to interact with interesting materials or animals, and most tended to work conscientiously to complete their worksheets or records of observations. Students were more likely to be bored when the lessons were very mechanical and did not allow for student interaction about the results of their investigations. There was considerable variation in the extent to which students participated in discussions. In many classes, only a few students ever volunteered information or were called on. A few teachers, however, were particularly adept at engaging students with unusual investigations, humor, and their own sincere interest in students’ results and thinking. Teachers noticed students’ interest in science and tried to use it to their advantage. Teachers often mentioned that science is a good subject to teach in the afternoon, normally a difficult time to engage students, because students enjoy it so much. Several teachers even said they use it as a disciplinary tool – if students misbehave, they threaten to take science away.

We examined our data for instructional differences related to the proportion of minority students in the classes but found only one small difference. We compared ratings of instruction and number of minutes spent on various learning activities for classes comprised of less than 50% minority students and for classes comprised of 50 to 100% minority students. There was no difference in quality of instruction or time spent on learning activities with one exception. Classes with fewer minority students had slightly more or better writing tasks than classes with more minority students (2.0 compared to 1.6 on a scale of 1.0 to 3.0, with 3 being high).

During systematic examination of instruction in the 40 classes we observed, we identified three general patterns of practice, which correlate somewhat with those found by Spillane and Zeuli in math reform classrooms (1999). (See Figure 2.) Although teachers had been selected to represent good practice in these reform districts, less than one-fifth of them came close to meeting expectations of science reforms and general good practice as interpreted through our rubric. Our focus was on identifying strengths and weaknesses in dimensions of practice that could inform teacher professional development efforts as well as district policy and program funding policies of external agencies such as NSF. The patterns are briefly summarized in Table 1, and each pattern is described below.

![Figure 2. Percent of Classes in Three Patterns](image-url)
Table 1. Summary of Patterns of Practice in Elementary Science Classrooms

<table>
<thead>
<tr>
<th></th>
<th>Recipe Science</th>
<th>Principled Science</th>
<th>Minimal Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus and class</td>
<td>Focus on steps to do activity. Students work cooperatively in groups.</td>
<td>Lesson has clear focus &amp; directions; Students work cooperatively in groups</td>
<td>Confusing directions, unclear focus. Ss may be poorly controlled.</td>
</tr>
<tr>
<td>management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific</td>
<td>Ss tell what they did or observed, but superficial discussions. Ss may be</td>
<td>Most of classes were like recipe science but with a bit more focus on</td>
<td>Little or no opportunity for Ss to tell about or discuss or make meaning of</td>
</tr>
<tr>
<td>thinking</td>
<td>asked to make predictions, but seldom w/ rationale. Focus may be more on</td>
<td>understanding and linking data to claims. T encourages Ss to discuss their findings</td>
<td></td>
</tr>
<tr>
<td></td>
<td>vocabulary/terms &amp;/or recipe activities. Ss are busy, but only partial or</td>
<td>w/ others. Ss are more intellectually engaged throughout lesson.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sporadic intellectual involvement in activities.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing tasks</td>
<td>Ss nearly always record observations. May sometimes answer questions but not</td>
<td>Ss record observations and answer questions; some are to explain reasoning about</td>
<td>Ss sometimes record observations. And may answer superficial questions.</td>
</tr>
<tr>
<td></td>
<td>usually much focus on reasoning or explicitly linking data to claims.</td>
<td>phenomena or describe claims with supporting evidence.</td>
<td></td>
</tr>
<tr>
<td>Methodology and</td>
<td>Occasional or very superficial attention drawn to inquiry process, e.g. “now</td>
<td>T frequently draws Ss’ attention to inquiry process; relates student activity to</td>
<td>Occasional or very superficial attention drawn to inquiry process</td>
</tr>
<tr>
<td>metacognition</td>
<td>we’ll write in our science notebooks like scientists do”--no explanation</td>
<td>what scientists do and how they think.</td>
<td></td>
</tr>
<tr>
<td>S-driven</td>
<td>Ss may be asked for own ideas but don’t get to investigate them. Must follow</td>
<td>Similar to Recipe Science but in a few classes Ss generate own questions and</td>
<td>Prescribed steps only; no opportunity to generate own questions -- or totally</td>
</tr>
<tr>
<td>inquiry</td>
<td>prescribed steps.</td>
<td>investigate</td>
<td>on own to play; no science</td>
</tr>
<tr>
<td>Links to other</td>
<td>Superficial or none</td>
<td>Mix of no links to meaningful links to language arts or math</td>
<td>Superficial or none</td>
</tr>
<tr>
<td>subjects</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pattern 1: Recipe Science

The majority of classrooms in this study, 25 out of 40 (62%), comprised a pattern that could be called “recipe science.” They received total ratings in the range of 9 to 12 on a scale that ranged from 6 to 21. “Scientific inquiry” in these classes resembled carefully following the steps in a recipe more than conducting true investigations of natural phenomena. Teachers tended to follow the scripted curriculum activities fairly closely with minimal group discussion and virtually no student-driven inquiry. Most of these classes were managed moderately well. Teachers tried to elicit students’ prior knowledge but typically in a fairly superficial way with little apparent skill in drawing out what students already believed or understood about the topic. Instead they often simply reminded students that they had heard of the topic before. They asked students a few questions about the activities; however, the questions typically called for simple recall, such as vocabulary words or what steps the teacher had told the students to follow. Much

1 Six was the lowest rating since in a couple of the classes one of the sub scales was not rated.
of the time was devoted to teachers giving directions for the steps in the investigation they were about to do, and then students following the steps of the investigation prescribed by the curriculum. Students often recorded observations in writing or drawings, but they were seldom asked to explain anything about their observations or to support their claims with evidence from their investigation. The lesson often ended with a few rushed minutes of clean up. Sometimes students were asked to recite what steps they had taken or what they had observed but seldom to reason, for example, about patterns in their observations.

*A vignette from a “recipe science” classroom*

The third grade class is about half minority students. Their desks are arranged so that they work in groups of four. On the walls are credos for good behavior and grammar charts, stories written by students, drawings of bees and plants, and commercial charts of the parts of a plant and parts of a bee. There are light boxes and plants on a table in the corner. Today they are working on the “Fast Plants” unit.

As the students return from physical education, the female teacher asks them to sit down and immediately moves to the overhead projector.

T: Today we’re going to talk about our plants. We’re going to take a look at them and record changes in our growth chart. Let’s pass out the magnifying glasses. (She draws on the overhead the two things they are to do: (1) measure and record Day 19 growth, (2) observe and draw your plant.)

T: Take out your growth charts. I need to remind you to measure and record the size of your plants. Last time we did that it was the 13th. We have to determine what day it is today. (She counts the days on a calendar.) Today is Day 19. Measure your plant by putting the bottom of the stick at the base of the plant.

Students are looking at plants, using measuring sticks.

T: Write how tall your plant is on your growth chart. How tall it is, then how many buds. What else will you be counting, Tyler?

S1: How many leaves?

T: What else? What’s the most exciting part of your plant right now?

S2: How many flowers?

T: Those two tasks need to be recorded right now. I will walk around and see how you are measuring and recording.

Children help each other put in sticks on which plants grow.

S3: It’s 20 centimeters tall!

T: How can you show that on the chart? (the chart does not have enough units to represent this) Can you extend the chart? (To another student…) Does yours also extend above the chart? How might you show that?

Student extends blocks on chart.
T: Good. I like the creative way you decided to show this on your chart.

... 

T: Zero voices! You’ve had a chance to measure and record. You are observing and writing now. Don’t forget to start with today’s date. Make your drawing and then tell about your plant. Tyler, you’re ready to move on to the next step. Okay, sit. Have you finished recording all the things we listed on the board? Sit and write about the plant. I should see you taking information about your plant. We need to label plants. This is a “scientific journal.” It needs to be labeled and be written in full sentences.

... 

T: What’s happening in between those two seed leaves? Now what did we call these long more jagged leaves?

S4: True leaves.

T: Now what’s happening at this stage? Buds.

S4: Yeah.

A parent volunteer cruises the room to help students with their journal.

PV: “How many buds do you have?” (Aid and student count together.)

T: Okay, now we need to stop.

Recess. When they return, the teacher resumes.

T: Right now our plants need help from our friend the bee. Excellent listening posture! What changes do you see in your plants? Does it look the same?

S1: It has more leaves and buds.

S2: It grew bigger.

T: Thumbs up if your plant grew.

(Many thumbs up)

T: Your plant is in a new stage of the plant life cycle. Let’s see a picture of the life cycle. (shows stages of the plant on the overhead – first stage: seed beginning to germinate). What is this stage called? The Umbrella stage?

S3: No. It looks like a seedling. Just poking through the soil.

T: What are the two leaves fully opened out?

S4: Seed leaves.

T: Remember we studied seedlings? (resumes describing stages).

T: Our plant is now over here. It needs the bee. Why? (blank stares from students) It goes from one plant to another and takes pollen from one plant to another. Why does the bee go to the flower? Now I’m seeing lots of thinking.
S5: Because he wants the honey?
T: Do flowers make honey or do bees make honey? What does the bee have to do with that?
S3: He wants pollen and nectar.

Teacher writes on the board: “pollen/nectar.” Later she writes “cross-pollination.”

T: What makes the bee realize that there is some stuff going on in the plant? What would make the bee stop at the plant?
S1: It’s healthy?
T: How does the bee know? What calls out to the bee?
S1: The colorful flowers?
T: What else? What do we do when we see a flower? (no response) The smell calls out to the bee. Do you see these hairy legs? What do they pick up when they get the nectar? The hairy body picks up the pollen. In your flowers, what color is the pollen?

Class: Yellow!
The teacher continues to tell the children how to use the sticks with dead bees glued to the ends (provided by the kits) to pretend to pollinate their plants. The children do this.

T: It’s time to finish up. I saw some good science, some good cross-pollination. Very important. Take a look with your hand lenses at your bee. Do you see the bits of pollen on the hairy parts stuck to the bee? Now put your bee sticks into the cups, put your activity sheets where they belong, and clean up.

The class began with directions that students were to follow rather than interesting questions they posed about their plants. It ends without any real opportunity for students to articulate their own ideas. They are not prompted to observe closely enough that they can answer the questions the teacher poses later (e.g. what features of the flowers attract bees) so the answers more likely depend on recall of facts rather than reasoning with their evidence. Students are not expected to look at their own data over time or to compare across the class to determine patterns. While the class was reasonably well managed, students said very little during the lesson and did not look very engaged. The teacher did most of the talking and asked primarily recall questions, although some of her questions were attempts to get students to engage with the ideas of the lesson. They seemed relieved when they could finally give the teacher one of the correct answers she seemed to be searching for: “What color is the pollen?” “Yellow!” This lesson gives students the chance to see flowers and bees up close, but they did not get to use this opportunity to pursue their own questions. They have did not learn much about being scientists (except the slightly wacky implications that scientists write in their notebooks in complete sentences or that they cross-pollinate well.)

Pattern 2: Principled Science

The pattern in classroom lessons that most closely matches the expectations of science education reformers and illustrates generally good instruction might be termed “principled science.” This pattern was evidenced in 7 out of 40 rooms (18%), and they
received total rating scores of 14-17. While the teaching was strong, it was not as exemplary as one might hope.

The classes in this pattern were moderately to very well managed and focused. In addition, they were rated moderate to high on elicitation of students’ prior knowledge, helping students see that they were utilizing strategies that real scientists use, and expecting students to reason about their inquiry activities. In general, these classes represented science work as more than merely procedural, not just a series of steps. The discourse norms in these classrooms supported attention to principled science knowledge. The focus was on articulating the thinking process or logic, and students were asked to defend their predictions, explanations, or claims. In two classes, we observed deeper conceptual questions and a strong lesson wrap up that called for scientific reasoning. For example, one teacher concluded the lesson by asking students to recount what they had observed, to explain why it had happened, and to make claims tied to their evidence. She also clarified distinctions about definitions and provided additional conceptual information tied to students’ observations.

Despite their strengths, these classes had their limitations. Many of the writing assignments were limited to recording observations and did not call on students to support their claims or interpret their findings as much as might be desired. Most of the thinking was called for during oral discussions, where not all students have to participate. Most of the probing and questioning of students for evidence to support claims or opinions came from the teachers. Students had not yet learned to take on this role towards each other. Only two classes had activities that allowed students to pursue their own inquiries.

A vignette from a “principled science” classroom

A third year, white female teacher has a first grade class of 19 students the day we observe (usually it is 20), mostly Asian children, all fluent in English. One Latino and one Russian child, also fluent in English, are in the class. We observed a one-hour lesson, immediately after lunch. Half the time, students worked as a whole class, either discussing their findings or listening to directions. The other half of the time, the students worked in pairs to classify and describe their rocks. All students appeared to be engaged throughout the activities.

The class is studying a geology unit called Rocks, Sand, and Soil. Last week, in the previous science lesson, the class had used hand lenses and sieves to compare grain size, shape, and overall texture of three types of sand. They drew pictures of each type and constructed a class chart of the characteristics of each sand type.

The room is pleasantly cluttered, with the charted sand observations (in the teacher’s handwriting) dominating one bulletin board. Sample entry: “Brian’s sand – black, soft, some gray, softer than Jordan’s. Drops fast when there is a hole in your hand.” A new chart is already prepared, to display the data from today’s lesson, comparing the characteristics of salt and sand (size, shape, color, sound, etc.). There are also student paintings of the night sky, computer generated illustrations of student poems about wishes. In the corner is a reading area with a sofa, pillows, stuffed bears, and six shelves of books (two half-high bookshelves). Five computers, two of which are new, fill one corner. They look well-used (fingerprints, stacks of paper next to the printers).

This teacher has a good rapport with the students, although these first graders are rambunctious after lunch. They become engaged quickly in the instruction as she begins the whole-class discussion about last week’s two-hour lesson. Usually science is “at least
one hour a week” even when she is between kits. Last week’s lesson, however, “… went into overflow. Last week [the students] were so into comparing the three types of sand it went two hours. And sometimes it takes an extra hour or so when we come back from recess and talk about it.”

The main activity today is to compare the appearance of salt and sand, to describe the similarities and differences in as many ways as possible. The teacher distributes film canisters of salt and sand to each student, and they are to work in pairs. (The classroom is already set up in pairs.) For about 15 minutes, the students observe the sand and salt with hand lenses, shake the canisters, and make comparisons any other way they can think of. They record their observations with written words (the teacher has told them that it is not necessary to write complete sentences) in their notebooks. The teacher encourages students to use all their senses to compare the materials. Students explore; the noise level rises; and they are getting excited thinking of comparisons. All chatter about what they are doing. Below are examples of student and teacher conversation:

S1: It looks like snow. It’s white and soft.
S2: No. It looks like a rock.
T: What looks like a rock?
S2: Sand. When you spread it out it looks like a rock.
S3: It's really tiny. Salt is tiny.
T: Good, so you're using your sense of sight. What other senses?
S4: Sounds like music [shaking the cans]
T: Good, write that down.
S5: Hey, guess what. When you write on the sugar, it stays. [writing with a pencil, pushing the sugar around]
T: Let's stop and think together about what we have learned so far. Randy and Hanna have a good idea - they divided their paper in half to record salt on one side, sugar on the other -- I'll do the same. Now, what did you find out?
S3: Sand sounds loud. Salt sounds small when you shake it.
T: OK, what else?
S1: It looks like snow.
T: Right. What sense did you use?
S1: Sight.
T: Sight, right. Hey, did you see that? Harry looked back at his paper. Good. That's why we write things down in science - so you can look back.
S2: Sand looks like a rock.
T:  How did you know that, what makes it seem like a rock?  Was it shape or color or...?

S2:  Shape.  It was round.

The teacher guides the students enough to keep them on task, such as reminding them to write down what they observe, but otherwise they are free to pursue their own line of investigation. She uses their own ideas (such as dividing the paper) and appreciates and acknowledges students’ scientific behavior, such as referring to their notebooks. The culminating activity, which is cut short by the recess bell, consists of filling out the chart at the front of the room, recording their data to compare it:

T:  I don't want to hear any noise, but you may keep your papers so you can refer to them. We need to organize the information from your notes. We need to organize your data.  [teacher refers to the first column on the chart]  Color - is it the same or different? Right. Different. Kevin, come up and put a big D here. What were the colors?  [Students raise hands to answer.]  

The size column is next - some think they were different in size, some the same. Teacher asks several students why they think as they do. Students are instructed to defend their findings. But there is an obvious difference of opinion among the students about the data collected and student observations of the sand. Teacher uses theses varying observations as an opportunity to expand on the students’ scientific thinking – how will they resolve the differences of opinion?

T:  A lot of kids think they [the granules of sand] are different sizes. Lisa, how did you find that out? How did you know?

S1:  [waving her hand lens]  I looked very closely and saw the salt was smaller than the sand.

T:  Brian -- what did you think?

S2:  I agree with both of them.

T:  How can you do that?

S2:  First I thought they were different, then I thought they were the same.

T:  Hmm, so we have a difference of opinion. What can we do to resolve this? Any ideas?

S7:  Look again with the hand lens. Only look at that one thing – we’ll just look at the size and see if we can decide if they are the same or different.

The recess bell rings. Before the students are allowed to leave, the teacher asks them to think at recess about resolving the differences; after the break, they will return to the topic of science. After the students have left, I ask about the lesson. The teacher is frustrated. She wanted to work through observed differences before students left, wanted to push them to isolate one variable and replicate the observations until they could come to a conclusion, but she ran out of time. She plans to continue after recess.

In this lesson, we observed a strong focus on science methodology rather than a lot of geology facts or concepts, and this is appropriate for first graders. The teacher seemed to
have a good grasp of what her first graders were capable of understanding, and
couraged them to pursue their own inquiry. She also encouraged and modeled
scientific behavior, by asking children to provide evidence in support of their findings, in
ways 6 and 7-year-old students could emulate. She used scientific language such as “We
need to organize your data.” This was a simple lesson, but it laid a firm groundwork for
conducting scientific inquiry in later units and grades.

**Pattern 3: Minimal Science**

Classrooms in a third pattern, 8 out of 40 (20%), failed to meet the expectations of
science education reformers. These classes could be called “minimal science,” and they
received a total rating score of 6 to 8. The focus of these classes was on games, crafts, or
going through the motions of the kit activities without any significant cognitive demands
on students. These classes received the lowest rating on virtually all scales, although
about half the classes at least had students complete some work sheets or record some
observations in writing or drawing. Teachers did not attempt to elicit students’ prior
knowledge about the topic studied or ask them to reason about what they were doing. In
addition, most of these classes were poorly managed, making it hard to accomplish
serious work. Students seldom had good small group discussions since teachers did little
to facilitate it. Crosstalk was about recess, clothes, or friends. Some of these teachers
were relatively new or had not yet been trained on the science kit they were expected to
teach, and one had a class comprised mostly of students who did not speak English, but
others were simply out of their depth or burned out. In general, these teachers had
sketchy notions of the purpose and methods of inquiry science although they might not
admit it. One teacher complained to the observer that, “All the interesting science stuff
has been covered already this year,” implying this was the reason his class was boring
and lacked challenge, and that there was no way he could make the remaining activities
interesting or think of other worthwhile investigations.

*A vignette of a “minimal science” classroom*

The teacher is a woman with 10 years experience. She has a third grade class of 24
students, who look to be mostly white and about one-fifth Latino. All are fluent in
English. The room has very little work or decoration on the walls. One corner is devoted
to a library, but no science work is visible, and there are no charts, pictures, or science
equipment in evidence. Two computers are in the corner, with plastic covers over them,
and no signs of classroom use.

The lesson topic today is “Predators and Prey” from a core life science unit that is an
introduction to animal adaptation. Students study different kinds of camouflage, structure
of teeth, and animal movements. This particular lesson is an hour long. The
introduction, which lasts for about 15 minutes, consists of a teacher-led class discussion
of food chains. The teacher asks primarily recall questions. She reminds the class that
“predators eat their prey, they are higher on the food chain.” There is no follow-up
question and answer period.

The remainder of the introduction period is used to explain the “predators and prey”
game, which is part of the prescribed curriculum. Half of the students are designated as
“prey” and put on red vests. The rest of the students are “predators.” Predators kill their
prey by tagging them and removing them from the game. By varying the number of
predators, the game demonstrates how food webs work – when there are more prey than
predators, the game runs for a longer time, because the food chain functions longer.
When predators far outnumber prey, the game is over quickly because the food is
captured and the predators die out.
The students move out to the nearby field to play. Most of them don’t understand the rules, and the teacher does not provide clarification. The game becomes a rambunctious game of tag for about 20 minutes. The observer asks several students to explain what the concept is that the game demonstrates. Among the answers: “the food chain,” “how animals eat each other,” “I don’t know,” and “I’m not sure.” When encouraged to explain a bit more, none of the students would attempt a response.

Back in the classroom after the game, the teacher debriefed the students:

    T: What happened when there were too many prey? Could the predators get food?
    Ss: Yes.
    T: How about when there were fewer prey? Was it easy to get food then?
    Ss: No.

The questioning continued, with mostly unison yes or no answers. Several times during the discussion, the teacher tried ineffectively to coax longer explanations of the food chain or food web concept from the students. Although they understood that some animals ate others to live, the concept seemed related to size, as in bigger animals always ate smaller ones.

During the remaining class time, about ten minutes, the teacher assigned her students to draw a picture, using ballpoint pen and white paper, of either a predator animal or a prey animal. No writing task accompanied the drawing.

This lesson, although from the prescribed curriculum, was conducted without focus and was not conducive to student inquiry. To introduce a higher level of inquiry, the teacher needed to solicit more student-generated ideas and questions. Perhaps a student-drawn web generated by whole-class discussion, or students’ own experiences with food chains (such as humans eating animals, or a bird observed eating bugs and worms) could have clarified the concept for students. However, the lack of clear introduction and connection to stated concepts, the almost free-for-all, unfocused activity, and lack of meaningful discussion afterward was typical of the “minimal science” classes observed.

What reform practices are most challenging for teachers?

In the majority of classrooms observed, teachers often missed important opportunities to provide the rigor and depth of science instruction intended by science education reformers. The primary challenges for teachers that emerged from our data were in the areas of developing scientific thinking, understanding scientific methodology, and allowing student-driven investigations.

Developing scientific thinking. The ultimate goal of elementary inquiry science is to give students the opportunity to develop their own powers of reasoning and to increase their ability to solve problems in a scientific way (Elstgeest, 1985). Unfortunately, in most classrooms we observed, this goal was not prominent. Students in nearly all of the classes we observed were not given many opportunities to respond to questions, either orally or in written work, that asked them to reason about what they had done or to relate their results to the big ideas of the unit. Most of the questions they were asked were simple recall or reporting of observations (“What is the first thing you’re going to do in your groups today?” or “What did you clay soil look like when you got it wet?”). As with high school teachers (Tobin and Gallagher, 1987), elementary teachers in our study often allowed a few target students to answer all the questions, so the rest of the students could
just listen and copy, not fully processing the experience. Thus the cognitive demands remained small for many of the students.

When teachers asked students to make predictions about what they thought would happen during an investigation, they almost never asked students to explain the basis for their thoughts. The predictions nearly always amounted to sheer guesses, with little purpose or effect.

At the end of the science period, many teachers closed the class with clean up rather than any serious discussion of findings. When they occasionally asked students to draw conclusions from an investigation, they seldom asked students to support those conclusions with evidence. Very few teachers had their students report the results of their investigations to the class, with authentic reflection on the credibility of their claims based on the evidence they had collected and analyzed.

Even in these long established inquiry science programs, many teachers seemed to focus on students getting the “right answer.” When students didn’t, teachers typically kept searching for a student who did “get it.” If the whole class didn’t understand, the teachers tended to be at a loss. Only a few teachers, in the “principled science” classes, were focused on students’ learning to think scientifically. These teachers responded to students’ inaccurate claims by suggesting that it could be useful to reflect on the degree to which their inquiry had been a fair test and that the student might attempt to confirm (or revise) their ideas by further testing.

Writing tasks also typically posed low cognitive demands on students. They were seldom asked to do more than record observations, to copy phrases or vocabulary words that the teacher wrote on the blackboard, or to provide superficial answers to vague questions like, “What did you learn today?” When teachers or aids gave criteria for good responses, they tended to cite correct spelling and complete sentences with no mention of conceptual understanding or scientific reasoning, such as supporting claims with evidence from observations.

**Understanding scientific methodology.** Another type of opportunity that was missed frequently was to help students understand the value and use of scientific methodology. There were very few interactions between teachers and students about the following kinds of issues: how to design a fair test, how anomalous results might be explained by reflecting on methods or explored further through replication, or how to organize data with charts, graphs, or diagrams to see patterns and make sound claims or generalizations. For example, most teachers provided students with pre-made charts for recording their data and never commented on the design of the charts. While it is understandable that teachers want to save time, and charts are often provided by the teachers’ guides, exclusive use of this approach robs students of the opportunity to think for themselves and generate a solution. The need to organize and analyze data seemed to be largely ignored, yet it is a set of skills that needs to be taught. Very few teachers ever talked, for example, about ways to display the data to help see patterns that lead to claims. Only a few teachers, mostly those in the “principled science” classes, asked students how they had recorded their data and how the class could chart students’ results so they could compare findings across the class.

Moreover, in misguided attempts at classroom management, more than a few teachers used comments that trivialize science such as “Scientists write in complete sentences,” and “Scientists clean up quickly and quietly.”
Allowing student-driven investigations. Science reformers have suggested that if students are to learn how to conduct scientific investigations, they must have appropriate practice. That is, they must have occasional opportunities to do more than follow someone else’s recipe. It is important for them to learn over time to pose their own small researchable questions and to design and conduct their own very basic investigations. We saw only 2 out of 40 classrooms engaged in student-initiated inquiry during our observations for this study. Since we saw only one lesson out of the 10 to 20 that might comprise a typical unit, and the curriculum kits apparently tend to emphasize fairly scripted investigations, we were not too surprised that we did not see a lot of student-driven investigations. It is possible that most teachers allow students this experience in several units and that we just did not happen to see it. However, given teachers’ concerns about classroom management, their tendency to treat the lessons as recipes, and their frequent ignoring of students’ questions, we doubt that a lot of student-driven inquiry is going on. If this goal is a priority, the extent of student-initiated inquiry is worthy of attention by districts and policy makers. We did see two good examples of what might be done, one in the class of a young teacher who had an undergraduate degree in science. In her class, a multi-day investigation involving the entire class was prompted by students’ own questions about what their new class hamster would eat. Prior to our visit, the teacher and students had come up with a plan to do the following: examine different types of possible foods for the hamster; make predictions; give the animal free access to the foods, and observe and analyze what he would eat first, next, and not at all. The teacher managed to turn students’ questions into a full-class activity that taught them a lot about how to think and work scientifically on an issue of importance to them.

Discussion and Conclusions

This study provides evidence of widespread implementation of hands-on inquiry science curricula in districts where such a program has been established for some time. Teachers are making attempts to give students opportunities each year to do first hand scientific investigations in several topics and to link the lessons to students’ lives outside the classroom. Students are actively engaged in classroom science activities, perhaps enjoying it more than much of schooling. Nonetheless, in each district studied, it is estimated that at least a fourth of the teachers are not teaching science, and many teach less science than is expected.

Our results document practice that is in the spirit and direction of reform, but the quality of “inquiry science” implemented in most of these classrooms falls short of reformers’ visions. Most of the classrooms we observed were taught by teachers who were selected by principals or resource teachers to represent their district’s efforts, yet in only 7 out of 40 were students engaged in real inquiry and scientific thinking. As Spillane and Zeuli (1999) found in math classrooms, elementary teachers in this study also “had managed to challenge the behavioral regularities of instruction much more than the epistemological regularities.” They were teaching the kits but in recipe-like fashion, with too little opportunity for students to reason effectively, to understand scientific methodology, or to pursue their own scientific investigations.

The three districts in this study are all well-established programs that were initiated and guided by strong coordinators who had a background in science teaching and clearly understood the nature and value of inquiry science education. Yet in each district there were many teachers who fell far short of reformers’ intentions. What district factors could help account for this?
Districts in this study all took professional development of teachers seriously and provided a range of training opportunities. One even provided training for principals so that they would know why and how to support teachers’ science instruction. But despite all the resources that went into the wide array of professional development opportunities available, mechanical use of the curriculum persists in all districts. In addition, although one district collected some data about the program to improve it in years past and all currently have kit use data available, none of the districts were systematically utilizing it to improve classroom practice.

For a variety of reasons, including reductions in class size and increases in teacher turnover, districts are struggling to keep up with providing the basic kit training to new teachers and those who change grades. This type of training basically familiarizes them with what the kits contain and focuses on the logistics of the activities and basic classroom management. These are necessary but not sufficient. This basic professional development does not help teachers attend to the epistemological regularities – how to teach scientific design, methodology, and reasoning. Successful implementation of reform requires that teachers come to deeply understand these reforms – and that will take time and iterative opportunities to do and reflect with colleagues and scientist partners. Inquiry science reform requires elementary teachers to teach in ways that many have not done before nor experienced when they were students. Thus the success of this reform, beyond existence as recipe science, depends on teachers’ learning new concepts and skills and developing internal incentives for practicing them. It also requires that they unlearn some prior misconceptions, practices and beliefs. That would be a serious challenge for members of any profession. We do not mean to portray teachers as unwilling or unable to learn the deep meaning of reform intentions. It is critically important that schooling be designed so that a regular part of the system is that teachers have continual opportunities to reflect on their practices and fashion new knowledge and beliefs about content, pedagogy, and learners (Darling-Hammond & McLaughlin, 1995; Stigler & Stevenson, 1991).

One coordinator told us that she despaired at the enormity of this task, particularly given frequent changes in grant foci and administrative politics. She was considering the possibility of having students learn science from “specialists” rather than their classroom teachers, but she acknowledged several problems with this approach. This approach would make it far more difficult to link science to learning in other subject areas. Teachers would be less likely to appreciate and build on students’ strengths in science inquiry to improve their enjoyment and success in other areas. And teachers’ overall practice would no longer have such opportunities to improve through influences from the inquiry methods learned from teaching science.

As external funding decreases, districts struggle unsuccessfully to shift the locus for monitoring program implementation and quality control to the schools. Making each school truly accountable for providing high quality implementation of the curriculum as well as for student achievement requires a fundamental shift in the organization and administration of schooling, and cannot be accomplished easily in a couple of years. Without sufficient time, money for staff, expertise, and incentives, neither districts nor individual schools can be successful in providing real science education reform to all students.
References


