Urban Science Classrooms Amidst a Technological World

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Abstract

Between fourth and eighth grade, American students' achievement and understandings of complex science decline relative to their peers internationally (Linn, Lewis, Tsuchida and Songer, 2000). For urban students, these gaps are even more pronounced such as in high poverty urban Detroit where standardized test scores are among the nation's lowest. In one approach to addressing this issue, technology-rich, inquiry-focused science programs such as *Kids as Global Scientists: Weather (KGS*) (Songer, et al. 1999*)* have been developed, refined, and researched with tens of thousands of students nationwide, then more recently customized to the needs of thousands of students and teachers in urban settings such as Detroit Public Schools. This paper documents an examination of the patterns that occurred, including both successes and challenges, within student achievement and enactment among nineteen middle school classes taught by six teachers in one large urban district. Focus questions included: Knowing that even with an established inquiry-based program that challenges were large for these classrooms and teachers, what pockets of success were realized, and what barriers were insurmountable? What patterns emerged, including what profiles of student learning and classroom enactment occurred?

Results indicate that the challenges of implementing these programs are predictably complex and unpredictably systematic, while on balance, after only one year pockets of success and models of support structures are beginning to emerge. One realization is that the systemic efforts of interdisciplinary teams, containing a range of experts both within the school system and outside it, are essential. A second conclusion is an awareness that current reforms need to specifically look at the tension between general programs or ideals and local conditions, and to specifically address the role adaptation plays in both the success of the reform and the measurement of impact. Without research that addresses adaptation and differential enactment, patterns amidst individuality cannot be observed and reforms cannot become part of the schooling and therefore sustained. We conclude with a call for longitudinal studies that explore customized adaptations by various schools within one district as an important research vehicle for both fostering change with an adaptive support structure and measuring impact across a range of adaptations.

Introduction

Between fourth and eighth grade, American students' achievement and understandings of complex science decline relative to their peers internationally (Linn, Lewis, Tsuchida and Songer, 2000). For urban students, these gaps are even more pronounced such as in high poverty urban Detroit where standardized test scores are among the nation's lowest. In one approach to addressing this issue, technology-rich, inquiry-focused science programs such as *Kids as Global Scientists: Weather (KGS*) (Songer, et al. 1999*)* have been developed, refined, and researched with tens of thousands of students nationwide, then more recently customized to the needs of thousands of students and teachers in urban settings such as Detroit Public Schools. This paper documents an examination of the patterns that occurred after the first year of this adaptation to a specific set of urban classrooms, including both successes and challenges within student achievement and enactment among nineteen middle school classes taught by six teachers in Detroit Public Schools. Focus questions included: Knowing that even with an established inquiry-based program that challenges were large for these classrooms and teachers, what pockets of success were realized, and what barriers were insurmountable? What patterns emerged, including what profiles of student learning and classroom enactment occurred?

Why Study Urban Science Programs That Embrace New Technologies?

While much recent media attention has been directed towards documenting the "digital divide", little research has been conducted to assess what accounts for the discrepancies noticed or how these patterns can be overcome. The digital divide refers to differences between "the information 'haves' and 'have nots'" –in other words the documented differences that exist in computer access and use by race, particularly in education and among K-12 students (Hoffman and Novak, 1999). While studies so far have only documented the demographic patterns, recent research tends to suggest that the gaps between race in computer ownership and Internet access are increasing rather than diminishing. These gaps are increasing even within a technological world where nearly 100% of public schools have access to networks and computers and practically all other major institutions, such as business and medicine, are witnessing dramatic transformations catalyzed by technological innovations.

In a recent address at the National Education Summit, President Clinton discussed his understanding of why education's digital divide is increasing rather than diminishing when he stated,

> "The problem now is that the economy has changed much faster than the schools. People used to say, 'you know, the schools just aren't what they used to be.' The problem may be that too many of our schools are too much like they 'used to be,' but the world the children move out into is not at all as it used to be. …We've got the give the schools the tools they need to do the job " (Clinton, 1999).

The work described in this paper outlines one approach to educational reform that aims to provide students currently classified as digital divide "have nots" with our answer to "the tools they need to do the job"-i.e. technologically-rich inquiry science that encourages students to analyze and synthesize data, provide arguments and explanations to complex science questions and communicate science explanations to others.

<u>Why Urban Science Reform Now?</u>

Many educational researchers such as Robert Slavin (1996) share Clinton's enthusiasm for current educational reforms stating that "never in the history of American education has the potential for fundamental reform been as great." Others are more specific about the role of technology in current reforms when they state that technology is already "ubiquitous in our living space and will become more so" and therefore we should embrace technology as the vehicle for societal transformation and a means of changing both the "what" students learn and the "how" it should be accomplished (Pea, 1998).

For the last hundred years, American educational reform has been ardently pursued towards a range of goals. Despite the ranges of: approaches (i.e.top-down mandates or bottom-up approaches), level of focus (i.e. national, state or district-level) and agent of change (i.e. intended curricula or professional development), most accounts conclude that efforts have achieved mixed results (Knapp, 1997) and gradual changes which, according to some experts, have only "added complexity" to a highly complex system (Tyack and Cuban, 1995, p. 83).

Most reform experts document that teachers are a critical link in the success or failure of educational reforms, including recent reform efforts with emerging technologies (PCAST report, 1997; Slavin, Dolan and Madden, 1996; Cuban, 1993). Our earlier work and that of others (i.e. Ball and Cohen, 1996) supports the idea that what teachers do with curricula, i.e. enactment, is critical to the success of the reform. Also critical are teachers' beliefs about the ideas behind the reform, as beliefs are inherently tied to program enactment (Putnam and Borko, 2000). Focusing research on teacher adaptation causes some aspects of thinking about reform to shift, for example from focusing on an intended, or written, curricula as a potential change agent to focus on the enacted curricula as the change agent (Cuban, 1993). Expressing this idea more clearly in a recent book, Tyack and Cuban (1995) argue not for top-down or bottom-up approaches, but for change "from the inside out" where policies such as national standards are provided as goals to strive towards, but the crucial focus of reform should be teachers. In this inside-out approach, efforts for reform should be directed towards the work within classrooms and school systems to re-interpret and rework best means of reaching these high standards. Current thinking in systemic reform resonates with the "inside-out" approach when researchers state that large scale educational development projects which address many aspects of the school system in concert is the only means of obtaining long-term success (Vinovskis, 1997).

Our work in urban Detroit utilizes the *adaptation* approach to urban educational reform and sustained use of innovations fostered by researchers such as Louis Gomez in Chicago Public Schools (1997) and others in New York (i.e. Central Park East School and District 2 in New York City). Gomez describes the work in these urban areas as "leading to sustained curricular and structural innovation in challenging urban contexts" in part because of a key insight –that the local context is used to shape the innovation, and that the innovation allows such shaping even while maintaining some level of programmatic coherence (Gomez, 1997). Others discuss a similar necessity of local adaptation of programmatically coherent approaches when they discuss how the school frame of reference should be utilized as an inside lens from which the innovation from the "outside" should be interpreted (Darling-Hammond, 1996).

Following this thinking the research presented in this paper is one piece of a multi-institution partnership that focuses on local adaptations of programmatically coherent curricular programs in large urban districts. The Center for Learning and Technology in Urban Schools (LeTUS) is a two district, two university partnership that advocates change "from the inside out" through brokering of complex, technology-rich curricular programs between district insiders and university and district personnel. A curricular program that was successfully nationally first and therefore had established a level of programmatic coherence seemed an ideal vehicle for the study of adaptation within several Detroit Public School middle school science classrooms. The work described in this paper chronicles the enactment of this program for the first time in the classrooms of six different DPS middle school teachers leading to a characterization of the patterns of success and challenges that occurred.

<u>Why An Inquiry Approach to Learning With Technology?</u>

The literature helps us understand that inquiry involves several different kinds of thinking sometimes confused into a simplistic definition or set of tasks (Bransford, Brown and Cocking, 1999). To address the complex thinking embedded in inquiry within a given content area, our research program has worked to examine the kinds of inquiry that are a good match to the study of weather for middle schoolers as well as to build scaffolded tools, both within our teacher supports, our student activities and our learning technologies, that will foster productive inquiry and rich content understandings. The following research findings quoted from Bransford et al's *How People Learn* and other literature summarize the major learning tenets that we have adopted as central foci for the development of our program to foster inquiry. These include: a) an emphasis on activities that foster deep foundational knowledge and a strong conceptual framework, b) learners' natural problem solving abilities and c) the need to provide effective guidance and modeling for their own queries, and d) the importance of working with students' own ideas, beliefs and conceptions. See also Table 1 for a characterization of the National Standards addressed in the KGS curricular program.

• "To develop a competence in an area of learning, students must have both a deep foundation of factual knowledge and a strong conceptual framework…Key to expertise is the mastery of concepts that allow for deep understanding of that information, transforming it from a set of facts into usable knowledge." (Donovan, Bransford and Pellegrino, 1999, p.2)

"• Children are problem solvers and, through curiosity, generate questions and problems: Children attempt to solve problems presented to them, and they also seek novel challenges. They persist because success and understanding are motivating in their own right (Bransford et al, 1999, p. 222).

• Children's natural capabilities require assistance for learning: Children's early capacities are dependent on catalysts and mediation. Adults play a critical role in promoting children's curiosity and persistence by directing children's attention, structuring their experiences, supporting their learning attempts, and regulating the complexity and difficulty of levels of information for them (Vygotsky, 1978)." (Bransford et al, 1999 p. 222-223).

• While adults play a critical role in scaffolding and mediation sometimes these supports are best provided by the teacher to small groups of students, sometimes by peers or other learners, sometimes by technological tools, and sometimes through reflective prompts which encourage self-reflection (Vygotsky, 1978; Songer, 1998).

• "There is a good deal of evidence that learning is enhanced when teachers pay attention to the knowledge and beliefs that learners bring to a learning task, use this knowledge as a starting point for new instruction, and monitor students' changing conceptions as instruction proceeds." (Bransford et al, 1999a, p. 11) Inquiry learning should take students ideas as a starting point, such as in the form of a driving question (Blumenfeld et al, 1994).

In summary, recent educational reforms, both generally and in urban areas, argue for an adaptation approach where change is advocated "from the inside out" and where reforms are fostered with specific emphasis on local adaptations within a system of programmatic coherence. Current media also document dramatic and increasing gaps between minority and white students' use and access of information technologies sometimes called the digital divide. Applying these literatures to urban science educational reform as one means of working directly with the digital divide, one research group took a program with existing programmatic and national coherence and implemented it through a systemic reform program within one urban science district to look at pockets of success and challenge. The following sections outline both research methods utilized and results obtained.

Methods: Programs and Participants

Inquiry Science Through the KGS Curricular Program

The *Kids as Global Scientists: Weather* (KGS) curriculum is an eight-week, inquiry-based, technology-rich curricular program for middle school students (Songer et al., 1999). For eight years the KGS research project has focused on best means for fostering rich understanding of atmospheric science concepts through a three-phased inquiry-focused curricula which included: the analysis of real-time weather data, data comparison and critique, concept development and peer critique and exchange, hands-on experiments, and a culminating real-time forecasting activity. The KGS curriculum, was designed to exemplify a inquiry approach where students develop rich explanations and interpretations of complex science phenomena through the development and communication of evidence and investigations of science questions of their own design over multiple activities and extended periods of time (Newman, Griffin and Cole, 1989). In addition, the KGS program culminates in students' application of their understanding of weather concepts towards the prediction and interpretation of current weather events (Songer, 1996). The program maintains programmatic coherence through a series of "core activities" that are suggested as guidelines to follow within each of the 200 nationwide classrooms enacting the program at the same time. In addition, each classroom is encouraged to adapt the program to their learning goals and audience through flexible interpretation of the core activities combined with extension activities provided at each time point. Core and extension activities are designed to occur in three sequential phases, each of which emphasize inquiry skills and content standards (NRC, 1996) and build on the experiences in the previous phases.

The software developed for this program consists of a KGS CD-ROM and a web-based threaded discussion board. The KGS CD-ROM houses both a Director-created web browser for the retrieval and presentation of multiple representations of current weather imagery, and the presentation of archival storms for when Internet connections are unavailable or unreliable (Samson et al, 1999). Student classes are organized into ten different “clusters” on the message board for more focused and productive discussions with peers their own age, as well as more focused interactions with on-line scientists.

The combination of the eight weeks of activities and the corresponding software encourages students to foster deep understandings of foundational science concepts such as temperature and pressure, and then apply these understandings to the prediction of often sensational current storms. Previous research results on KGS programs demonstrate that students develop rich understandings of weather concepts (Songer, 1996; 1998), greater initiation of conversations and control of their own learning (Lee and Songer, 1999) and greater time-on-task compared to more traditional middle school science units. Table 1 summarizes the curriculum progression, inquiry skills, and national science standards emphasized in the KGS program.

The Detroit Public Schools and the LeTUS Center

The Detroit Public Schools (DPS) serve a population of urban minority students of which over 70% of the students are eligible for free or reduced lunch. As a result of strong leadership, DPS is making dramatic improvements in many areas including teacher professional development and technological readiness. Funded in part by the National Science Foundation, (Gomez et al, 1997) the LeTUS Center is working through partnerships with school administrators, teachers and university personnel to focus on technological readiness, teacher professional development and curriculum development as one means towards high standards in science for all students in this district. Now in its second year, the Center has implemented five curricular programs with approximately 6% of the students in this district.

KGS Program Participants

The KGS weather program (Songer et al, 1999) was implemented simultaneously in 258 classroom settings with approximately 240 teachers and 10,861 4^{th}-9^{th} grade students from 40 states. The classrooms were diverse along many criteria including setting, ethnic diversity and Internet reliability. Settings consisted of rural (33%) suburban (13%) and urban (45%) locations. Ethnic diversity consisted of 42% of classrooms with 50% or greater minority students, 20% of sites with 20-50% and 38% of sites with 19% or less minority students. By self report, Internet reliability was largely unreliable with 6.6% of sites declaring their reliability to be very reliable, 25% adequate and 37.6% as poor. Therefore unlike many other technology reform programs that target high tech classrooms in more affluent areas, a common profile of a KGS site was an urban school with largely minority students and unreliable Internet technology.

Focus Study: Six Urban Classrooms

Within this larger KGS population we selected six local sixth grade teachers for a focused study of the implementation of the program within the DPS district. Although the program has been implemented in thousands of classrooms over the past eight years, all of these six teachers were implementing the KGS program for the first time.

The six teachers' classrooms were composed of approximately 95% minority students. All classes were 95% African American with the exception of Gomez's classes which contained very high majorities of both Hispanic and African American students. When implementing KGS, these teachers worked with from one to five different classes of students each, for a total of 429 students distributed among 19 classes.

Instruments and Data Analysis

Pre and Post Content Assessments. All classes of students implementing the program in this district were given written pre and post content assessments. The assessment instrument contained a total of 14 open-ended and multiple choice items chosen because of their match to the foundational science content addressed in the program. Because the focus of this paper is on trends and patterns across all nineteen classes, only analysis of the 11 multiple-choice items will be discussed in this paper. Rich case-study analyses of student learning in particular classes, including both open-ended and multiple choice analysis, are on-going and will be discussed in future papers. The content pre and post assessment was identical at both time points so that repeated measures anovas could be utilized to illustrate changes in student' science content.

The multiple-choice items included a sample of seven released National Assessment of Educational Progress (NAEP) items on temperature, weather measurements, weather chart interpretation, and inquiry-focused questions such as the nature of a hypothesis. The test also included four modified Michigan Education Assessment Program (MEAP) items on fronts, the relationship of pressure to weather patterns and the interpretation of weather maps. Copies of the content assessment are available from the paper authors.

Enactment Descriptives--Observation Forms and Teacher Interviews

Two data were utilized to document the actual classroom enactment of the eight week program. These data include Classroom Observation Forms and Post-Teacher Interviews.

Classroom Observation Forms. One or two graduate student researchers were assigned to each of the six teachers for detailed observations of classroom enactment. Researchers were required to observe each classroom a minimum of two hours a week during at least eight weeks of enactment time. The six classrooms were observed from eleven to twenty-seven 50-minute class periods each for a total of 132 observations. At the completion of each observation, a Classroom Observation Form was completed by the researcher(s). This form recorded a range of information regarding classroom activities including length and duration of student and teacher activities, challenges or difficulties observed, responses to these challenges that were initiated, successes observed and types of support utilized by the classroom participants. A complete copy of the observation form is available upon request from the paper authors.

Teacher Interviews. At the completion of the program detailed teacher interviews were conducted with all six focus teachers. The interviews were semi-structured (Merriam, 1998) modeled after previous project interviews (Yorker and Songer, 1999). The interviews focused on teacher motivation and expectations, challenges and successes in enactment, evaluation of student learning and motivation, a characteristic lesson, resources utilized, and a description of support systems utilized by the teacher including administrative support, peers, teachers in other locations, and project staff and scientists. On average the interviews lasted 25 minutes, although they ranged from 20-50 minutes in duration. After the program ended all interviews were transcribed in full for detailed analysis.

Data Analysis of Classroom Observation Forms and Teacher Interviews. Once the program was complete, researchers adapted the qualitative analysis protocol of Chi

(1997) for the analysis of the two types of enactment data: teacher interviews and the coding of the 132 observation forms. Beginning with the coding of the observation forms, we followed Chi's (1997) eight functional steps for coding qualitative data including sampling the data, reducing the data and choosing a coding scheme which in our case was the development of enactment categories. Once preliminary enactment categories were determined, we coded each classroom on all enactment and school factors, and then checked and re-checked data sources for consistency. As in Chi's work, we used multiple data sources to develop measures of validity including observation forms, teacher interviews and data from the district to support and elaborate information available from the observation forms. Patterns which emerged were checked for consistency with interview data and discrepant cases were discussed among the primary researcher in that classroom and other researchers until consensus was reached. In addition, three other data sources were utilized to strengthen the information and patterns emerging from primary data sources. These sources included: data from the LeTUS staff on the degree of technological readiness, message board data to document students' degree of online correspondence with other students, and records of attendance and involvement of teachers in the Teacher Workshops. For coding each classroom on each factor, qualitative evaluations in the form of a three-point scale (i.e. low, moderate/average, high) were determined.

Results: What Patterns Emerged?

We analyzed our data to address the question, what patterns emerged, including what patterns of student learning and classroom enactment occurred? The following sections outline the trends we observed.

Student Learning

We looked at patterns evident from statistical analysis of nineteen sixth grade classes of our six focus teachers on pre and post content assessments. Table 2 shows student scores on these items by class, and as a group. Note that all classes demonstrate statistically significant differences from pre to post assessment, and the group of nineteen classes also demonstrates statistically significant differences from pre to post assessments.

When we reviewed the patterns of change from pre to post assessments we found that student learning results fell into three patterns that we called Achieving, Diverging and Marginal. Each of these terms is defined below, with the classification and explanation of student learning patterns available in Table 3.

Achieving. A total of six classes from two teachers fell into the Achieving category. In these classes student content understandings demonstrated large increases from pre to post assessments with a slight increase in dispersion patterns across the class. Acevedo's[*] class demonstrated an interesting example of Achieving. In this class, the 19 students demonstrated a very high pre-test score and a very high pre-test standard deviation between students, perhaps due in part to the selective population within this science magnet school. Acevedo's class exhibited statistically significant content gains and a much lower standard deviation on the post test which can be interpreted to mean that the students who started out lower on the pre test achieved a level more similar to their classmates by the post test. In general, when we look across the six Achieving classrooms, we see that the majority of students in all of these classes demonstrated significant content gains from pre to post assessments, and the level of content gain was somewhat similar across all students in these classes.

Diverging. A total of six classes from three teachers fell into the Diverging category. Diverging classes demonstrated medium to large increases from pre to post tests with a large increase in dispersion patterns (high standard deviations) across the class. Our interpretation of students in Diverging classes is that the majority of students achieved significant content gains from pre to post tests, but the amount of increase varied substantially.

Marginal. Seven classes from two teachers fell into the Marginal category. Marginal classes exhibited small but significant changes for the majority of students from pre to post assessments. Because the gains were significant we interpret these results to mean that students achieved to various extents from pre to post tests, with some students exhibiting strong gains, and others showing relatively no change.

[*] All names are psuedonyms.

Inconsistency Among Different Classes Taught By the Same Teacher. Of the six teachers and nineteen classes analyzed, all classes by the same teacher were categorized similarly with one exception. This trend indicates that, in general, teachers practices and population were largely similar across their classes and, most likely, the differences between schools and teachers is much greater than the differences between classes with the same teacher. The one exception is the three classes of Lee. Ms. Lee had one class (1) that was classified as Diverging and two classes, (2 and 3) which were classified as Marginal. For these reasons, in the student learning results, Lee's classes are grouped as both Divergent: Lee (1) and Marginal: Lee (2 and 3).

Enactment Analysis and Results

Table 4 illustrates the Enactment and School Factors Coding Rubric which was utilized for the determination of enactment in each classroom. Figure 1 illustrates a visual mapping of all twelve enactment and school factors for each teacher. Note that we have chosen to order teachers from top to bottom of Figure 1 by the number of positive factors we observed for each teacher. In other words, in the classrooms of Acevedo we observed the greatest number of favorable enactment factors; in contrast we viewed the least number of favorable enactment factors in the classrooms of Sparks.

Our results suggest that we observed the greatest number of positive enactment factors in the classrooms of Acevedo and Brown. Not only did both teachers' classrooms demonstrate seven of the twelve enactment factors as favorable, but also both teachers had positive factors in all three of the enactment areas of curriculum, technology, and support.

In contrast, the remaining four teachers, Gomez, Jackson, Lee, and Sparks, all had enactment patterns which we observed to be positive in some areas but not positive in others. In other words, while these four teachers varied in terms of which factors their observed classrooms were individually weak or strong, all four of these teachers' classrooms had roughly equal amounts of factors that were rated favorable (+), mixed (o) and unfavorable (-).

Looking at general trends within these four teachers' classroom profiles also reveal some similarities and differences. First, while these classrooms were rated overall to have approximately the same numbers of favorable ratings, the classrooms do not necessarily demonstrate strength in the same areas. For example, while both Jackson and Lee had similar numbers of favorable, mixed and low factors, Jackson had a relatively strong technological infrastructure but mixed levels of support, while Lee had low levels of technology but reasonable support except at the administrative level.

An interesting trend highlighted in Figure 1 is the presence or absence of administrative support for teachers' enactment of the program. Administrative support was determined both by teacher self-report (within teacher interviews) and classroom observations. While both Acevedo and Brown, the teachers with the strongest classroom enactment patterns, also had strong administrative support, only two of the mixed-profile teachers, Gomez and Jackson, had strong administrator support. The two remaining teachers, Lee and Sparks, expressed strong dissatisfaction with administrative support in their school. This observation will be discussed more fully in a subsequent section.

Do Student Learning Patterns and Enactment Patterns Converge?

Our student learning results demonstrate that all classes experienced statistically significant pre to post content gains although the degree of significance varied among classes. As all six of these teachers were enacting a complicated technology-rich reform science program in their classrooms for the very first time, we were pleased with the overall gains in content understandings and were not discouraged or surprised by the variance in gains between classrooms that we observed.

We now shift our focus to whether patterns observed in student learning converge with patterns observed in enactment. Following trends suggested in the literature that urban innovations need to be allowed local customization within an infrastructure of programmatic coherence and support, we would speculate that classrooms with strong support structures and other means of encouraging local customization might also be the classrooms with the strongest student learning results. In comparing teachers who were at the top of both Figure 1: enactment factors and Table 3: student learning profiles we observe that we did see similar trends in both student learning and classroom enactment factors. In other words, both the classrooms that had student learning classified as achieving, Acevedo and Brown, were also the classrooms with the strongest classroom enactment profiles and support structures. It seems likely that Acevedo and Brown were able to provide a learning environment for their students' content gains, in part, because of the support structures, reliable technology and time to enact the program that they experienced. To support the idea of convergence in these data, we provide samples from Acevedo and Brown's interviews to illustrate some of their own explanations for their students' success with this program, including articulation about the content their students learned, students' motivation, and learning among diverse students.

<u>A quote focusing on what students learned about weather:</u>

"I think the kids learned a lot about weather… I think that some of them really got some complex ideas about weather and kind of the idea being that it is this huge system with lots of different factors. "

<u>A quote focusing on student motivation:</u>

"It [the KGS program] caused the kids to have a great enthusiasm for learning…Kids were always excited…another expectation I have…is that they would gain self esteem…I think this made them feel very special and that their self-esteem was raised tremendously because um they had someone else who cared about them and they really felt good about themselves. They would smile in the halls, they was like, KGS today!!…and it helped attendance for many of them, cause they knew the days they were gonna do KGS, and it was like, I'll be there for KGS."

<u>A quote supporting learning among traditionally under-motivated students:</u>

" [My partner teacher] noted that she has had students that have done nothing all year and have done this and done well. She has had some students who ware in the "A" caliber who are used to reading and regurgitating and they found this challenging because they didn't know what was expected of them….So she found that it was a challenge for the bright students…and then she found.these hard core few that I tend to ignore actually came on board and have done very well. Some of them for the first time ever perhaps are going to get a C or D…I think the kids like it [the KGS program} and therefore they are going to do more than were we to do it any other way."

In contrast, Gomez and Jackson were two of the teachers with mixed enactment profiles who had students that demonstrated divergent learning patterns. While both these classes had reduced time to enact the program because of winter and spring breaks, they also had high degrees of computer access and administrative support that inevitably might have enabled the learning environment of their students to support moderate gains in science despite some obstacles. Jackson shares his thoughts on how he overcame time limits.

"I did experience the unfortunate timeliness of KGS. We had two weeks off. We had a winter break…and a easter/spring break. And that was unfortunate. We had to play a lot of catch up…That was probably the biggest problem I encountered."

Interestingly, convergence between patterns in student learning and enactment was also noticable among Lee and Sparks, the two teachers with the most challenging enactment environments and with students who were classified as exhibiting marginal learning gains. While both teachers had strong support from research project staff, they also both had inconsistent technology and inconsistent support in other areas, primarily from some levels of their school administration infrastructure. In each case at least one of the major enactment categories was poorly supported even if the other areas had moderate support. In Lee's classroom all aspects of the technology were largely non-functional despite moderate support levels in other areas. In Sparks' classroom both technology and support levels were often very low.

Are their Enactment Patterns That Appear More Essential Than Others?

In the teacher interviews we found that teachers with strong enactment patterns and those with weak enactment patterns discussed support structures in very different terms. For example, one of the teachers with a strong enactment profile and high student learning gains described administrative support in very glowing terms,

"I'm honored when I'm asked to something other than what I normally do [like the KGS program]…because it shows me that the district and those that are my superiors have confidence in me. And when they ask me, especially with a new program… they will allow me to work the program in order to get some data that will be used for the district. Well, I feel really honored that I was asked."

In contrast, Lee and Sparks mentioned that at times they did not feel strongly supported to try new innovations, and in their interviews both teachers discuss the challenges of enacting this program largely on their own,

"I did not get any support at all. In fact even to hear something negative would've been at least an acknowledgement that I was teaching the program. There was nothing said negatively, nothing said positively. It was as though I was invisible. Which is zero support. I'd rather have something negative then to be just nothing."

“Maybe it seemed like I lost my enthusiasm over the program, it wasn’t because of KGS or from you. It’s just that from things happening inside of the school I just wanted to finish.”

A third teacher, Gomez, seemed to take her own initiative to ensure that the project was known to her administrators and peers,

“Often times I’m not asked how things are going. What I do instead, especially during staff meetings I will just volunteer information to let them know what we are doing…it would behoove them to know that our students are challenged and succeeding.”

As discussed earlier, research on systemic educational reform by Vinovskis (1997) and others discusses this connection between local school adaptation and larger district and programmatic support for sustainable reform success. While no magic bullet for successful reform appears to work across situations and programs, the connection between internal support, the freedom to customize to individual class needs and pockets of success appears strong. From this we speculate that even with the highest level of technological reliability, support from colleagues, and large amount of time working with a strong curricular program, the degree of administrative support is a critical link in allowing the teacher to feel valued to adapt the program where they need to amidst a strong infrastructure and program.

In summary, our results indicate that the challenges of implementing established innovations and programs in urban settings are predictably complex and unpredictably systematic, while on balance, after only one year pockets of success and models of necessary support and structures are beginning to emerge. One realization is that the systemic efforts of interdisciplinary teams, containing a range of experts both within the school system and outside it, are essential so that the infrastructure of programmatic coherence and individual adaptation can flourish. While all of the classrooms we observed showed content gains our observations suggest that finding a means to support teacher customization is an important dimension of successful enactment of technology-rich reform programs in these urban settings. Our work suggests that reform programs which work directly from the “inside out” seem well-suited for the difficult work of adapting complex innovations to urban settings. While we believe our patterns are important, we also advocate the extension of our work and others towards longitudinal studies that can study teachers and classrooms through multiple iterations of local customization within programmatic coherence. We hope these studies will allow us to more clearly articulate support mechanisms that encourage local customization, as well as essential dimensions of the programmatic coherence necessary for sustained science reform in urban classrooms.

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Table 1: The KGS '99 Curriculum and the National Science Education Standards, National Research Council (1996).

NSES Standard and Fundamental Concepts	KGS Learning Activities	Phase
Science as Inquiry **Content Standard A: All students should develop the abilities necessary to do scientific inquiry and understandings about scientific inquiry. (p. 143)**		
· Identify questions that can be answered through scientific investigations	· Exchange information and data with other sites, develop questions and predictions	All Phases
Physical Science **Content Standard B: All students should develop an understanding of transfer of energy. (p. 149)**		
· Energy is associated with many substances, including mechanical motion, and is transferred in many ways.	· Tornado in a Bottle experiment	2
Earth and Space Science **Content Standard D: All students should develop an understanding of the: (a) structure of the earth system and (b) earth in the solar system. (p. 158)**		
· Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate, because water in the oceans holds a large amount of heat.	· Compare weather data from different geographical sites and explain similarities and differences · Report currently occurring severe weather worldwide	3 Any Phase
Science in Personal and Social Perspectives **Content Standard F: All students should develop understanding about (a) natural hazards (b) risks and benefits, and (c) science and technology in society. (p. 166)**		
· Processes of the earth system cause natural hazards, events that change or destroy human and wildlife habitats, damage property, and harm or kill humans. Natural hazards include floods and storms.	· Report a current severe storm (descriptions of severe weather: floods, blizzards, storms, especially that are experienced locally)	Any Phase
History and the Nature of Science **Content Standard G: All students should develop understanding of (a) science as a human endeavor, and (b) the nature of science. (p. 170)**		
· Women and men of various social and ethnic backgrounds engage in the activities of science. Some scientists work in teams, and some work alone, but all communicate extensively with others.	· Communication with weather specialists and other students. · Students work in small groups.	All Phases

<u>Assessment Standard A</u>: Assessments must be consistent with the decisions they are designed to inform. (p. 78)		
· Assessments have explicitly stated purposes.	· see the "purpose" section of activities	All Phases
<u>Assessment Standard B</u>: Achievement and opportunity to learn science must be assessed. (p. 79)		
· Achievement data collected focus on the science content that is most important for students to learn.	· curriculum questions; weather recording forms	1, 2
<u>Assessment Standard C</u>: The technical quality of the data collected is well matched to the decisions and actions taken on the basis of their interpretation. (p. 83)		
· Students have adequate opportunity to demonstrate their achievement.	· curriculum questions, e-mail, data collection, hands-on activities, group presentations	All Phases
<u>Assessment Standard D</u>: Assessments practices must be fair. (p. 85)		
<u>Teaching Standard A</u>: Teachers of science plan an inquiry-based science program for their students. (p. 30)		
· Work together as colleagues within and across disciplines and grade levels.	· Message Board communication; Teacher listserv	All Phases
<u>Teaching Standard B</u>: Teachers of science guide and facilitate learning.		
· Focus and support inquiries while interacting with students.	· all activities	All Phases
<u>Teaching Standard C</u>: Teachers of science engage in ongoing assessment of their teaching and of student learning. (p. 37)		
· Use multiple methods and gather data about student understanding and ability.	· written messages, hands-on activities, group presentations	All Phases
<u>Teaching Standard D</u>: Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. (p. 43)		
· Identify and use resources outside the school.	· Weather specialists, students from other sites, World Wide Web.	All Phases

Table 2: Class Pre and Post Assessment Results

	Acevedo	Brown	Jackson	Gomez	Lee(1)	Sparks	Lee (2&3)	all
N	**19**	**96**	**53**	**54**	**30**	**128**	**43**	**492**
Pre assessment	**5.95**	**4.09**	**3.34**	**3.96**	**4.67**	**4.52**	**3.37**	**4.17**
St. deviation	**2.37**	**1.73**	**1.89**	**1.74**	**1.49**	**1.57**	**1.43**	**1.83**
Post assessment	**8.05***	**5.59****	**5.06****	**5.22****	**6.40****	**5.06***	**3.79***	**5.23****
St. deviation	**1.55**	**1.82**	**2.41**	**2.09**	**2.14**	**1.82**	**1.58**	**2.09**

***= p<.01**
****= p<.001**

Table 3: Student Learning Profiles

Type	**Teachers /# of Classes**	**Distribution Pattern**		**Interpretation**
		Median change	Dispersion change	
A. Achieving	Acevedo /1 class Brown /5 classes	Large increase	Slight change	The majority of students had similar and large pre to post content gains
B. Divergent	Jackson /2 classes Gomez /3 classes Lee /1 class (1)	Medium to large increase	Increase	The majority of students had different amounts of medium to large pre to post content gains
C. Marginal	Sparks /5 classes Lee /2 classes (2 & 3)	Slight to no increase	Increase for the top half students	The majority of students with high pre-test scores had marginal pre to post content gains while the majority of students with lower pre-test scores had marginal to no pre to post content gains.

Table 4: Enactment and School Factors Coding Rubric

Note: All classifications are listed as N/A when corresponding evidence was not available)

Category	**Sub-Category**	**Data Source**	**Criteria**
Curriculum and Enactment Time Estimates	Total enactment time	Observation	+ more than 8 weeks 0 8 weeks – less than 8 weeks
	Implementation of Foundational KGS activities (total=11 activities)	Observation	+ 9-11 0 7-8 – <6
	Implementation of Foundational KGS correspondence (i.e. gross evaluation of the frequency of messages posted on the message board per class)	Message board data base	+ high- average 4 or more class sets per program 0 medium-2-3 class sets per program – 1 or fewer class sets per program
Technology	District Evaluation of Technological Readiness	LeTUS Center evaluations, 1/99	+ high degree of readiness 0 mid-level of readiness – low degree of readiness
At School Setting	Computer Access	Observation	+ < 50% observed reliability 0 ~ 50% observed reliability – > 50% observed reliability
	Technology reliability for curriculum enactment	Observation/ Interview	+ no restrictions 0 minor restrictions – major restrictions
Support	Admin. Support	Observation/ Interview	+ helpful/satisfactory support 0 not a factor – limited teacher's curriculum enactment
	Colleague Support	Observation/ Interview	+ helpful/satisfactory support 0 not a factor – limited teacher's curriculum enactment
	Researcher Support	Interview/ Classroom supporter's account	+ helpful/satisfactory support 0 not a factor – limited teacher's enactment
	Online Support (email with researcher or manager, fax, teacher listserv, teacher message board)	Records of teachers' use of communication tools	+ use more than one resource during program 0 use at least one resource – use none
	Workshop Experience (summer + 3 Saturday workshops)	Records of workshop attendance	+ participated in all 4 occasions 0 missed one – missed two or more
Student Population	Nature of student population	Observation/Interview	+ selective for academic talents 0 non-selective, mixed abilities – unusually challenging population

Figure 1: Enactment and School Factor Schematics By Teacher

Teacher	Enactment			Technology			Support						Factor Totals		
	Time	KGS Activities	Message Board Use	District Evaluation	Computer Access	Reliability	Administrative	Colleague	Researcher	On-line	Workshops	Student Population	+	◎	–
Acevedo	+	+	◎	+	+	–	+	◎	+	◎	◎	+	7	4	1
Brown	◎	+	+	+	◎	–	+	+	+	+	–	◎	7	3	2
Gomez	–	–	+	+	+	◎	+	◎	+	◎	◎	◎	5	5	2
Jackson	–	–	◎	◎	+	◎	+	◎	–	+	+	◎	4	5	3
Lee	◎	+	◎	–	–	◎	–	◎	+	+	+	◎	4	5	3
Sparks	◎	◎	+	–	+	◎	–	–	+	◎	◎	◎	3	6	3