# Section III

# Critical Elements

# for

# the Systemic Reform of

# Elementary Science Education in Urban Districts

# CRITICAL ELEMENTS FOR THE SYSTEMIC REFORM OF ELEMENTARY SCIENCE EDUCATION IN URBAN DISTRICTS

The case studies of the four districts, as well as the stories shared by the other three districts, illustrate all too well the difficulty of establishing good hands-on science teaching across an entire urban district. The lessons learned from these cases show, on the optimistic side, the power of individual commitment and leadership, and, more pessimistically, the unworkability and intractability of urban school systems.

## *Engineering For Consistent System-wide Best Practice*

The change models that underlie these district-focused elementary science projects (and many other NSF-funded projects) is one based on Hope. That is, it is Hoped that if teacher leaders are created, if kits are adopted, and if schools develop plans for their science curricula, then good elementary science teaching will begin to spread throughout the district. If pilot schools are created, then it is Hoped that other schools will follow. If some materials are purchased, then it is Hoped that they will be maintained.

The assumptions underlying the change efforts in these districts are essentially those of a minimalist and best-case scenario. The projects represent efforts to put some (often a minimum) of the necessary ingredients of successful reform in place, leaving to Hope that the rest will follow. Because resources are so limited, projects are put in a position where they have to do the best work they can and then Hope that their efforts will produce results that go beyond their own work. There is even a familiar funding language that has evolved around projects like these. It is Hoped that their projects will "catalyze" good science teaching, "leveraging" their funds in ways that will allow the system to "replicate its best practices" and "grow its own" good science teaching.

Some of the discouragement one might feel about our current educational reform efforts may arise from the fact that it is easy to misunderstand the nature of the systemic reform process. More specifically, research and development, in any field, can be thought of in three distinct and long-term phases.

In the first phase there is a lot of research and experimentation aimed at determining underlying principals and theories. For example, in aviation one conducts wind tunnel testing and computer modeling in order to better understand the underlying aerodynamic principals of flight. In education, there are educational and psychological experiments that help define the rules of good teaching and learning.

In the second phase, the lessons learned in the first phase are put to use -- there is a period of trying to create prototypes and generating instances of success in real-life settings. In aviation, this phase is represented by prototype and experimental aircraft. In the educational system, most outside-funded projects seek to learn about creating instances of good teaching and learning in real school settings. In both cases the goal is to make the innovation work, but it is understood that the outcomes will be marginal, temporary, and non-sustainable.

The third phase, which is very different in both scale and nature, is aimed at creating a comprehensive, reliable system. The innovations are no longer the exception, but rather they become consistent mainstream practices. They are supported and sustained by the system itself. In aviation, this third phase corresponds to the development of the modern aviation system with its huge infrastructure including the airlines, FAA, aircraft factories, pilot training facilities, and air traffic control system. The transition from the second phase, in which one creates a few isolated prototypes and temporary instances of success, to the third phase -- creating a large-scale, reliable system capable of sustaining and supporting best practice on a regular basis -- is a huge step.

The analogy with the aviation system also illustrates another important idea -- that reliable system-wide practice only results when projects engineer their efforts based on a <u>worst-case scenario</u>. In the aviation world the routine approach to designing systems is to look for <u>all possible sources of failure</u> and, then, to very carefully engineer them out. This a "fail-safe" approach to design. Unlike education, little is left to Hope in the airline business. In the educational system, by contrast, we are Hoping that our reforms "will fly" if we only provide minimal amounts of support and effort. Unlike aviation, we do not attempt to identify and then engineer out all the ways in which our educational reform efforts might fail. In this sense our efforts are much more like prototypes. We must realize that we are, in fact, still working in the second phase of development.

The district projects presented in this conference, and the discussions that grew out of a collective examination of those case studies, illustrate the many dimensions that must be addressed if we are to ensure that our reforms do not fail. In the rest of this section we make an attempt to identify what we believe are critical elements that must be present if significant district-wide reforms are to happen. Like the aviation system, we also believe that the absence of any of these critical elements puts the entire reform effort at risk. Before pilots take off, they go through a check-list, and <u>all</u> of the items must be passed. One does not attempt to fly if a mere majority of the things needed for safe flying are present. In educational reform, however, we often try to "fly the plane" if we have only one or two of the checklist items satisfactorily in place, while many others are likely to be absent in the foreseeable future. This leads us to undertake reform efforts that we Hope will bring about widespread and deep change in science teaching, but realistically have little chance of doing so.

One message, then, that is clear from this conference and from our other evaluation efforts, is that we need to be honest about what permanent and system-wide reform is really going to require. To date, we have not come close to providing the supports that are needed. As a corollary, we need to reconceptualize the rationale for investing in the kinds of projects represented at the Inverness conference. Their ability to bring about permanent and system-wide changes in teacher practice and student learning is highly limited, and thus their rationale and place in the larger and longer process of overall reform must be reassessed. The work they are doing is good and necessary, but it is far from sufficient if the goal is to establish sustainable, high quality, hands-on science teaching across an entire urban district. It is neither fair nor wise to expect that degree of change from these projects.

We draw upon the conference and also upon our own experiences in evaluating the programs in these districts to outline what might be thought of as a "checklist" for science education reform efforts. We do not see this "checklist" as providing a trivial prescriptive and/or mechanical way to implement reform. Rather, in this checklist we try and specify those critical elements of support that must be present if one is to have a reasonable chance of effecting significant and widespread changes in science teaching across an entire urban district. (Note that throughout this monograph we are assuming that the end-goal of these efforts is to have good hands-on science experiences that are rich in inquiry happening on a regular basis for all of the children in the district. The emphasis on "hands-on" and on "inquiry" comes from the participants themselves.) We also discuss the extent to which and the ways in which the districts involved in this effort have strategized to meet each of these elements.

The "checklist" can be broadly divided into four different domains of concern, each of which requires a wide array of supports that must be carefully engineered:

- Vision and Leadership
- Professional Support
- Curricular and Logistical Support
- Political and Financial Support

In what follows we discuss each of the critical elements of each of these domains in considerable detail. (The Checklist is summarized on pages III-32 and III-33.) We outline what must be in place, and we explore the experiences of the participants in their own projects as they seek to put these supports in place.

### *Vision and Leadership*

Like any other organizational development effort, the quality and efficacy of a district reform project depends upon the quality of its leadership and the power of the vision that shapes its work. The leaders of a reform effort must shepherd the effort through years of political and educational reform processes. The path that is to be followed is never clear ahead of time, and the activities of the project must unfold along the way, in unpredictable ways. In the chaos of everyday work, the leaders must be able to return to a guiding vision and purpose, or they can get easily lost in the myriad details of the political landscape in which they reside.

The leadership of a district science education reform effort may reside in an individual or be distributed among several team members, but that leadership must:

- be able to define and articulate a comprehensible and compelling vision of good science teaching, and, more specifically, inquiry learning.

- have a vision of science education that rests in a deep personal knowledge of and commitment to inquiry-based, hands-on science teaching. Simply put, leaders cannot share with others what they themselves have not deeply experienced.

- have a vision of the change process that is drawn from a deep understanding of the nature of the system they are trying to change, both in terms of its structure and culture. They must also have the capacity to think strategically about the change process, and design their efforts accordingly.

- be politically powerful. The leadership of the project should be closely connected with the leadership of the district. The project leaders must involve, or be able to work closely with, key district administrators and decisionmakers. Project leaders must possess enough stature to be part of the district's central planning process.

Again, failure on any one of these counts will severely limit the chance that a district-wide reform effort can succeed.

<u>Vision</u>

Because of the long history of inquiry-based reforms and curricula, the leaders of the district projects who came to Inverness were familiar with and committed to hands-on science teaching. The tenacity, creativity, and resiliency that was evident in the leaders of these projects was a direct result of their deep commitment to the importance of what they were trying to do for the children in their communities. They shared a belief in the power of inquiry-based science education and how it can provide a transforming learning experience for both teachers and students. More than a desire to teach the discipline, most of the leaders were ultimately motivated by the desire to provide young children in inner-city settings an opportunity to experience themselves as capable of learning and of making sense of the world for themselves. Science, for this group, was largely seen as a very good vehicle for letting children experience themselves as successful learners and inquirers. One participant described the project as her chance to make a real difference in the lives of the students:

> *I came to realize, my god, in doing science and inquiry, we are actually going to have a chance to do something that is going to let children really learn.*

The ways in which the project leaders expressed the visions of their projects varied considerably, but their individual project visions all tended to be complementary aspects of a more ambitious transformation of the practices and culture of schooling. Collectively, their visions included all of the following ideas: science as vehicle for a pure inquiry experience; science literacy as an overarching goal; science "for all children"; science as a way of recognizing children’s natural inquisitiveness; "every teacher should teach science"; science as an organizing theme for teaching all subjects at the elementary level; and science teaching as an example of reflective teaching practice.

The lofty visions of these projects have sustained participants individually as they have struggled to make real their project goals. Vision statements were really mission statements, and they have both energized and shaped projects.

> *The vision we have is bigger than the project....I think we all agree, everybody has to have the same underlying vision...then it isn't like just your work...then it is almost like it is your life...and you hate to say that, because it takes so much time....It really does. The vision is what drives you, and the people that don't have that same vision, they just don't end up putting in the time that it takes to get something to happen.*

Besides motivating the leaders, a clear and coherent vision was important in communicating the nature and importance of the project to others. In particular, communicating and sharing a vision of good inquiry-based science teaching with the district's teachers and administrators was seen as a critical first step in the life of these projects. This was usually accomplished through some shared experience of hands-on teaching and a subsequent discussion of the approach and its benefits for students. Throughout each district, this process of vision creation through "awareness-level work" has taken several years. A good deal of the work of their projects has been to help others come to understand and value the kind of inquiry learning that takes place in a good elementary science classroom:

> *So we found that the time it takes to keep reinventing the vision, and sharing it over and over...is monumental. Trying to get people to see what you see -- it is like waiting for a whale to surface -- you keep waiting and waiting and hoping that when it surfaces you will get to see all of it. But in the meantime you have to share the vision bit by bit with everyone who comes along....It is frustrating -- you have to start all over again every time new people come aboard...but the time it takes for them to come together, and to create that vision for the first time for themselves -- is so very important.*

The vision-making and vision-sharing was not, however, a process that one completed. Instead it was an activity that the project had to continually return to, almost like a home-base.

Leadership

Leadership and vision are closely connected. A lack of leadership and an absence of vision are both fatal flaws to any elementary science education reform effort.

Projects such as these depend heavily upon leadership that has a vision of good science teaching. The leaders of a project provide both the "floor and the ceiling" for what is possible in that project. Ultimately, participants must benefit both directly and indirectly, from the deeply-embedded skills and attitudes of project leaders. Similarly, it is unlikely that the participants' experiences will go far beyond what the leaders themselves have personally experienced. (This is the main reason why professional development for project leaders is so important.)

> *We can't teach inquiry unless we ourselves are having rich inquiry experiences. We cannot create professional development communities if we ourselves are not part of such communities...there is a real need for symmetry between project leaders, teachers and students...*

What became clear in the discussions at Inverness is that all of these districts needed to find more people who really understood inquiry-based, hands-on science teaching. The vision of good science teaching -- the images of children engaged with materials carrying out their own inquiries -- is far from current reality.

> *It's critical for teachers to see what good inquiry is; what real inquiry is...they need examples.*

Good examples are rare, and it was very difficult for these projects and districts to find teachers who could serve as teacher leaders in inquiry.

> *...we have to be more serious about how you find such people, how you create them, how you stimulate them, how you encourage them, how you educate them...*

In a district with thousands of teachers it is often difficult to find three or four who have a deep personal knowledge and experience in facilitating inquiry learning in science in their own classrooms. Unfortunately, the courses people take in college, their experience in teaching in the classroom, and the relatively scarce professional development activities in elementary science have not empowered many individuals to be leaders in this area. In fact, it is important to recognize that one of the most important outcomes of these elementary science reform projects will be the development of such individuals.

It is also clear that professional development in the domain of inquiry and leadership are important not only for teachers, but for project leaders, district administrators, and, very importantly, principals.

> *We are reconstructing teacher roles; we are reconstructing curricula; we are reconstructing a lot of things -- the role of principals is going to have to reconstructed also . The principal has to be really in the loop, not just casually as a member of the group, where they are "monitoring" instruction...but really in the loop, asking questions of children parents, community people...*

The leaders of the projects not only had to have a deeply personal and embedded vision of good science teaching, but they also had to understand the political and educational landscape in which they were working. The design of each project called for the making of a number of strategic choices and creating an overall change strategy that was tailored to the realities of their own district. Many of the leaders who were part of these projects had been chosen because of their love of elementary science. And yet, the major tasks they now face on a daily basis often have little to do with elementary science, but rather they lie more in the domain of program design and organizational development. Many times their work requires political expertise as much or more than it demands educational expertise. Thus, a deep love and knowledge of elementary science was a prerequisite for this work, but not nearly sufficient.

***Professional Support***

The highest priority for most projects was professional development. Project leaders realized that not only were they trying to bring the inquiry experience to the students in the classroom, but they were also facilitators of an inquiry process among the teachers in their project communities. They also realized that creating a culture of inquiry was a long-term process:

> *...our work requires a long term relationship with teachers...I also think the movement toward an inquiry approach -- both in the teaching of science and inquiry into the learning and the teaching process -- is something that happens, as far as I can tell, in stages. The development of inquiry skills and attitudes is very incremental, particularly with teachers who are in classrooms full-time.*

Creating a wide range of opportunities for teachers at all levels of sophistication was seen as essential to the success of the overall reform effort. The projects represented at Inverness all focused heavily on creating a multitude of professional development supports. To optimize the chances for district-wide implementation of hands-on science, the range of professional development activities optimally would include the following:

- opportunities for the leaders of the reform effort to continue to develop their own skills and to reflect upon their work with others engaged in similar work

- long-term professional development opportunities for a leadership cadre of teachers who can illustrate real, concrete evidence of hands-on science teaching in their own classrooms, and who can also provide professional support for their colleagues in both district and school venues

- long-term support for teachers who are just beginning the process of teaching hands-on science in their own classrooms

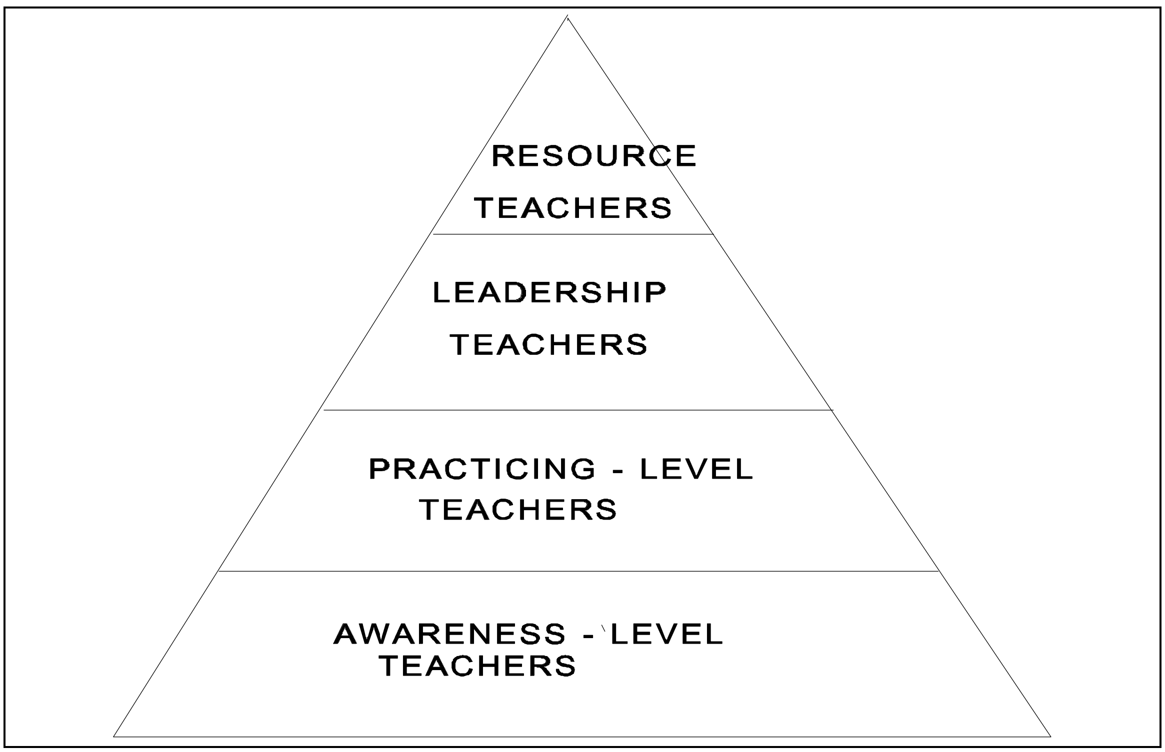
- introductory workshops and technical assistance for those who are completely new to hands-on science teaching

One shared, and almost unstated, assumption held across all projects was that teacher leadership was a key, if not the key, ingredient, in the reform effort. None of the districts, for example, designed their efforts around the idea of outside experts, e.g. university faculty, doing most of the work and/or being at the center of the initiative. Rather all projects and all districts in different ways based their change strategies on the premise of teacher leadership.

The projects attending the conference felt that they could not overestimate the value of teacher leadership, and ultimately, the importance of teacher ownership of the project. Though most of the project leaders knew teacher leadership was important before they even began the project, its critical importance was illustrated in concrete ways time and time again. The conference conversations focused not so much on the fact that teachers needed to "buy in" to the program, but rather on strategies for facilitating their participation in the effort, and then, in turn, finding them leadership roles so that they could help make the project happen.

> *We all knew that professional development would be the key to these efforts....But what we learned, I think, is that the teachers themselves need to be the owners of the project...*

Thus, the design issue for most projects was how to select, develop and empower those leaders.




In essence, each project sought to create a pyramid of professional development opportunities as shown in Figure 1. The pyramid allows teachers to move through developmental "stages of concern" as teachers become aware of, try out, and become expert in hands-on science teaching. Not only are appropriate opportunities needed at each level of the pyramid, but also there need to be connections between levels so that, for example, resource teachers can work with lead teachers; lead teachers can work with their grade-level representatives, and so forth.

In a comprehensively designed system, each layer of this professional development hierarchy has to exist and be fully supported. The overall effect of putting in place a functioning pyramid of opportunities is to create a system of professional development that can sustain itself by continuing to generate increased capacity in a cumulative fashion. That is, the longer the pyramid operates the more it strengthens itself and expands itself.

In the conference, many issues of teacher leadership were raised, ranging from strategies of identifying teacher leaders, to supporting the development of teacher leaders, to the design of opportunities for teacher leaders to support their colleagues.

Identifying teacher leaders

The selection and recruitment of teacher leadership is one of the most important, and perhaps most overlooked aspects of a district reform effort. Some projects ran into great difficulties when leaders were picked too early, or worse, were assigned to be leaders by the district, sometimes for the wrong reasons.

In many districts, project funds supported valuable growth opportunities for a group of skilled and committed teachers who chose to leave their classrooms and to become part of the project staff. Indeed, many of the key players of the reform efforts who came to Inverness were originally classroom teachers who had taken on the role of district resource teacher, or materials coordinator or science specialist. Thus, one key characteristic that all projects seemed to share was their agreement that the best teachers were to be identified, supported and asked to be the key agents of change. Given this central assumption, it becomes doubly important as to how and why the teacher leaders, who play pivotal roles in the overall project, are selected.

In general, projects had more success if project leaders were empowered to pick and hire the key teacher leaders. In its first year, one district assigned six resource teachers to the project, many of whom were not familiar with inquiry or skilled at working with their colleagues. In a bureaucratic fashion, the district had made the choices based on the fact that by law the teachers simply needed to be assigned to some district position. The impact of this less than optimal selection was that the entire strategy of the project, which relied heavily on the work of these district resource teachers, had to be revamped so that the lead teachers at the schools became much more important.
Also, it tended to work out better if projects did not have to pick leaders too early. The best leadership was found in those districts where leadership emerged from the work of the project and "rose to the top" in a more natural way:

> *In our first pilot school, we had teachers that we all thought were going to be the lead teachers, and yet as the project went on, some of them didn't turn out to be good leaders....So what really happens is that the people that start to form the same vision as the project, who become excited by this kind of teaching -- those are the ones that kind of rise up to be the leaders. You don't know necessarily who the leaders are going to be going in...*

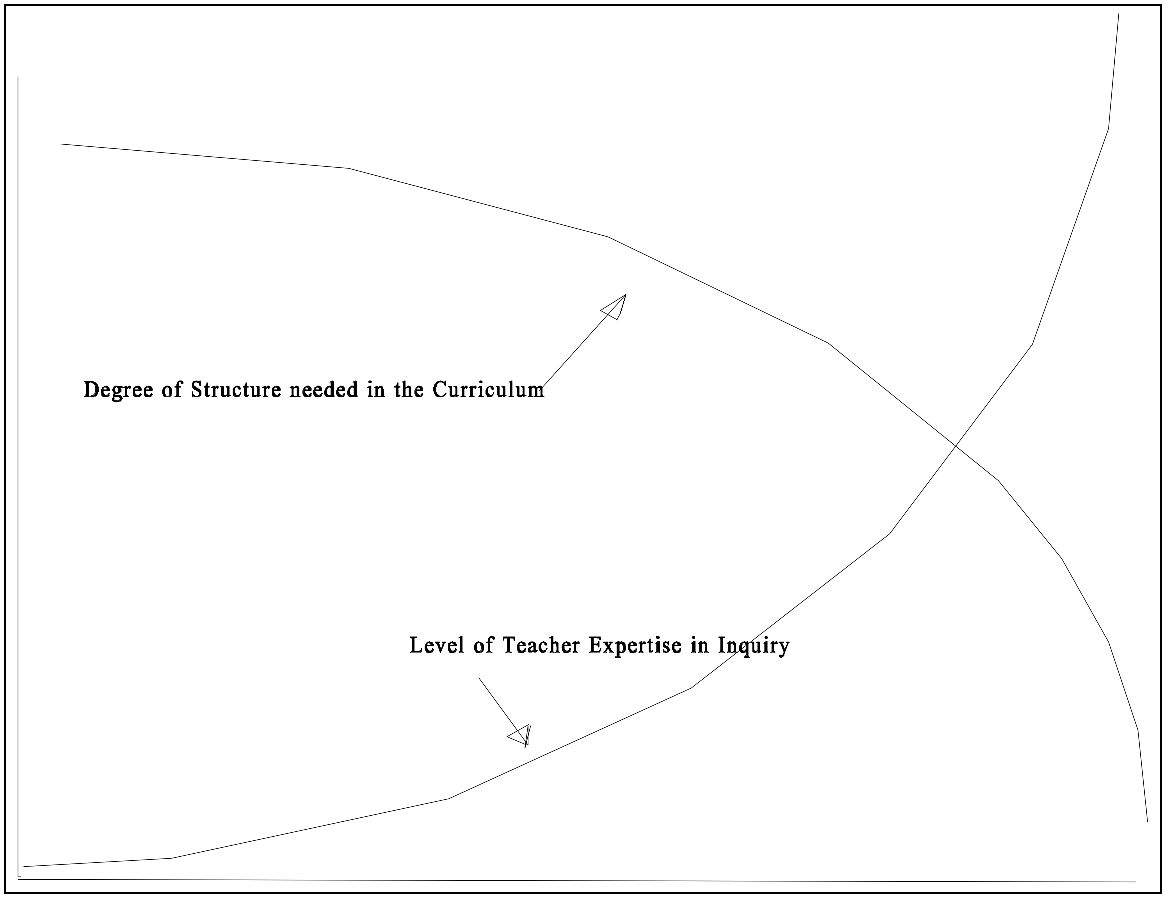
Supporting the development of leaders

One might think of both formal and informal ways of supporting leadership. More formal mechanisms involve institutes and workshops that push leaders to the next level, both in terms of their own classroom practice, and in terms of their leadership roles. However, it is also very important to realize that a lot of leadership development happens in informal and unstructured ways. Resources can be made available so that teachers are able to pursue their own avenues of growth. For example, we heard of teachers who met informally every Friday night to have an early dinner and discuss their own science reform efforts in their own school; teachers who team taught or otherwise assisted each other in their teaching; and many teachers who went to conferences or workshops on their own in order to continue pursuing their own interests in inquiry teaching. With a little forethought, projects can anticipate, encourage, and then support these initiatives.

Conference participants were in agreement about the general features of a high quality professional development program. Teachers needed an opportunity to have an "immersion" experience in inquiry learning. In these experiences they would be able to do inquiry themselves as adult learners -- learning directly from materials. In this way they would have an experience, not a unit, that they could share with their students. They would know what it feels like to be a student in a hands-on, inquiry-based science classroom.

Teachers also need professional development experiences that introduce them, in a safe environment, to good curriculum with appropriate and varied levels of structure. The more experienced the teacher, the more familiar with inquiry, the more knowledgeable in the topic area, the less the need for highly structured units. In fact, we found many very good teachers complaining about the constraints and the mechanicalness of many hands-on kits. By contrast, for those teachers, who don't like science, who are new to hands-on teaching, and who have had little inquiry in their own background, it was essential to have well-designed and highly structured kits. Both groups of teachers, in fact, need good starting points for their work; they just happen to be at quite different starting points. Even though both groups of teachers are at very different starting points, they all need an opportunity to experience and come to terms with the materials on their own.

*It is hard to step back and let them struggle. You want to go in there and you want to show them: "Yes, this is how you do it, just so you get to point B, or whatever"....But if you want ownership, you have to let them struggle with it and then let them achieve it on their own.*




Finally, all teachers need more than a "one-shot" experience, even if it is an extensive summer institute experience. (The fact that we feel a need to say this illustrates some of the simplistic assumptions about reform that exist in communities outside of those actually involved in the work.) Traditionally, professional development is often conceived of in terms of "institutes" and "follow-ups." Many of these district projects were thinking more in terms of professional development experiences being designed in ways that would contribute to the long-term and overall reform of science teaching in the district. Thus, leadership development efforts were conceived of, in some districts, as three-year efforts involving institutes, support in the classroom, seminars, and increasingly demanding roles in working with other teachers.

Importantly, professional development in some of these districts moved from being seen only as a technical endeavor (e.g. learning how to use a specific kit) to one that involved the building of relationships and community. That is, it was recognized that the development of the professional teacher happens through their informal interactions with each other and with other experts working in their field. Even if initially projects were more dependent upon “specialists,” ultimately the core activities of the project must be based on teachers working with one another. Thus, the work of the projects was not only trying to impart skills, knowledge, and attitudes to individual teachers; but also to build, and then support, a "learning community" of committed teachers.

One resource teacher who attended the conference remembered her own experience as a participant in the project and was clear about the importance of developing a project community in which teachers made real contributions to the collective knowledge-base:

> *Our project leaders really listened when we said, "This lesson can be improved by doing such and such"....There was nobody who pretended that they knew best...Then, later as a resource teacher, when I said, "We need your help," everyone was willing to contribute....People like to know, teachers like to know, that they are valued and what they learned is of value.*

The district leaders also pointed out that professional development needs to “build” on itself, but not sequentially in a lock-step manner pursuing an overly simplistic model of linear skill enhancement. Rather, professional development activities need to both reflect and take advantage of the advancing levels of experience of teachers in the classroom. Teachers need opportunities that integrate their professional work and their professional education. For example, during the first year of a district initiative, sessions might focus on the modular units, but eventually training must branch out to focus on second-order issues such as instructional methods, inquiry and the art of questioning, organizing for small group work, and so on. Reform issues that seem to emerge later in a project life often center around documentation, assessment and the development of original inquiry units. Designing and maintaining multitiered teacher training opportunities is one of the more complex challenges for districts, particularly as “new crops” are brought on board, and veterans need to be provided with the next challenge appropriate to their own growth.

Developing mechanisms and arenas for teacher leadership

It is not enough for a project to simply "train" and then designate teachers as leaders. The educational system typically lacks any structural supports for teacher leadership. There are no formally recognized teacher leadership roles or "niches" within most urban districts. Consequently, the project, working closely with the district, needs to create a variety of structured opportunities for teachers to work, and to learn from each other. Some districts created teacher leadership teams; others found coaching roles for teachers; others had teachers involved in various committees and task forces. The conversations at the conference raised questions about how projects could best support teacher leaders in working with other teachers in explicit, planned ways.

Teacher leaders talked eloquently about the difficulty of their assignments as "leaders." Although they shared the vision and excitement of hands-on science teaching, many of their peers did not. Moreover, many of their peers have seen many reforms "come and go," so that they are not swayed by the enthusiasm of the hands-on advocate. In inner-city environments in particular cynicism runs high:

> *I thought: "I have been around the block, I know staff development and I know inquiry"....I really thought that if I could share this enthusiasm and this special brand of sunshine and experiences, that other teachers would come along with me...and it turned out to be the closest thing that I have done to selling vacuum cleaners door to door...because the other teachers just didn't want it.*

Coupled with the structural barriers to leadership, the egalitarian ethic that pervades the teaching community makes it very difficult for teachers to assume designated leadership roles. Several sites mentioned that teachers not used to serving in leadership positions with their colleagues were reluctant to present themselves as more knowledgeable or experienced in a field. This discomfort was particularly acute for mentors when working with their former colleagues. (It is interesting to note that other professions have a great deal of peer interaction and education, but have not found it necessary to designate their relative status. There are, for example, no "lead doctors" or "lead lawyers.") Participants at a few of the sites acknowledged that even when they had fostered leadership opportunities for teachers, these teachers had not always been comfortable taking on these roles.

Solutions developed at some sites included having teachers from differing schools work in teams of two or three, so that their leadership responsibilities were shared. Another strategy was to assign teachers to work at schools that were not their own, or to make sure that when they visited their own school, that they were accompanied by a trainer from another school site. Many teacher leaders or mentors had to discover their own way to support their peers in their attempts at hands-on science, without seeming superior. The key notion here appears to be "collegiality" so that teachers are put in the position only of sharing their own experiences with their fellow teachers -- often humbly and with a sense of humor.

An issue for all the teacher leaders was the burden of doing "double duty." In many districts the issues of leader "overload" and "burn-out" were becoming increasingly severe. At the elementary level the strain is increased because good teachers are reluctant to leave their classrooms. The work of teacher leadership far outstrips whatever time or compensation the district can offer. Only altruism and a sense of mission keep these teachers going. One teacher participant at the conference even suggested that withholding information about the difficulty of reform was an essential part of recruiting good leaders. Her comment was intended to be humorous, but held an ounce of truth:

> *If my principal had told me when he first came into my classroom what this would be like..if I knew ahead of time what it would take to carry this project into this school and into this district, I would have said, "You can go over next door and try somebody else." So perhaps part of it is not telling the whole truth to the teachers early on....Yes, I think that not telling the whole truth is essential.*

Finally, the friendships that developed between these lead teachers and the project leaders turned out to be very important. Many relationships were clearly symbiotic, with both teacher leaders and project leaders benefiting greatly from each other. While each project was a technical effort -- a designed set of strategies and activities -- it was also a community. In some way the relationships developed were as important as all of the workshops that were given, as some of the teacher leaders expressed:

> *We all worked together on this project from the very beginning, when everyone was clumsy and not sure what we were really doing....And yet we all hung in there and worked together....There is a certain degree of trust and understanding that develops among people when this happens...*

**Some Current Myths About Professional Development**

It is possible to provide lead teachers with intensive summer institute experiences and follow-up sessions, and then expect them to "train" other teachers in their own schools in less time and in circumstances far less advantageous than those they had for their own learning.

Simply by assigning each school a lead teacher, the quality and quantity of the science taught in the school will increase.

Because teachers are in a workshop, they will teach what they have learned to their students.

Including principals in workshops along with a pair of lead teachers is equivalent to undertaking a whole-school change effort.

Two or three weeks is enough time to create a "lead teacher."

Teachers can provide their students inquiry experiences, although they themselves have never experienced themselves as inquirers.

Professional development can effectively take place on the margin -- after-school, on Saturdays, without stipends -- all done by lead teachers out of the goodness of their heart.

### *Curricular and Logistical Support*

A district-wide reform effort needs to include good curricula and to provide teachers with the materials needed to implement that curricula. While this postulate seems obvious, few of the districts represented at the conference were able to assure the needed supports in this dimension. In particular, we would argue the following are critically important ingredients for success:

- the identification, selection, and district-wide certification of a curriculum that is well- designed and compatible with inquiry-based learning processes

- a system for identifying, purchasing, distributing, sharing, maintaining, replenishing, and storing hands-on materials

- a system for providing realistic levels of support to teachers as they arrange hands-on learning experiences for their own students in their own classrooms

- a systematic way of scheduling time for teachers to engage in professional development, to work together as school or district teams, to handle the logistics of materials, and to schedule time for science in the context of the other demands placed upon them

Again, we argue that if any of these components are missing it will severely curtail the degree to which high quality, hands-on science teaching will actually happen throughout the district.

Curricula

The districts represented at the conference included some who had adopted pre-existing curricula in the area of hands-on, inquiry-based science (e.g. Insights, FOSS, STC), some who had developed original curricula, and some who were attempting a combination, with adaptation of prepackaged materials and development of some original lessons.

Curriculum development is a huge and difficult task. At least one district at the conference cautioned the others against taking on this dimension of work as part of an overall urban reform initiative. They, like others, found it extremely difficult to develop original and high quality curriculum. Their work resulted in uneven activities and writing, which ultimately required heavy editing. The process proved much longer and more labor intensive than they had anticipated. In retrospect, they testified that they would definitely not attempt curriculum development in the start-up phase of this project, when professional development activities are also under development. If districts decide to develop original curriculum, then they should be aware that something like an eight-year cycle is likely to be required from conceptualization to implementation of the curriculum.

If a district decides to adopt and use some of the published curriculum, there is good news in that there are more and more good materials currently becoming available. Also, such NSF-developed and commercially published curricula may be more acceptable to teachers and administrators because they can be formally associated with the National Science Standards under development.

Just as pre-packaged curricula may be viewed as more reliable and valid by some teachers, the piloting of the individual units of these curricula can be a strategy for introducing science reform in a district. In several sites, these experiences as "pilots" for new curricula ended up being the crucial foundation for the project. Also, such pilots can provide a strong demonstration to the district about the viability of hands-on, inquiry-based science.

Many of the projects had struggled with their own districts around curricular issues. In particular, they frequently encountered adoption policies and traditions that chose materials incompatible with the goals of the project; they found districts unwilling to let go of traditional textbooks, science fairs, and other long-held rituals of science instruction; and they found themselves having to deal with the strongly held notion that the elementary curriculum should be interdisciplinary and thematic. All of these forces tended to dilute the priority of many of these projects which was to provide young children with an opportunity for science inquiry learning.

Materials

*What is a an inquiry-based, hands-on science reform effort without materials?*

Materials are the Achilles' heel of hands-on science teaching. Schools are places that are set-up to handle books, pencils, and papers. Some schools have special places and resources for physical education or drama; they have baseball fields and auditoriums. By contrast, very few schools are prepared to handle the needs of elementary science education in terms of materials.

Many, if not most, of the participants had undergone a complex series of learning experiences concerning the development and dissemination of materials in their own districts. This was one area where simultaneous sensitivity to quality issues, resource possibilities, and political realities were all paramount.

The experiences that the districts described at the conference illustrated several common issues and dilemmas. The selection of a published curriculum (e.g. FOSS, Insights, BSCS) facilitated the selection of materials (they are published and integral to the curricula).

However, the kits associated with these curricula are quite expensive and also large. Thus, initial expenditure (outlays), storage, sharing, and replenishment become major issues.

The selection of modules, kits, and materials from multiple sources (e.g. NSF curricula projects, AIMS, other commercial publishers) -- a kind of "mix and match" strategy -- can help customize science to individual schools, and lessen the cost. However, it also adds to the complexity, and makes the issues of purchasing and maintenance at a central level much more difficult. Moreover, the greater the number of different curricula involved, the less likely it is that the district will be able to play a useful central role.

The "science on a shoe-string" or the "grassroots scrounging approach" describes the reality in some districts where the district purchases the curricular (written) materials but the leadership teachers (or all teachers) must find the materials on their own. This approach reduces costs to the district, and minimizes hassles with the district bureaucracy. Joint efforts to get materials can even serve as a useful shared task or rallying point for the teachers in a school, but the constant need to find and handle materials greatly raises the threshold for individual teachers to teach hands-on science. Ultimately, this approach is not viable for a district-wide effort.

Closely related to the whole issue of selecting and purchasing materials were issues of distribution and ownership. Should materials be distributed and maintained at a central district resource center? Should individual schools be the owner and maintainer of materials? Or should individual teachers (or groups of teachers) have the locus of control? The district resource center is an appealing approach because of the benefits of centralization. On the other hand, if and when the district has financial difficulties or changes in priorities, the entire science program can be eliminated by a change in a line item of the budget.

There are strengths and weaknesses in all of the different approaches to distributing, storing, and replenishing science materials. These correspond to the strengths and weaknesses of centralization and decentralization. In fact, the issue of materials is so overwhelming that it is almost ignored by many districts, or simply, by default, left up to the teachers and schools to handle. Most districts would be lucky to get any system in place. To date, the issues around the provision of materials for hands-on science remain largely unsolved for urban districts.

Logistical supports for teachers

It is important to realize that good hands-on science is a labor and material intensive endeavor. In our own evaluation efforts, and at the conference, we have come across examples of very successful instances of hands-on, inquiry-based science teaching. What is common about these examples is the "infrastructure" that underlies the teaching situation. The following story is true and points out both the potential and fragility of good teaching situations:

> *In a particular school, the principal asked her small staff, "What is it that is keeping you from teaching hands-on science?" She then designed a system of supports addressing each barrier the teachers identified. The system they evolved not only made it possible to teach hands-on science, but it actually made it difficult for a teacher not to succeed.*
>
> *With the help of a supplementary grant the school set up a science room and purchased high quality kits to support the curriculum they chose. They also hired an aide who was excited about science teaching, and whose job it was to make sure that the room was ready and prepared for the teaching sessions which were scheduled every week for all teachers and their students.*
>
> *Each teacher brought their class to the science room twice a week at a pre-scheduled time. One-half of the students worked in an adjacent computer lab while the teacher conducted a lesson from NSRC, or Insights. In this way, the teacher taught each lesson twice each week, but had a manageable number of students to work with each time. The aide not only set up the materials but helped the students during the lesson. In informal ways the aide, who knew the lessons well, coached the teacher where necessary.*
>
> *In addition to the aide, there was a lead teacher in the building who helped with the overall program. Importantly, there was also a full-time resource specialist -- a woman who was very energetic and supportive of many of the school's reforms including the science reform project.*
>
> *In this setting where the logistics were handled, where time was allotted, where good curricula and units were in place, and where there was a uniform and explicit expectation about the teaching of science, hands-on science succeeded. Teachers who told us they "did not like science" were now enthusiastic about the successes they were having, and they were particularly moved by the way their students were responding to the opportunity. It is important to note that the teachers were doing the teaching, not a specialist. Some teachers extended the lessons back in their own classrooms.*

> *Unfortunately this story does not end happily. In the past year the supplementary grant has expired, and the aide is no longer at the school. Because of political changes in the system, the principal and the lead teacher have been moved to another building. The resource specialist has been returned to the classroom. The future of the science room is not clear, and the degree to which science is now being taught is unknown.*

The case described above illustrates that it is possible, at least on a school level, to engineer the supports needed to ensure successful hands-on science teaching. The degree of support present in this setting made it difficult for the least knowledgeable and least confident teachers to fail. By contrast in most other settings it takes the heroic actions of the most capable teachers in order to succeed. This story also illustrates, regrettably, that once in place urban school districts may not be able to sustain such supports.

Time for elementary science education

In many surveys that focus on elementary science education the barrier that is rated the highest by classroom teachers has to do with time. Just as there is no space in elementary schools for materials and kits, there is also no time in the school schedule for all of the activities that are part of an elementary science education reform project. Time is a crucial factor to the effective establishment of hands-on science teaching. Some "times" that are needed include time for lead teachers to do their leadership work in their own schools with their own colleagues. This includes time for them to plan with other teachers, time to visit their classes, time to have grade-level meetings, time to handle the materials issues, time to meet with the principal, and time to meet with the parents. Lead teachers also need extensive amounts of time to continue their own development through institutes, network meetings, attending conferences, and informal work with other teachers.

There is also time needed for other teachers (non-leadership) to attend inservice events where they have the chance to learn about specific kits and materials. Back at their schools, they need time to review the units, and adapt kits and materials for their own classes. They need time to set-up and take-down the materials for each lesson; they need time to attend school and grade-level meetings; and not insignificantly, they need time to reflect on their own teaching.

Most difficult, perhaps, there needs to be time in the day for teaching science. Too often, science is relegated to the afternoon where it may or may not happen. Time is the real measure of priority. Districts and schools will have to be much more explicit about how much time is to be spent on science, and then provide the support to make that expectation realistic.

The scarcity of "time" in schools reflects the marginality of science, of professional development, of teacher leadership, and indeed of educational reform. The current school system is set-up to operate with very little redundancy or extra capacity. The system has no slack, no extra capability, and no room for changes. The current system is designed to operate, not to adjust itself. This makes the job of elementary education science reform much more difficult.

### *Political and Financial Support*

Up to this point we have argued that for there to be a realistic chance for widespread teaching of inquiry-based, hands-on science across an entire district, there have to be a number of critical elements in place in terms of leadership and vision, professional development, and curricular and logistic support. In turn, for these elements to be put in place, and for them to be sustained by the system itself without the external support of the project, there has to be an underlying foundation of political and financial support for science reforms. A new science curriculum, especially one that is a dramatic departure from the current practices of elementary science teaching, requires an acknowledgement of the changes that are to be made, and explicit, unambiguous, and broad support for those changes. More specifically, the reform effort must establish:

- clear and shared expectations at both the district and school level as to how much science is to be taught and what the nature of that teaching is to be.

- a clear understanding of and acceptance of inquiry-based science in the district and the broader educational community.

- a broader community of parents, school boards, journalists, etc. that understands, supports, and even demands, good hands-on science teaching as a "basic" subject at the elementary level.

- an assured system of district and school-level financial supports for leadership, professional development, materials, and other elements required to overcome barriers to the teaching of hands-on science.

- a willingness and commitment to identify and remove systemic barriers to good hands-on science teaching e.g. inappropriate testing, textbook adoption processes, contradictory district policies, and lack of materials.

These elements are all manifestations of an underlying, broadly-shared and serious intention to make hands-on science a basic staple of elementary schooling. Again, if any of these elements are missing, it is unlikely that there will be a base of support strong enough to create the capacity for good hands-on science teaching; nor is it likely that science will find a substantial place in the curricula; nor is it likely that any successful instances of good teaching will be sustained.

It was clear from the discussions in Inverness that political considerations were paramount in the work of the reformers. Simply put, project leadership could not avoid district and school politics, nor could they overestimate the extent to which political issues impacted their efforts. As we have noted earlier, reforming a district turns out to be more of a political task than an educational one. Not surprisingly, the projects at the conference found themselves fighting very similar political battles.

Gaining district-level support

Enlisting the authentic support and genuine participation of upper levels of the district leadership was seen as a critical issue in most of the districts represented:

> *I would say to others that the most important thing to do -- right when you are working on a grant -- is to get the involvement of the superintendent and the Board members....I can't stress enough the importance of getting the involvement of the upper administration at the beginning; and don't narrow it to the discipline, because that can create artificial competition with other disciplines....You have to cultivate the administration's ownership right from the beginning.*

Participants agreed that it was important for projects to begin their efforts with the goal of developing, from the very start, a broad ownership of the reform effort, both at the administrative and grassroots levels. Their advice to other districts would be to try to get administrators on board as well as significant Board members, appealing as much to their personal interests and ambitions as to their sense of altruism.

> *I think another key element of this reform effort is top-level support, what I call "authoritative" support....Our school board has embraced this program; our superintendent has embraced our improvement efforts; and the assistant superintendent as well as all of the supervisors of the elementary division have embraced this program.*

Involvement of principals has also turned out to be very important. Principals are key to combining discipline-based reforms (e.g. science) with overarching whole-school change efforts (e.g. restructuring). Project relations with principals helps clear the way for teacher experimentation in their own specific schools. Additionally, a group of articulate and committed principals can be a powerful force in the district in terms of setting priorities and making the case for science reform as a top concern. Finally, principals can create bases for reforms in their own schools that can provide the reform effort with some inertia to help keep it moving in turbulent times:

> *If there is success in building the capacity for good science teaching at the school-level, then, in theory, the disruption of the constant changes that happen at the district level are not so critical.*

Beyond administrators, there is also political power in the collective voices of teachers. A cadre of lead teachers, who are articulate and outspoken about the importance of science education reforms, can also be a powerful ally at the grassroots level.

> *After about four years we now have a teachers union that sees this program as beneficial to the welfare of the teachers...because our teachers have been consistently telling them that...*

Gaining outside support -- partnerships

Political support for the science reform can also come from outside the district. This is where partnerships are important. Three examples from the conference were quite powerful.

In one case, a prestigious university partnered with the district to have scientists help with workshops and in the classroom. Normally, one thinks of the benefits of such a partnership in terms of the support of the individual scientists. But equally or more importantly, was the voice of the university as it advocated for the program in its relationship with the district. That is, an outside voice pushing for the reform project probably had more clout in this case than the pleas of those inside the district working on the project.

A second example illustrates both the benefits and dangers of outside support and advocacy. A prestigious science museum provided support for the district in terms of the in-depth institutes on inquiry. They also housed a "teachers in residence program" whereby two district teachers lead workshops at the museum and work with their colleagues in their classrooms. However, in another project, a university also working with the district has had political difficulties in advocating for their program. Because they bring a model of reform incompatible with the district's own vision, the district felt their outside voice was too strong, thus in some sense challenging the district's right to design and govern its own reform effort. The impasse has caused considerable friction and, until recently, lessened the degree to which the university has been able to contribute to the overall science effort.

In a third case, teacher's unions served as an outside force that put a severe constraint on the elementary science reform effort. This particular district had developed a whole system for providing professional development only to run into union opposition as it "requires teachers to work without pay." The teachers, themselves, wanted to participate, but larger systemic forces made this impossible.

The notion of "partnerships" was one that most projects believed in, but they did not always know how to create and sustain them. Collaboration is a very time-consuming and politically difficult process. There is always the danger of partnerships and collaborations being "all dressed up with no place to go." That is, the raison d'être for the collaboration is never completely clear, nor therefore are the roles and responsibilities of the separate partners. Finally, of course, the partnerships must be symbiotic. Currently, the belief in the notion of partnerships exceeds the ability of most projects and districts to create and sustain successful examples of them.

Gaining community support

Another kind of partnership that projects thought about was with the community itself. "Public relations," though not often considered a critical part of the plan itself, was repeatedly suggested as an issue which should be recognized as very important in facilitating the widespread implementation of a hands-on science program in a district. Participants increasingly recognized that as their efforts expanded beyond a pilot stage, that they would need the broad support of the community and parents. Certainly, one could not risk their opposition. The technology for generating such support, however, is relatively primitive. Conference participants could only brainstorm about such ideas as using the news media, generating video tapes of good classrooms, conducting Family Science classes and creating newsletters.

> *We need much more public awareness and public education...we really need to change the perception of why we are doing things differently, and share with people why we think there is a better way for kids to learn...*
>
> *If parents are aware of our efforts, and know what good science teaching is supposed to be, and agree with our goals, they can be a force in our efforts by helping to keep a light shining on the project and keeping it visible in the district...*

Connecting with other reforms and trends

It also goes almost without saying that those who attempt to initiate district-level reform need to be able to interpret political trends so that science reform is consistent with, or better yet anticipates, other district-level priorities and trends. In one district, the project strategically anticipated science reform in the district, planning for several years ahead so that the district would be ready to capitalize upon the science adoption cycle. In another district, the pedagogy of the elementary science program was seen as a model for reforms in other subject areas, as well as for a local middle school reform effort. Thus, the district investment in science was partly justified in terms of this multiplier effect on broader district reform efforts.

The state-level context is very important to most of these projects and districts. Many states are currently overseeing and promoting educational reforms. The state frameworks, as well as the national standards, can help provide additional credibility for experimentation in science teaching. According to participants, district-level reformers need to attend to changes in the state-level context, and look for ways in which they can anticipate and build upon these within their own districts. For example, several of the districts were able to justify their science agenda on the basis of state curricular reforms which in turn, are based on national efforts, described in Project 2061, and Goal Four of Education 2000, calling for U.S. students to be ranked first in the world in science and math. Related reform efforts in subjects such as math or environmental education, or in instructional goals such as critical thinking, can also bolster arguments for hands-on science education.

Some projects were successful in drawing other funds to support their work. Participants mentioned using funds from mentor teacher programs and school restructuring initiatives to support school-based efforts. Other districts mentioned using Chapter 1, Chapter 2, Eisenhower, Migrant Education and Title VII funding to support their efforts. Both politically and financially, science reforms cannot afford to remain isolated. If they are not successful in attracting the political and financial support of other broader and more generic reforms, it is not likely they will achieve a long-lasting, district-wide impact.

Coming to terms with assessment and accountability

Perhaps the greatest surprise at the conference was the degree to which the conversation focused on issues of assessment and accountability. It was a very strong emotional issue for many of the project leaders. Many, in fact, were angry at what they saw as the counter-productive effects of the calls for accountability and assessment. Assessment and evaluation are clearly two areas where the politics play themselves out in a very concrete and dramatic fashion.

Currently, at the national level, and also at state and local levels, there is a prevailing belief in "standards-based" reforms. That is, reforms should be driven by clear outcomes of what students "should know and be able to do." This translates, sometimes, into simplistic practices of student testing and program evaluation. No one at the conference was happy with the current state of affairs in these domains, and they felt that these were areas that had large implications for the work of their projects.

The ways in which assessment and evaluation practices affected their projects were multiple. Within some districts, projects faced testing practices that interfered with their reform efforts. In these districts there were science tests that were seen as inappropriate for an inquiry-based approach, and that re-enforced the need for textbooks that "covered" many topics. In some other districts, there was such a heavy emphasis on the testing of reading and writing that it was difficult to make science a priority.

From a student assessment perspective, the possibility of a student who has experienced inquiry-based science scoring less on a traditional standardized test than a student using a textbook is possible. Yet, alternative tests based on hands-on instruction are not yet well understood or available.

One participant posed a formidable challenge:

> *In doing real science there is an understanding that the kids won't always discover the right answer the first time. They will, if the inquiry is good, pursue their own questions about the things they study....What then should the students have learned? If we can't measure these things for all students in a uniform way, how then do we know what we taught or prove that our process is a good one for students?*

Most projects were also disturbed by what they saw as a tendency toward over-simplicity when it came to measuring the impacts of their own projects. The projects did not feel that the capacity-building nature of their efforts was recognized by those calling for their evaluation. Most projects conceded that in most classrooms in their districts after the end of their projects, one would <u>not</u> find a steady diet of goods hands-on science teaching. They felt their projects were providing an important contribution to the capacity of the system, and they were starting to put in place an infrastructure for good hands-on science. They were not, they argued, in a position to manage all of the variables required to support district-wide, inquiry-based science teaching:

> *What a teacher does in a classroom, is shaped by a million things -- and one tiny source of variance is the professional development experience they have. So I am cautioning us against trying to pretend that professional development can do it all....If you want to do a political thing, then do a political thing, but don't pretend you are doing anything scientific by "testing" the effect of professional development*

> *experience on student achievement. It think that is very bad science, almost invariably.*
>
> *I understand the demands for accountability...but I am just worried about trying to play that game and meet those requirements in the terms they are given to us, when in fact the work we are doing is not going to contribute directly and immediately in a causal way to those measurable student outcomes...*

Conference participants examined the issue of measuring student achievement and how it might be used to indicate the success of their projects. While some discussed their exploration of student performance or alternative testing tools as ways to "prove" the success of their efforts, the focus of most conversation was directed more toward the incompatibility of traditional student achievement measures and the character of their long-term systemic reform efforts.

> *Particularly early on in the project, I would say you can't measure student achievement because, in fact, there isn't any -- you can't measure it because you are seeing something very different happening. Our work is not immediately getting to students. So I wouldn't bother trying to measure student achievement because it's not there yet.*
>
> *One of our funding agencies wanted proof that their money was being put to good use and wanted to see some test score results. We did some pre and post testing. But, frankly, this is really kind of phony data.*

There was a real ambivalence about how best to deal with the existence and power of this "accountability movement." Some participants found themselves wishing for science tests so that their subject would get the same degree of attention from teachers. There was some hope that performance assessments and portfolios might actually encourage more hands-on teaching. In this view, district-wide science testing was perceived as a useful mechanism for mobilizing recalcitrant elementary teachers into teaching science in their classrooms. Many teachers, especially those working in urban districts, want to be sure to be in compliance with existing system regulations. More importantly, many teachers genuinely want help in knowing how their students are doing. Some participants felt it was ultimately hopeless to resist the pressures for accountability and assessment, and argued rather that the science reform movement should try and take advantage of it, assuming a significant role in developing alternative kinds of assessments.

Other participants in the conference, however, were advocates for ignoring or even resisting the testing of science at the elementary level. They saw the testing culture to be "generally perverse," undermining of good classroom instruction. They argued that one would never see good inquiry or constructivist teaching simply because teachers feared doing badly on district tests. These participants felt that all testing and assessment that is used for system accountability should be rejected outright, because they felt testing should not drive instructional practice, particularly in the area of inquiry.

> *There is a tendency to look at these hands-on modules the way you used to look at a textbook, where you memorized the names of things....Let us say there is a kid who has done this electrical circuits hands-on module....Should he be able to instantly tell the difference between a "series" and "parallel" circuit...in some way we continue to make the same mistake. We try to assess what children ought to have learned, rather than study what they actually learned...*

One recommendation that everyone seemed to feel comfortable with was using more alternative methods to document what takes place in hands-on science classrooms. Suggestions included videotaping, using student and teacher portfolios, doing case studies -- in essence “making pictures” that are narrative and visual about what is happening in science classes. Participants applauded the national movement towards so-called "performance based, alternative or authentic forms of assessment" but also recognized that this is a complex and emerging field. To date, it seems these assessments have had no real track record in terms of feasibility on a large scale or in terms of their being acceptable for purposes of accountability. Some continue to worry that even the best performance-based assessments, when used for accountability purposes, risk perverting classroom instruction as other, more content-driven tests have done in the past.

Overall, there was a sense amongst conference participants that they needed to be more clear about the nature of their enterprises and more assertive about evaluation measures that are, and are not, appropriate to their efforts. To date, many felt that they had tried to "jump through the assessment hoops" that were put in front of them, even though they made little sense and were based on incomplete, simplistic, and faulty logic. There was an emerging sense of militancy about the whole issue of assessment and evaluation:

> *We need to be more proactive about debunking the science assessment/accountability piece.*

### ***Summary of the Critical Elements***

The previous sections discussed the critical elements needed to assure the existence and sustainability of high quality, hands-on science teaching across the district. The picture that was painted is, in one sense, quite depressing if you accept the fact that all of the critical elements described up to this point must be in place for good hands-on science education to happen system-wide, and you also realize how far we are from assembling all of the requisite supports.

As discussed earlier in this monograph, it appears that as a nation we have not yet realized the tremendous differences between the different phases of research and development. The third phase -- instituting reliable, ongoing, system-wide practice is a very different endeavor than creating isolated instances of success, a second phase activity. The district reform projects which came together in Inverness are, in reality, projects of the second phase. Their goal is to create instances of success within the district, albeit large scale and multi-year. To a large degree, they have done this well and they have started to move the system toward a place where it might be ready to begin looking at creating system-wide supports. The current projects are not, however, positioned to create a reliable system of hands-on science teaching throughout the district. Districts are not capable or ready to sustain good hands-on science teaching as a regular part of their daily business. Perhaps one of the most important lessons learned from these projects is that, like in aviation, the development of large scale reliable systems is a huge task, and one that has to be engineered very deliberately. So far, as a nation, we do not seem to have the incentive or the will to honestly address this engineering task. We are willing, and indeed we insist that it be done in our aviation systems. For example, we are not willing to fly on airplanes that are part of projects that are trying to create a few instances of success. Someday we will have to realize the "crashes" that occur every time a school or teacher fails, are as destructive as the more visible and dramatic crashes of airplanes.
The charts that follow provide a summary of the critical elements posed in the form of questions. Following them is a comparative (fictional) set of questions relevant to the aviation system. It is illuminative to see the difference in approach and mentality that exists in the societal attitudes, and the resultant commitment, toward the two endeavors.

**A Checklist for District-wide Elementary Science Education Systemic Reform Projects**

**Critical Questions**

*Districts must be able to answer all of these questions if there is to be any reasonable expectation of sustainable, district-wide, hands-on science teaching.*

**Vision and Leadership**

Are there leaders in the district who:

- have a deep personal knowledge of and commitment to inquiry-based, hands-on science teaching?
- are able to define and articulate a comprehensive, compelling vision of good science teaching and inquiry learning?
- understand the nature of the system they are trying to change, and can think strategically about the change process?
- are politically empowered because of their connections with the leadership of the district and have enough stature to be part of the district's central planning and decision-making process?

**Professional Support**

Is the district developing and supporting a "pyramid" of teacher leadership opportunities where there are:

- opportunities for leaders of the reform effort to deepen their own skills and to reflect upon their work with others engaged in similar work?
- long-term and ongoing professional development opportunities for a cadre of leadership teachers who are committed to inquiry and willing to serve as resources to their colleagues?
- continuing workshops and classroom support focusing on the teaching of specific units for teachers who are in the midst of developing their own classroom skills and building their own repertoire of hands-on activities?
- introductory institutes and workshops for those who are new to hands-on science teaching?

**A Checklist for District-wide Elementary Science Education Systemic Reform Projects -- Critical Questions**

*Districts must be able to answer all of these questions if there is to be any reasonable expectation of sustainable, district-wide, hands-on science teaching.*

**Curricular and Logistical Support**

- Is there a process for identifying, selecting and achieving agreement on a high quality curriculum that is well designed to support inquiry and be feasible on a large scale?
- Is there a district-wide system for identifying, selecting, purchasing, distributing, sharing, maintaining, replenishing, and storing hands-on materials?
- Is there a system of supports (e.g. aides, parent volunteers, supplemental funds) for teachers as they arrange hands-on learning experiences for their students?
- Is there time allocated for teachers to engage in professional development, to work together in school teams and/or district networks, and to handle the logistics of the materials?
- Are there specific times allocated for and reserved for science teaching in the school schedule?

**Political and Financial Support**

- Is there a clear, shared and explicit expectation at both the district and school level as to how much science is to be taught, and what the nature of that teaching is to be?
- Is there broader community support for, and a demand for, good hands-on science teaching as a priority ?
- Is there a system of continuing financial support for professional development, materials, and other requisite supports?
- Is there a willingness to identify and remove systemic barriers to good hands-on teaching (e.g. testing policies, textbook adoptions, etc.)?

**A Comparative Checklist Contrasting the Aviation and Educational Systems**

It is interesting to compare how one answers these questions for the aviation system with how they might be answered in the educational system.

- Has the aircraft (curricula) that are permitted in the system undergone extensive design and testing work?
- Is there an extensive system of initial professional development for pilots (teachers)?
- Is there a system for ongoing professional development for pilots (teachers)?
- Are there sufficient logistical supports so that pilots (teachers) can perform their essential duties without distraction?
- Is there built-in redundancy in the system so that there are back-ups for critical parts of the system (e.g. two pilots, back-up instruments, double controls, etc.)?
- Are there sufficient resources in the system so that the system can operate as it is designed?
- Are there logistical systems in place for handling all of the necessary "materials" (e.g. fuel, food, charts, luggage, etc.) involved in the operation of the system?
- Are there systems (e.g. air traffic control) to monitor and safeguard the progress of each flight (school)?
- Is there broad community support for maintaining a high-quality system and for doing whatever is necessary to avoid failures?
- Are there systematic inspections and other mechanisms for <u>anticipating</u> failures and avoiding them before they happen?
- Are there systematic investigations and other mechanisms for reviewing failures and avoiding them in the future?