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Networking for Leadership, Inquiry, and Systemic Thinking: A New Approach to Inquiry-Based Learning

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Recent changes in science education standards have mandated a prominent place for inquiry learning in science curricula. However, change from traditional teaching methods to a more inquiry-centered approach is difficult to enact. While research to date demonstrates a number of successful inquiry implementations, it also reveals a slow rate of change along with possible reasons for difficulty in adopting inquiry instructional methods. Further, inquiry reforms have failed in the past. The Networking for Leadership, Inquiry, and Systemic Thinking (NLIST) initiative, sponsored by the Council of State Science Supervisors and NASA, proposes to facilitate inquiry through systemic reform designed to avoid the mistakes of the past and incorporate new knowledge about teaching and learning. Systemic elements targeted for change include a standard conceptualization of science as inquiry, instructional materials, professional development, administrative support and leadership, facilities, community involvement, and technology infrastructure. To date, the initiative has created a detailed definition of inquiry learning and a rubric for evaluating instructional materials against this definition. This paper presents the theoretical and empirical foundations for the NLIST initiative, describes its progress, and outlines future goals.

KEY WORDS: inquiry; science education; systemic change.

INTRODUCTION

Over the past 8 years, the science education profession has achieved two important milestones: the Project 2061 Benchmarks for Science Literacy (American Academy for the Advancement of Science [AAAS], 1993) and the National Science Education Standards (National Research Council [NRC], 1996). With the advent of these documents, arguments over what science content students should learn have subsided. Additionally, 49 states now have adopted their own science education content standards, derived from the Benchmarks and the National Science Education Standards (NSES).

A prominent feature of these new Standards is inquiry. The NSES contain substantial inquiry components, asserting that students acquire the abilities to conduct scientific investigations and understand how inquiry works. They also set forth standards for teaching scientific inquiry. According to NSES,

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (NRC, 2000, p. 1)

This definition, along with the standardized expectation that inquiry must occur in classrooms, provides an important impetus for the reformation of science education. In an effort to increase understanding of inquiry, the NRC produced *Inquiry and the National Science Education Standards* (NRC, 2000), popularly known as the "Addendum." However, lasting and pervasive reform requires more than

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standards, definitions, and guidelines alone. The definition presented above needs elaboration. Although the Addendum provides exciting examples of classroom inquiry, reproducing these results in typical science classrooms under prevailing conditions is difficult. A teacher motivated to use inquiry learning is faced with a number of questions: How might an educator identify instructional materials that support inquiry? What strategies make inquiry learning manageable and productive? On a broader scale, what components of the educational system need revision from an inquiry perspective if it is going to improve?

A new initiative called NLIST[4] (Networking for Leadership, Inquiry, and Systemic Thinking) has been launched to facilitate the implementation of inquiry at the classroom level. Sponsored jointly by the Council of State Science Supervisors (CSSS) and the National Aeronautics and Space Administration (NASA), the NLIST vision has initiated creative and collaborative networking processes to encourage more effective science education program implementation. The purpose of the NLIST initiative is to describe the ways in which key system elements need to change so as to implement science as inquiry. In this paper, we seek to begin a dialog regarding important questions addressed by NLIST. To do so, we will first explore some of the research supporting inquiry as an instructional model, followed by some possible explanations of why it has failed as a reform effort in the past. We then examine theoretical and empirical underpinnings of systemic change theory, synthesizing them with a description of how NLIST expects to apply them to enact these changes.

THE VALUE OF INQUIRY IN SCIENCE EDUCATION

Few professionals in the science education community today believe that science education should exclusively involve rote fact recitation at test time. Inert knowledge devoid of deeper conceptual understanding limits the application and transfer of knowledge to new and unique situations. Many scholars agree that while relevant prior knowledge is a prerequisite for construct development, content knowledge alone does little to advance the habits of mind and comprehension of the scientific process that we wish to develop in our students (NRC, 2000). At least since the days of John Dewey, inquiry learning has been suggested as a solution to this problem.

At its core, inquiry embodies the scientific method. Students participate in experiments and investigations that require them to develop questions and hypotheses, collect data, analyze data, and draw and test conclusions. Inquiry learning typically seeks to excite curiosity in students, encouraging them to investigate questions on their own initiative and grounding this activity in authentic situations. In addition to the basic abilities of conducting a scientific investigation, inquiry learning should include an understanding of how scientists do their work (NRC, 2000). As part of these two key elements, science inquiry should engage students in the overall evaluation of existing and evolving scientific knowledge.

Working from this basic and traditional understanding of the nature of scientific inquiry, substantial research supports the efficacy of inquiry as an instructional model. The Addendum presents some of these research findings, drawing heavily upon Bransford *et al.*'s report called *How People Learn* (Bransford *et al.*, 2000). This comprehensive report provides not only key research findings regarding inquiry, but also explanations for why inquiry has enjoyed success as an instructional method

- Understanding science involves more than obtaining a knowledge base alone, including comprehending what these ideas mean, application of these ideas, and strategies for scientific thinking and problem solving
- Students build scientific understanding (as well as misconceptions) at least in part upon observations they have made about the world around them
- Students modify scientific understanding when they discover conflicts between their observations of the natural world and their understanding, adapting new explanations that seem plausible to them
- Learning is a social activity, and students specifically "benefit from opportunities to articulate their ideas . . . challenge each others' ideas, and in doing so reconstruct their own ideas" (p. 119)

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- Powerful learning situations involve metacognition, initiative, choice, and some degree of control on the part of the learner
- When students comprehend concepts, they are better able to transfer this understanding to new contexts

Further support for encouraging inquiry in science teaching based upon research is presented in the form of seven arguments, summarized by Lazarowitz and Tamir (1994, p. 98). Briefly, these arguments are

1. Concrete activities and manipulatives help students grasp abstract concepts
2. Inquiry participation allows students to experience the "spirit" of science and understand how it works
3. Inquiry promotes the development of higher order thinking skills
4. Inquiry promotes the development of basic skills, including communication and facility with science procedures
5. Inquiry provides the opportunity to grasp the components of the scientific method, such as hypothesizing, assumptions, predictions, and conclusions
6. Inquiry promotes habits of mind associated with science, such as openness, skepticism, curiosity, and honesty
7. Students enjoy hands-on exposure to scientific ideas and may have increased motivation to learn science

According to Haury (1993), inquiry-based science can produce scientific literacy, knowledge of science procedures, vocabulary, conceptual understanding, and positive attitudes toward science. In a meta-analysis of 140 studies comparing a number of science pedagogies, Wise (1996) found a mean effect size of +0.28 for inquiry-based pedagogies. In addition, he found that themes of inquiry pervaded other successful alternative methods of science teaching as well. In 1999, Von Secker and Lissitz found that laboratory inquiry correlated with greater science achievement. In summary, research produces a "pattern for general support for inquiry-based teaching" (NRC, 2000, p. 126).

REALITY

There is some evidence that students are being exposed to inquiry in American schools. In *the Third International Mathematics and Science Study—Repeat* (TIMSS-R) conducted in 1999, U.S. eighth-graders outperformed the international average on questions about scientific inquiry. Sixty-five percent of these students reported that they engaged in inquiry-like activities "often" or "pretty often" during their science classes (National Center for Education Statistics, 2000).

Although encouraging, this evidence is suggestive at best, and most of the existing literature presents a different picture. In 1999, Von Secker and Lissitz noted that little research was available describing how common NSES teaching strategies were in American science classrooms. Although no overall survey data describing the types of instructional strategies used in science classrooms exists, scattered reports are available. In 1987, Anderson and Smith reported that the lecture format was attractive for teachers, and it was difficult for them to deviate from this method for a number of reasons. A decade later, Ponder and Kelly (1997) reported that this pattern had changed little, and Von Secker and Lissitz (1999) reported that teacher-centered instruction and text-based learning were still "typical" throughout the 1990s (p. 1111). Sánchez and Valcárcel (1999) discovered in a qualitative study that only 44% of teachers in their small sample used "experimental activities," and of those, "systematic exposure was rare" (p. 502). At most, only 11% of the respondents saw lab work as having associated skills and objectives. Yager (1997) argued that inquiry is shallowly taught if at all at any educational level from kindergarten through college, due in part to the dominance of textbooks as the true curriculum, most of which were not inquiry oriented. He also asserted that inquiry has not figured as a target for research. A current review of the literature reveals a number of case studies, which report admirable results but do little to provide an overall picture. Wise (1996) summarized the situation, "Few would argue that traditional instructional strategies predominate in middle and secondary school science classrooms. Teachers dispense knowledge to passive student audiences, with textbooks alone constituting the science curricula; students are rarely involved in direct experiences with scientific phenomena" (p. 337).

A number of explanations for this lack of inquiry in science education are plausible. In an effort to simplify the extremely complex inquiry process for classroom application, authors of inquiry activities often present them as degraded cookbook-like activities. These activities are usually inadequate, because they do not include any or all of the elements of inquiry. It is likely that few educators have experienced inquiry personally (Yager, 1997) and thus may have little interest or enough firsthand knowledge to infuse it into their lessons. In a 1987 Australian case study, Gallagher and Tobin observed that the most dominant mode of instruction involved whole-class teacher-centered lecture activity. Teachers valued the degree of control and familiarity they felt in whole-class activities, which disappeared when students participated in the sometimes chaotic and noisy mode of inquiry. Costenson and Lawson (1986) summarized 10 reasons typically given when teachers are asked why they do not embrace inquiry as a learning model:

1. Lack of time and energy
2. Inquiry does not allow students to move along at a pace that will cover the entire curriculum in the time given
3. Students do not possess adequate reading skills to deal with the information-gathering tasks embedded in inquiry
4. Administrators do not understand inquiry or support it
5. Inquiry is perceived as an activity for "gifted" students, and inappropriate for average science classes
6. Students are too immature to manage inquiry activities, wasting too much time
7. After lecturing for many years, experienced teachers are reluctant to change
8. Inquiry activities disturb the sequence of concepts presented in the text or curriculum
9. Lack of control in the classroom
10. Lack of resources (p. 151)

Thus, it seems clear that there are a number of reasons why inquiry may not be happening in classrooms. A number of factors are involved: teacher attitudes and preparation; administrative support; resource allocation; pressure on the curriculum applied by community leaders and stakeholders; and student behavior, motivation, and preparation. The Benchmarks, NSES, and Addendum together provide the impetus to include inquiry in the curriculum, rich illustrations of inquiry in the classroom, enumeration of the pedagogical benefits of inquiry learning, and a sketch of necessary systemic changes. Now, a detailed outline and action plan for change is necessary: a plan that will address the individual components of the educational system that are necessary to make inquiry happen on a wide scale. The purpose of NLIST is to provide such a plan. This plan must address the authentic challenges and barriers revealed in the literature as hampering inquiry science. Unfortunately, large-scale inquiry reforms have failed in the past, and it is important to examine history for reasons why.

INQUIRY IN THE HISTORY OF SCIENCE EDUCATION REFORM

The current structure of our educational system resists new and innovative ways to learn. Teacher training, school organization, administrative operational procedures, and the way politicians typically address educational problems all collude in a system that most easily retains the status quo (Fullan, 1993). As a general rule, change efforts have often attacked discrete parts of the entire educational system, seldom addressing context and the system as a whole (Jenlink, 1995). The story in science education, however, has been somewhat different. Knapp (1997) notes that science education reform efforts have typically assumed that a range of systemic elements must be involved to achieve effective science instruction. However, he identifies several factors that have led to reform failure:

- Teachers have not internalized the change
- Classroom implementation of reforms has typically incorporated parts of a reform rather than the whole process or idea
- School systems did not invest in long-term support of the reform
- Preservice teacher preparation was not included as one of the systemic elements
- District level agents attempted to enact reforms without fully understanding them and without enlisting support of teachers first
- There were conflicts at the district level between existing policy and the reform

Inquiry itself has served as a prominent theme in science education reform since the late 1950s (Yager, 2000). In fact, science education reforms in the decades since Sputnik have been characterized by a fairly even alternation between inquiry-based curriculum and direct instruction (Ponder and Kelly, 1997). These lessons from the past raise a critical question: If inquiry reforms have failed to achieve pervasive and lasting change in the past, how can we expect the NSES to stimulate a new round of inquiry-rich teaching in the years to come? If we agree that science education should involve inquiry learning both as a content standard and as an ability, the question becomes: How can a local or state science education system hope to make permanent and consistent change within their system promoting science inquiry learning? The answers to these challenging questions lie at the heart of what the NLIST vision hopes to facilitate over a seven-phase campaign.

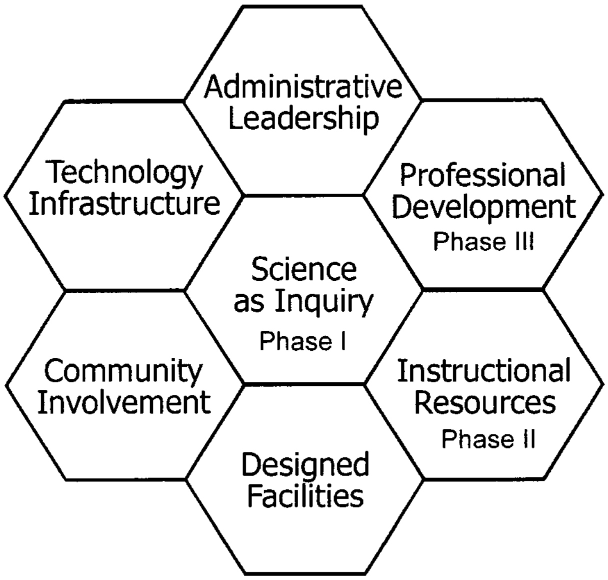

Fig. 1. Systemic components of NLIST. This image depicts all the systemic elements that will be addressed over the entire life of the NLIST mission. We are currently in Phase III.

NLIST'S VISION OF CHANGE

The first step in the NLIST initiative was to identify a set of systemic elements. An effort was made to describe in detail the change that was desired, as set forth in the NSES. To accomplish this, a set of systemic elements was identified as targets for reform. Working from the wisdom of change literature and a knowledge of the history of science reform, NLIST leaders chose this set of elements: instructional materials, professional development, administrative leadership, community involvement, technology infrastructure, and facility design (see Fig. 1). These elements are conceived as Phases to be carried out over a number of years. As Fullan and Jenlink suggest, these systemic elements must be brought into alignment with long-range goals and standards for students to insure successful learning outcomes. More specifically, each of these elements must be considered through the lens of a difficult but practical question, "In what ways do the key system elements need to change to implement Science as Inquiry?" For each of the systemic elements, this question expands into new questions:

- What specific characteristics of instructional materials support inquiry science? How might science educators identify and evaluate these instructional materials?
- What must teachers know to implement science as inquiry? What needs to change in the professional programs and certification standards for teachers? How should professional development be structured to support this change for in-service teachers?
- What are the implications for educational leadership? What must educational leaders and administrators know to enact and support a shift toward science as inquiry?
- What must community leaders know and do to support inquiry science in their neighborhood schools?
- How might technology support inquiry science?
- What facilities are necessary to support inquiry science? How can their construction be stimulated?

An important key to the success of the effort will be the development of practical instruments that suggest *how* to reform science education by specifically pinpointing *what* to do. This practical aspect of reform must be communicated and enacted, supported by philosophical arguments to explain *why*. In considering each of these elements in turn, NLIST will produce descriptions of exemplary practices, replicable templates, and comprehensive rubrics to assist the science education community in facilitating systemic change. These products will help state science supervisors and other science education leaders understand the systemic nature of their work and provide concrete strategies for accomplishing reform.

Phase I: Defining Science as Inquiry

Over the period of 1 year beginning in March of 1999, working in both face-to-face meetings and through distance communication technologies, NLIST sponsored the Science as Inquiry Working Group (SIWG) to define "Science as Inquiry." The SIWG consisted of 11 members representing the Council of State Science Supervisors, The American Academy for the Advancement of Science, the National Science Teacher's Association, and the NRC.

The NLIST group devoted days of study and discussion to the effort of understanding the inquiry process and to identify appropriate inquiry outcomes for students in modern society. Beginning with the brief definition of inquiry science learning given in the Addendum (see page 3), they synthesized current inquiry literature and crafted a Definition for science inquiry that would serve as the foundation for the reform phases to follow.

This Definition embodies an operational description of inquiry science learning, increasing the chances that all stakeholders may understand it. The Definition also contains a delineation of ways to demonstrate the successful attainment of inquiry teaching and learning. After months of construction work, the Definition underwent review by individual experts and through focus groups at the NASA Langley Research Center in Hampton, VA. The final version of the *Science as Inquiry Definition* is given below:

> Inquiry is the process scientists use to learn about the natural world. Students can also learn about the world using inquiry. Although they rarely discover knowledge that is new to humankind, current research indicates that students engaged in inquiry discover knowledge new to themselves.
>
> Student inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of the student's experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanation, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.
>
> As a result of participating in inquiries, students will increase their understanding of the science subject matter investigated, gain an understanding of how scientists study the nature world, develop the ability to conduct investigations, and develop the habits of mind associated with science.

Phase II: Instructional Materials

Based upon the Definition, it is clear that inquiry-rich instructional materials should have certain characteristics. First, instructional resources for inquiry learning must embrace a learner-centered perspective. Second, they should emphasize process as the basis of student achievement, incorporating important science content along the way. The necessity of this characteristic is based in the information explosion: Because our knowledge base is growing at increasingly faster rates, education must now focus on the process and skills of acquiring information relevant to current needs, rather than trying to embrace all knowledge. This process-oriented approach implies that instructional resources must emphasize direct and active involvement of the learner, and thus, these two characteristics work in concert. Unfortunately, most currently available instructional resources are designed to support direct instruction by the teacher and are not meant to be used directly and independently by the learner. In addition, they often do not match the established national, state, and local learning goals.

With the vision of ideal inquiry-rich instructional materials in mind, a second working group (the Instructional Materials Working Group, or IMWG) set out to construct a rubric in July of 2000. The object of Phase II was to create a process for describing instructional materials that best support inquiry science. This group began with the Definition and delineated characteristics of instructional materials that support science inquiry. A rubric was chosen as the instrument to assess the alignment of a given instructional resource against the Definition. From the beginning, this rubric was visualized as an on-line product to be widely shared with science educators. The four outcomes of inquiry learning presented in the Definition (content knowledge, understanding of how scientists work, ability to conduct investigations, and habits of mind associated with science) provide the basis for four sections of the resulting *Rubric for Evaluating Essential Features of Classroom Inquiry in Instructional Materials*. Each section contains a number of descriptors that materials should align with if they are going to adequately support learners in the acquisition of these outcomes. The Rubric provides four levels of variations that can help educators select or design instructional materials that best suit needs across the continuum of learner development. An educator with limited knowledge of inquiry can use the list of descriptors to develop an understanding of the desired characteristics of inquiry materials. Other applications include making informal analyses of materials for use in individual classrooms and selecting materials on a broader scale by training a group of reviewers to assess materials for entire school systems. Developers can use the rubric to produce more inquiry-oriented teaching materials.

An outline of the *Rubric* descriptors is given in the Appendix, comprising the skeleton of the instrument. The full Rubric can be found at http://www.inquiryscience.com/inquiry/resources/samplerubric.htm.

Phase III: Professional Development

The Addendum supplies rich ideas for implementing inquiry in the science classroom, and case studies illustrating successful inquiry instructional designs are abundant throughout the science education literature. However, examples alone are inadequate for at least two reasons. First, teachers must embrace an educational innovation wholeheartedly, and examples may or may not provide the motivation to undertake the daunting shift to inquiry. Second, examples seldom provide enough constructive detail to enable teachers to apply an idea in their own classrooms.

Often, the root of failure or success of an educational reform occurs in the expertise of teachers, guiding their day-to-day enactment of any systemic change. Change is difficult to begin with (Fullan, 1993), and several of the most powerful reasons for the failure of inquiry learning as a science pedagogy involve individual teachers. To recap an earlier section, Knapp (1997) listed the failure of teachers to internalize an educational innovation, piecemeal implementation, lack of involvement of preservice education, and the failure to enlist teacher support as reasons why math and science reforms have not worked in the past. Costenson and Lawson (1986) list 10 reasons why inquiry is difficult to carry out at the classroom level. One of the most important of these reasons is the difficulty in maintaining discipline and direction when students are given independence as required by the inquiry learning model (Gallagher and Tobin, 1987).

From a teachers' point of view, educational innovation can become one more layer of complexity in an increasingly chaotic teaching environment. On an annual basis, new changes in some aspects of the educational system are mandated. Preparation for change, enlistment of teachers, time to plan, and concrete strategies for accomplishing change are seldom provided at adequate levels. In addition, the backgrounds of most of our current teachers did not prepare them for effectively facilitating inquiry learning (Yager, 1997).

NLIST will address these needs during Phase III, which began in May of 2001. In this phase, working group members will examine both the long-term and short-term educational needs of teachers. Further, it will consider ways that new and emerging technologies can effectively address these professional development needs. An instrument, professional development template, an educational product, or both will be developed around the Definition, emphasizing objective suggestions for guidelines, policies, regulations, and budgets for increasing the effectiveness of classroom teaching.

Phase IV: Administrative Support and Leadership

Administrative leadership at the school, system, and state level is critical to the success of any educational reform. As Costenson and Lawson (1986) reported, inquiry-based instructional methods have failed in science classrooms in part because administrators have not understood them, and because of the scarcity of resources. Knapp (1997) identified lack of long-term administrative and financial support and conflict between existing policy and the reform as historical reasons for failure in math and science curricular reforms. Significantly, he pointed to top–down reforms that failed to enlist teachers as an important contributor. Senge (1990) emphasized the futility of reform visions that are imposed rather than shared by all stakeholders in an educational system.

One important role of leadership is to insure that important but often unseen infrastructure is in place that supports the implementation of science as inquiry, parts of the system that are themselves phases in the NLIST initiative. Elements of this infrastructure include

- supportive guidelines, policies, regulations, and budgets;
- appropriate staff;
- appropriate instructional resources;
- implementation of new and emerging technologies for learning and managing learning;
- involvement and support of the community; and
- appropriate facilities.

It is the task of the leader to identify, enlist, and coordinate the efforts of all systemic elements in a united effort to enact the inquiry reform. While the local superintendent and school principals must exert strong leadership in this area, other key leaders must be involved. Local school board members, members of county and city governing bodies, and prominent business leaders must help pass policy and provide the necessary budget. NLIST expects to produce a leadership template or other constructive instrument based on the Definition. This instrument will generate objective suggestions for guidelines, policies, regulations, and budgets for an effective administrative component.

Facilities Phase

Are our schools adequately designed to accommodate inquiry learning? Characteristics of facilities supporting inquiry learning include

- functional for the purposes of inquiry science;
- supporting multiple purposes; and
- technology friendly, including external information resources.

Unfortunately, most schools and community structures are designed, at best, on the basis of the needs of 1950s. For example, most high school science classrooms still have a single laboratory station at the front of the room for the teacher to use in demonstrations. Although science labs exist in most middle and high schools, these facilities are usually insufficient to support inquiry learning for large numbers of students at deep levels of engagement.

To address this issue more effectively, there is a need to bring together a broad-based representation of the local community to rethink the physical design for modern learning. These dialogs must involve teachers and students who can describe firsthand what an ideal inquiry classroom would look like. Other school features outside the classroom, such as living outdoor nature centers, will be required as well. Thoughtful meetings and discussions can lead to better design for learning in schools as well as better uses of resources for learning throughout the community. Again, NLIST will develop an instrument or template from these discussions that will guide the construction and renovation of science facilities.

Community Involvement Phase

The supportive involvement of a broad range of community members is critically necessary for successful implementation of inquiry learning. In addition, parents are essential for interacting directly with the administrative leaders and the teachers of the schools. It is also important to remember that only about 30–40% of taxpayers have children directly involved in schools. Nonparent community members often control large segments of the tax base and can sway political decisions through their power. Therefore, they must be informed about the importance of inquiry learning and how the outcomes from inquiry learning are fast becoming the new basic skills in modern society. Also, schools must make sincere efforts to understand the educational needs of society by soliciting and applying community feedback in designing educational programs.

Bidirectional communication is needed to inform the local community about the importance of inquiry learning, garner support, and engage community members in constructive dialog. Avenues for this communication include questionnaires, newsletters, web sites, seminars, open houses, and video and television programs. Parents, especially, need to be informed to pose stimulating questions to superintendents, principals, school board members, politicians, and others. As before, NLIST will develop an instrument after constructive discussions involving stakeholders to help incorporate community involvement in inquiry science reform.

Technology Infrastructure Phase

Technology infrastructure involves many broad uses of technology for more effective and efficient learning and management of learning. Learning technologies may enable learners to understand important but often abstract concepts through providing opportunities for firsthand experiences through simulations and virtual reality. For example, microcomputer-based laboratories (MBL) use digital and analog probes to provide instantaneous graphical and numerical feedback to students, and may facilitate their ability to grasp difficult constructs or relationships between experimental variables. Broadband and ubiquitous Internet access, wireless take-home student laptops, and personal digital assistants are now being examined for their educational potential. E-learning and electronic performance support systems (which provide targeted, individualized assistance at the point of need) are models of individualized pedagogy borrowed from the corporate world that may provide mechanisms to assist inquiry science learning.

On a broader scale, technology offers strategies for managing aspects of inquiry learning that reach beyond individual student experience. For example, data mining, now used in medicine, can provide new insights into problems. Managing student portfolios, gathering opinions and feedback, communicating with parents and other members of the community, surveying local businesses regarding their needs, analyzing changes in college/university requirements, and a number of other tasks can be accomplished effectively and expeditiously with new and emerging technologies.

However, emerging technology is too expensive to use for all aspects of learning. In addition, the unrealized educational promises of old technologies such as radio, television, and laserdiscs are all a reminder to proceed cautiously with the limited monies currently available. The important question when it comes to learning technologies is "What can this technology do for learning that is impossible or difficult to do with less technology?"

NLIST will investigate these issues and produce yet another instrument to guide change. Questions to consider during this phase include

- What does the existing research in instructional technology, science, and mathematics reveal about the effective uses of technology to facilitate learning?
- What pedagogical methods are best accentuated with various technologies?
- How might collaborative learning or student/parent motivation be stifled or enhanced with the technology infrastructure?

PROGRESS MADE AND NEXT STEPS

At this point, Phase I is complete, Phase II nears completion, and Phase III has begun. The first two phases resulted in two products: the inquiry Definition and the *Rubric for Evaluating Essential Features of Classroom Inquiry in Instructional Materials*. The Definition and Rubric were evaluated at a conference at the NASA Langley Research Center in Hampton, VA. Over 40 state science supervisors attended this 3-day NLIST conference. Evaluation procedures included individually written feedback, focus group discussions, and large group discussions.

The IMWG then addressed issues about the Rubric in follow-up teleconferences, and revisions were made. To help solve difficult issues and to evaluate it further, the Rubric was then sent out to 12 experts for another review. These nationally recognized experts provided written feedback, helping the IMWG achieve consensus over unresolved issues. Next, the NLIST Advisory Board (consisting of members from NSTA, AAAS, and NRC) reviewed the Rubric in February of 2001. Again, revisions were made incorporating consensus decisions from the expert review and the Advisory Board. Reliability testing of the Rubric is now underway. Depending on the findings, the Rubric will be edited again and retested to increase reliability to acceptable levels.

Phase III, Professional Development, began in May of 2001. The remaining Phases will be scheduled as funding is secured.

CONCLUSION

NLIST is a systemic initiative jointly sponsored by the Council of State Science Supervisors and NASA regarding science as inquiry learning in K-12 education. Working from current research in science education and from a democratically crafted definition of science as inquiry, NLIST committees are developing comprehensive instruments and templates that seek to align the components of the educational system with the principles of science as inquiry.

To make permanent and consistent change for science as inquiry, a systemic and multipronged approach must begin. Change phases must proceed in a coordinated manner. As this initiative plays out over the years to come, useful products will ensue and be made available to the science education community. For the present, NLIST initiative participants hope that the Definition and Rubric will help science educators implement inquiry even now as subsequent Phases unfold.

APPENDIX: RUBRIC FOR EVALUATING ESSENTIAL FEATURES OF CLASSROOM INQUIRY IN INSTRUCTIONAL MATERIALS

Outline

As a result of participating in inquiries, learners will

A. Increase their understanding of the science subject matter investigated
  - A1. Content
    - A1a. Material provides content aligned with national, state or local standards
    - A1b. Material provides opportunity to develop enduring understanding of subject matter content
    - A1c. Material contains accurate content

B. Gain an understanding of how scientists study the natural world
  - B1. Understanding of how scientists work
    - B1a. Material provides an opportunity to learn how different kinds of

questions based on prior scientific knowledge suggests different kinds of investigations

B1b. Material provides an opportunity to learn that scientists conduct investigation for a variety of reasons

B1c. Material provides an opportunity to learn that scientists use a variety of tools, technology, and methods to extend the senses

B1d. Material provides an opportunity to learn that mathematics is essential in scientific inquiry

B1e. Material provides an opportunity to learn that scientists use evidence, logic, and current scientific knowledge to propose explanations

B1f. Material provides an opportunity to learn that scientists collaborate and communicate with each other in a variety of ways to reach well-accepted explanations

C. Develop the ability to conduct investigations

C1. Posing scientifically oriented questions

C1a. Material provides an opportunity to ask questions that can be answered through scientific investigations

C2. Designing and conducting investigations

C2a. Material engages learners in planning investigations to gather evidence in response to questions

C2b. Material engages learners in conducting the investigations

C2c. Material engages learners in the use of analytical skills

C3. Proposing answers

C3a. Material engages learners in proposing answers and explanations to questions

C4. Comparing explanations with current scientific knowledge

C4a. Material engages learners in the consideration of alternative explanations

C4b. Material engages learners in linking explanations with scientific knowledge

C5. Communicating and justifying results

C5a. Material engages learners in communication of scientific procedures and explanations

C5b. Material engages learners in appropriately responding to critical comments

C5c. Material engages learners in raising additional questions

D. Developing the habits of mind associated with science

D1. Developing the habits of mind associated with science

D1a. Material promotes the questioning of assumptions (skepticism)

D1b. Material presents science as open and subject to modification based on communication of new knowledge and methods (openness)

D1c. Material promotes longing to know and understand (curiosity)

D1d. Material promotes respect for data (honesty)

The entire Rubric can be found at http://www.inquiryscience.com/inquiry/resources/samplerubric.htm.

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