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ABSTRACT

This report represents an effort to stimulate regional discussion and delineate issues of relevance for educators concerned with science education in the Pacific Northwest. It suggests topics of inquiry germane to the context of national initiatives and regional, state, and local challenges. Information is needed to understand "where we are" in order to make sound policy judgements and rational curriculum choices in determining "where we want to be." In the opening section of the report entitled "National Priorities and Context of Science Education," initiatives grounded in reports by the National Education Goals Panel are presented, and regional collaboration is suggested as a sound approach to enhancing the outcomes of science education. In addition, it is suggested that these caveats enumerated by staff of the Sandia National Laboratories may assist educators and policy makers in deciphering the plethora of national reports on the state of U.S. education and arriving at sound decisions. These caveats warn against the following practices and habits of thought: "Crisis" rhetoric; misuse of simplistic measures of dubious value; and pre-occupation with the link to economic competitiveness. A discussion of regional context and associated policy questions is provided in the second section, "The Northwest Region and Its Needs," and state science curriculum frameworks and the importance of teachers are analyzed in the third section, "State Influence and Local Reform." The next section "Recommendations for the Improvement of the Quality of Student Outcomes in Science" contains a comprehensive discussion of the following topics: Northwest consortium for math and science teaching design concepts; Northwest consortium for math and science teaching activities; curriculum renewal structure; framework for systemic reform; regional collaboration and equity concerns; and the evaluation of regional efforts. The fifth section, "Toward Scientific Literacy and Applied Academics," provides a detailed analysis of scientific literacy and an examination of current practices in applied academics. The final section, "Recommendations for Action," invites the reader to explore patterns of connections and roles of salient organizational and systemic concepts in science education. Concepts and recommendations are given in narrative style under the headings of Curriculum Design, Policy Analysis, and Teaching Enhancement, and a brief concluding section called "Beginning a Course of Action" lists three tangible steps known to be essential for planning systemic reform. Appendixes contain testimony of two researchers from the Sandia National Laboratories and a list of sample definitions that make for scientific literacy. (Contains 50 references.) (PR)

THE Northwest Regional Educational Laboratory
PROGRAM REPORT

Improving the Outcomes
of
Science Education
for the
Pacific Northwest

Science and Mathematics Initiatives

Northwest Regional Educational Laboratory
101 S.W. Main Street, Suite 500
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Foreword

Improving the Outcomes of Science Education for the Pacific Northwest is an effort to stimulate regional discussion and delineate issues of relevance for educators concerned with science education in the Pacific Northwest. Moreover, it suggests topics of inquiry germane to the context of national initiatives and regional, state and local challenges. Information is needed to understand "where we are" in order to make sound policy judgements and rational curriculum choices in determining "where we want to be." To better inform the curriculum and policy debates, regional collaboration will be suggested as a sound approach and key step to enhancing the outcomes of science education in the Northwest.

We begin with a look at *National Priorities and Context of Science Education* and national initiatives grounded in reports by the National Education Goals Panel. Recent suggestions, offered by staff of the Sandia National Laboratories, which assist in viewing federal recommendations, are contributed as emerging issues and are also found in the appendix. A discussion of regional context and associated policy questions are put forth in *The Northwest Region and its Needs.* State science curriculum frameworks and the importance of teachers are analyzed in the section *State Influence and Local Reform.*

Recommendations for the Improvement of the Quality of Student Outcomes in Science are put forth in a comprehensive *Framework for Systemic Reform.* And, finally, the role of scientific literacy and applied academics are given considerable attention.

Recommendations for Action are submitted to guide first steps at investigating systemic analysis and reform of science education in the Northwest.

The initial investigation of this report is intended to spark dialogue and explore science education on a region-wide basis. As notice is given to areas yet to be addressed, and perhaps relationships yet seen, the Pacific Northwest, as a region--and we educators specifically--will gain insight into a larger picture and emerging infrastructure of how we value and contribute to the scientific understanding of the Northwest's children.

The work of this report represents the efforts of many people, all of whom have contributed to its insight and timely completion. In particular, the conceptual charge and efficacy of investigating the state of science education from a regional perspective was born from the vision of Robert Rath, the Executive Director of the Northwest Regional Educational Laboratory. Responsibility for the development, evolving direction, and editing of the report is the Science Depiction Study Committee led by Don Holznagel, Jerry Kirkpatrick, Larry McClure, Rex Hagans, and Steve Nelson. Kenneth Hansen, Rex Hagans, Don Holznagel, and Steve Nelson contributed significantly to the section on policy analysis. The team is indebted to Phyllis Campbell Ault for her contribution of the sections, *An Analysis of Scientific Literacy* and *An Analysis of State Science Curriculum Frameworks.* Appreciation is also given to Charles Ault, for his suggestions on the draft, Helen Davis for her graphic work and to Marian Grebanier for typing and proofreading.

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December 13, 1991

> Implementation of several programs without proper coordination or a clear understanding of goals could result in little or no gain and possibly even set back the impressive gains of the past two decades.
>
> *Perspectives On Education in America*, Sandia Laboratories

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National Priorities and Context of Science Education

The improvement of science and mathematics performance has indeed been elevated to a national debate, if not, a national priority. This fact is borne out by many different statements formulated by the President of the United States, the National Education Goals Panel (NEGP, 1991), and a variety of national efforts calling for reform in science, math and engineering education (FCCSET, 1991).

According to National Education Goals Panel (1991), the United States must "develop an infrastructure that creates and nurtures a world-class educational system." This calls for the development of (1) supportive public attitudes; (2) belief that all children can and must succeed in school science and mathematics, with fairness and equity for all children; (3) teacher professionalism that is first-rate; (4) national curriculum standards for use in building mathematics and science programs with tests, assessments, and accountability systems; and (5) instructional materials, equipment, and tools.

In addressing the challenges of national curriculum reform in mathematics and science, the Pacific Northwest is charged to utilize two highly regarded national curriculum improvement initiatives: *Curriculum and Evaluation Standards for School Mathematics*, The National Council of Teachers of Mathematics (1989); and *Project 2061*, The American Association for the Advancement of Science (1989).

The challenge of implementing actual reform on par with these federal expectations and curriculum initiatives presents a challenge for regional, state and local participants. On the one hand, the expressed need of some to form a national consensus regarding the nature of reform in science education presents arguments on what should be done. On the other hand, the method and content, or depiction of the current state of science education, appears challenging as conflicting and often incomplete information confuses well-intended efforts to attain global preeminence in science education.

As articulated in the *National Study of the Eisenhower Mathematics and Science Education Program* (1991): "Something must be done to cultivate the 'market' for reform, or else the exhortations of reform commissions and the mandates of state legislatures will fall on deaf ears." This "market" suggests a sophisticated manner in which reform is articulated--in particular, an invitation to participate in reform by stimulating an interest in and need for reform at all levels of the educational community. However well-intended this call for reform is, its nuances suggest a truly complex process. Why we need to reform science education, the desired outcomes of reform efforts, and the manner used to gain baseline understanding of the current condition of science education--as well as the true measures of reform outcomes--compels rigorous investigation of complex social patterns.

To properly explore these implications, collaboration across traditional organizational and state boundaries appears central to reform for the following reasons: (1) it calls us to question the nature of reform, (2) it challenges us to depict accurately "where we are" based on curricular information and reliable demographic and work place projections, and (3) it aids organizations in exploring their respective role and identity--their niche in the larger educational delivery system.

Rather than camouflaging policy and curricular efforts under the somewhat empty labels of popular jargon, reform--in the national, regional, state, and local scene--must be articulated by practitioners through defined policy and tangible outcomes. Again, questions arise:

What is the nature of reform in science education?

What is the meaningful information needed and in what ways might we gather it in order to make informed policy and curricular choices?

The Status of Science Education in America: Emerging Issues

The popular depiction of the state of science education today is one of tragedy. "So many have said so often that the schools are bad that it is no longer a debatable proposition subject to empirical proof" (Bracey, 1991). National reports loom large in our consciousness as we are reminded, through a host of cultural messengers, that ours is a "nation at risk." Reform proponents, though well-intended, clamor for answers and hypothesize solutions to questions not yet framed and strategies untold. Any change, regardless of its course, has become synonymous with good. As eminent science educator Paul DeHart-Hurd reminds us:

> Key issues in the reform movement are the purposes of science education, the context of the science curriculum, the scientific subject matter most worth knowing, and the conditions that foster that knowing. These issues are neither identified nor defined by the array of statistics being publicized on the condition of science education in the U.S., such as student enrollments in science courses, declining achievement test scores, qualifications of science teachers, time spent on science, graduation requirements, and courses offered. These widely publicized facts are symptoms of a problem in education, by they are not very helpful to a reform movement." (1986)

However, in spite of the apparent nation-wide anxiety there appears to be some relief, however temporary, that "there is consensus that the U.S. system of education must change" (Carson, Huelskamp & Woodall, 1991). The dilemma comes in that there is little agreement, however, on the nature of the change. What's more, some proposed changes appear to be in direct conflict with one another (Carson et al., 1991). For example:

Parental choice	Support for troubled schools
Back to basics	Increased flexibility
Lifetime learning	Early identification and pipelining
Improved national test scores	Increased access
College preparation	Workforce preparation
Emphasis on local needs	National curriculum and school comparisons
Fewer dropouts	Tougher standards
Legislated improvements	Site-based management
Increased special education	Decreased special education pull-out programs

Perspectives on Education in America, (Carson et al., 1991) published by the Sandia National Laboratories, investigates the issues of science education reform and challenges the educational community to analyze basic rationale on which the reform movement is based. (The reader is encouraged to review congressional testimony on the Sandia study, found in the appendix). As Carson et al. (1991) point out, "Much of the recent debate is calling for revolutionary change--not for adaptation to the realities of changing demographics, but for anticipation of some future, yet unknown, requirements." Calls for such revolutionary change are indeed enticing and may perhaps garner support for funding. Yet, an implied "Chicken Little" perspective may indeed blind us from seeing the real questions, distract us from gathering meaningful information needed for policy and curriculum choices, and, in the end, prevent us from capitalizing on the strengths of a comprehensive educational system unequaled in the world. Professor Paul DeHart-Hurd, in a Ford Foundation study finds that:

> With every crisis in education during the last half century, the same ideas for changing the context of science teaching have emerged. But the basic reform has taken place in only a few schools--and then for only a limited time. Public pressure for immediate action and visible results overwhelms the major issues of reform before they can influence classroom practice or the reeducation of teachers. The current reform movement is making the same false start. (DeHart-Hurd, 1986)

Indeed, calls for deeper investigation of reform issues and critical analysis of information and data are becoming increasingly apparent and challenging of popular conceptions and reform efforts (DeHart Hurd 1986; Bracey, 1991; Hodgkinson, 1991).

In a summary of key findings, researchers at the Sandia Laboratories (1991) enumerate the following three caveats, among others, which may assist educators and policy makers in deciphering the plethora of national reports and arriving at sound policy and curricular decisions. These issues, which may indeed impact valuable educational change, suggest perspectives necessary to analyze and define the nature of reform.

"Crisis" rhetoric

The adoption of "crisis" rhetoric to enable funding or social support for education in general, and science education specifically, may well be flawed and actually may hinder positive change in science education. The notion of a crisis in education operates under assumptions that problems are systemic and that almost all hope is lost to remedy an already losing battle. Futility is not, in any reasonable sense, a motivator for productive and lasting action. Stanford's DeHart-Hurd also asserts that "most of the actions also serve more to create the illusion of reform and to obscure the issues than to foster conceptual changes in the curriculum (DeHart-Hurd, 1986, found in Exxon Education Foundation, Science Education in the United States: *Essential Steps for Achieving DeHart-Improvement*. New York: Exxon Educational Foundation, 1984). Moreover, Carson et al. (1991) suggest, by virtue of their research, that "system-wide failure in education...is simply not true."

Misuse of simplistic measures with dubious value

Although we receive daily reminders of the perilous state of science education, such information is often an attempt to simplify complex circumstances or conditions (Carson et al., 1991). In the translation, policy makers are often compelled to make decisions on popular belief rather than appropriate data. For example:

> Although it is true that the average SAT score has been declining since the 60's, the reason for the decline is not decreasing student performance. We found that the decline arises from the fact that more students in the bottom half of the class are taking the SAT today than in years past. Since 1971, the median test taker has dropped from the 79th percentile in class rank to the 73rd percentile. Additionally, every ethnic group taking the test is performing better today than it did 15 years ago. More people in America are aspiring to achieve a college education than ever before, so the national SAT average is lowered as more students in the 3rd and 4th quartiles of their high school classes take the test. This phenomenon, known as Simpson's paradox, shows that an average can change in the opposite direction than all subgroups if the proportion of the total represented by the subgroups change. (Carson et al., 1991)

This position, though challenged by the Assistant Secretary for the Office of Educational Research and Improvement for the U.S. Department of Education (Ravitch, 1991), is attracting increased interest as more educators examine the basis for a "crisis" approach in educational reform (Bracey, 1991; Hodgekinson, 1991).

Preoccupation with the link to economic competitiveness

In an age of rapidly changing global economies, popular claims often call for improvement in science education by assigning it the pivotal role in economic competitiveness. Atkin (1991) points out that while there are certainly reasons to improve science education, its link to economic livelihood is not one of them. Adding that the very nature of scientific inquiry is to "search for powerful principles," Atkin asserts that the connection to global economic success may mislead the public "by making exaggerated and implausible claims." Moreover, he promotes education in technology--"an enterprise explicitly directed toward altering the human condition"--as a reasonable educational response to global competitiveness.

Going a step further. economic competitiveness may still fall far short as a rationale for improving science education.

> Economic competitiveness is an extremely complex issue involving issues from worker productivity to monetary exchange rates and tariffs. Focusing educational improvement on economic competitiveness will only lead to frustration as any effect it has will be overwhelmed by the myriad of other variables affecting economies. (Carson et al., 1991)

By linking reform in science education to economic competitiveness, we may indeed be distracting ourselves from investigating a more meaningful role of science learning in our schools and from addressing improvement on student outcomes. We may be looking in the wrong places, at the wrong answers. "It is a tradition in America to find a scapegoat on which to foist all the sins of education [and society]. Teachers have always been our first choice" (DeHart-Hurd, 1986). For classroom teachers to find tangible rewards and results in science teaching, is it more reasonable to decipher the daily fluctuation of global market indicators or more closely understand student outcomes in learning? While the point may be exaggerated somewhat, it certainly calls to question popular beliefs upon which policy and curriculum choices are often made.

The challenges which this report addresses are complex. They involve not only issues of policy and curriculum choices, but the very perspectives which we hold in our understanding of science education. While taking tangible steps to enhance programs serving science teaching and learning, we must simultaneously investigate commonly held conceptions in how we design for change, in essence, examine the systems which impinge on science education.

Regional collaboration is suggested as a sound approach and key step to enhancing the outcomes of science education in the Northwest. This, of course, invites us to examine the Northwest.

The Northwest Region and its Needs

The five Northwest states include 1,305 public school districts which enroll 1,734,572 students in 4,623 schools. Fourteen percent of these students in the region are minorities, including 130,000 Native American and Hispanic rural students and 110,000 African-American, Asian, and Pacific Island students in urban areas. In regard to the instructional needs of these children, "One of the most striking findings of recent NWREL regional needs assessment work has been the deep and broadening concern among Northwest educators at all levels that they are being asked to do a job alone that, albeit much needed, they cannot succeed at without substantial assistance "(NWREL, 1991).

Three in five of the region's 88,822 classroom teachers are elementary teachers. Yet, the region's districts employ only 23 science curriculum coordinators and only 33 mathematics curriculum coordinators. Moreover, in a 1988 survey conducted by the Carnegie Foundation for the Advancement of Teaching, 24 percent of the region's teachers reported that they were now assigned to teach subjects in which they felt unqualified (1988).

District-Level Math and Science Coordinators in the Northwest Region

	Alaska	Idaho	Montana	Oregon	Washington	Total
Science Coordinators	2	3	2	3	13	23
Math Coordinators	2	7	6	6	12	33

Most states have moved in recent years to develop curricular frameworks in various subject areas, including science, which include instructional objectives. Such frameworks should concentrate on meaningful learner outcomes which are key indicators of performance, progress and application of critical scientific concepts. Moreover, frameworks should be the basis of policy attempts to define outcomes that can be met through restructured curriculum and instructional approaches.

At the regional level there is no information on science instruction at the elementary level aside from the requirements or expectations included in the state frameworks. In order to develop a strategy for reform, it is essential that we gain knowledge of the level of teacher competence, the effectiveness of school time actually spent on science, instructional approaches used, and performance measures of student outcomes.

In addition to gaining insight into the region's demographic and curricular support for science education, a host of other needs call for clarity and investigation: science assessment, community support and resources, teacher attrition, the interplay between national priorities and local implementation, etc. These needs, in the context of the above data suggest that the region is in need of vast improvement and enhancement of the science and math infrastructure--at all levels of organization--in order to improve student outcomes in science and mathematics.

It is recommended that the Pacific Northwest lead the nation in discerning the content and context of reform with particular inquiry into implications for enhancing science learning outcomes for children. Regional collaboration intent on implementing curricular innovations of national reform priorities, and fostering instructional renewal activities sensitive to national, regional, and local considerations may foster close investigation of educational policy and institutional roles, while designing processes for improvement. This, of course, compels organizations and institutions involved in science learning to reflect on their role, or niche, within a larger and interrelated, regional effort.

AAAS (1989) states this type of collaborative effort is needed and calls for institutions--often with diverse missions--to work together to capitalize on economic efficiencies, political strengths, and educational leadership of cooperating institutions.

The Regional Context for Collaboration

"Questions of policies for reform can only be meaningful if addressed in the context of the relationship between contemporary science and society" (DeHart-Hurd, 1986). Knowledge about the context of reform in science and mathematics education is integral to success--enhancing student outcomes in science and mathematics learning--and to the long-lasting implementation of systemic change in the region--providing the infrastructure to nurture a world-class educational system. This context, or system, is both highly layered and diffused within each layer (see the following diagram). In his book, *The Predictable Failure of Educational Reform*, Seymour Sarason describes such a system in the following manner:

> Once can see, touch, and interact with people and things, but not with the abstraction we call a system. System is a concept we create to enable us to indicate that in order to understand a part we have to study it in relation to other parts. I would be more correct to say that when we use the concept *system* it refers to the existence of parts, that those parts stand in diverse relationships to each other, and that between and among those parts are boundaries (another abstraction) of varying strength and permeability. Between system and surround are also boundaries, and trying to change any part of the system requires knowledge and understanding of how parts are interrelated. At the very least, taking the concept of system seriously is a control against overly simple cause-and-effect explanations and interventions that are based on tunnel vision.
>
> (Sarason, 1990)

To understand the abstraction of the science education system in the Northwest, the following depiction is suggested as a starting point.

At the national level, priorities and resources have been made available in two broad forms: curriculum initiatives and national partners. Highly regarded curriculum initiatives--proposed by the AAAS, Project 2061 (1989), and through the National Council of Teachers of Mathematics, NCTM Curriculum and Evaluation Standards for School Mathematics (1989)--have articulated clear and comprehensive visions of reform. Moreover, numerous federal agencies and national organizations support and foster innovation (e.g., The U.S. Department of Energy, The National Science Foundation, The U.S. Department of Education, and The National Science Teachers Association). This national context is essential to drive systemic reform across the nation. Moreover, the national context and priorities have the benefit of nationally regarded expertise and knowledge as seen in the members of the mathematics and science communities.

At the regional level, the charge is to increase the permeability across layers while facilitating the orderly accessibility of data and information for the purpose of supporting the core--students and teachers in individual schools. In addressing this charge, members of the math and science communities working with the regional energy laboratories, and other regional agencies (i.e., Bonneville Power Administration, Environmental Protection Agency, NWREL, etc.) are called to research and investigate the state of the regional math and science environment and strategies for its improvement.

From the teacher/student perspective, there is tremendous need to have the context forces and resources become coherent, manageable, and available, rather than appearing to be random pressures or absences. This can be accomplished by enhancing communication and information transfer across organizational boundaries.

In depicting the regional issues and challenges in math and science education, and establishing regional priorities of national goals, sensitivity to the unique context in which reform will occur is suggested. For example, the region's five states encompass 982,268 square miles--more than 27 percent of the nation's land mass. Within its diverse geographic and economic context, the Northwest has dramatic contrasts in the lifestyles and cultures of the people. In urban areas, the pervasive regional economic shift, from forestry and an agricultural-oriented economy to services and high-tech manufacturing, is dramatically apparent. For the rural area of the region, natural resource industries have prevailed for more than a century. Cultural differences exist throughout the region. Educationally, the ramifications are threefold. First, in unicultural settings, students may lack exposure to and appreciation of cultural differences. Second, limited English proficiency may impede students' school performance. Third, goals for education are dramatically influenced by the culture of the community and may conflict with state expectations.

General trends in the socioeconomic conditions of the region have also influenced its 1,305 school districts. In particular, the mobility of the population has increased in traditionally stable, rural communities. The population is aging, which results in both declining enrollments and reduced patron support for schools. The number of single-parent and non-traditional families is increasing in both rural and urban settings. The schools are experiencing societal pressure to deal with the increase in child abuse, substance abuse, and latchkey children. The small, rural schools have neither the resources nor access to the services needed to deal with these emerging problems, while service delivery is fragmented in the urban setting. The nostalgic past is gone. In its place is a dynamic modern region with all the promises and pitfalls associated with the coming of the information society and the 21st century.

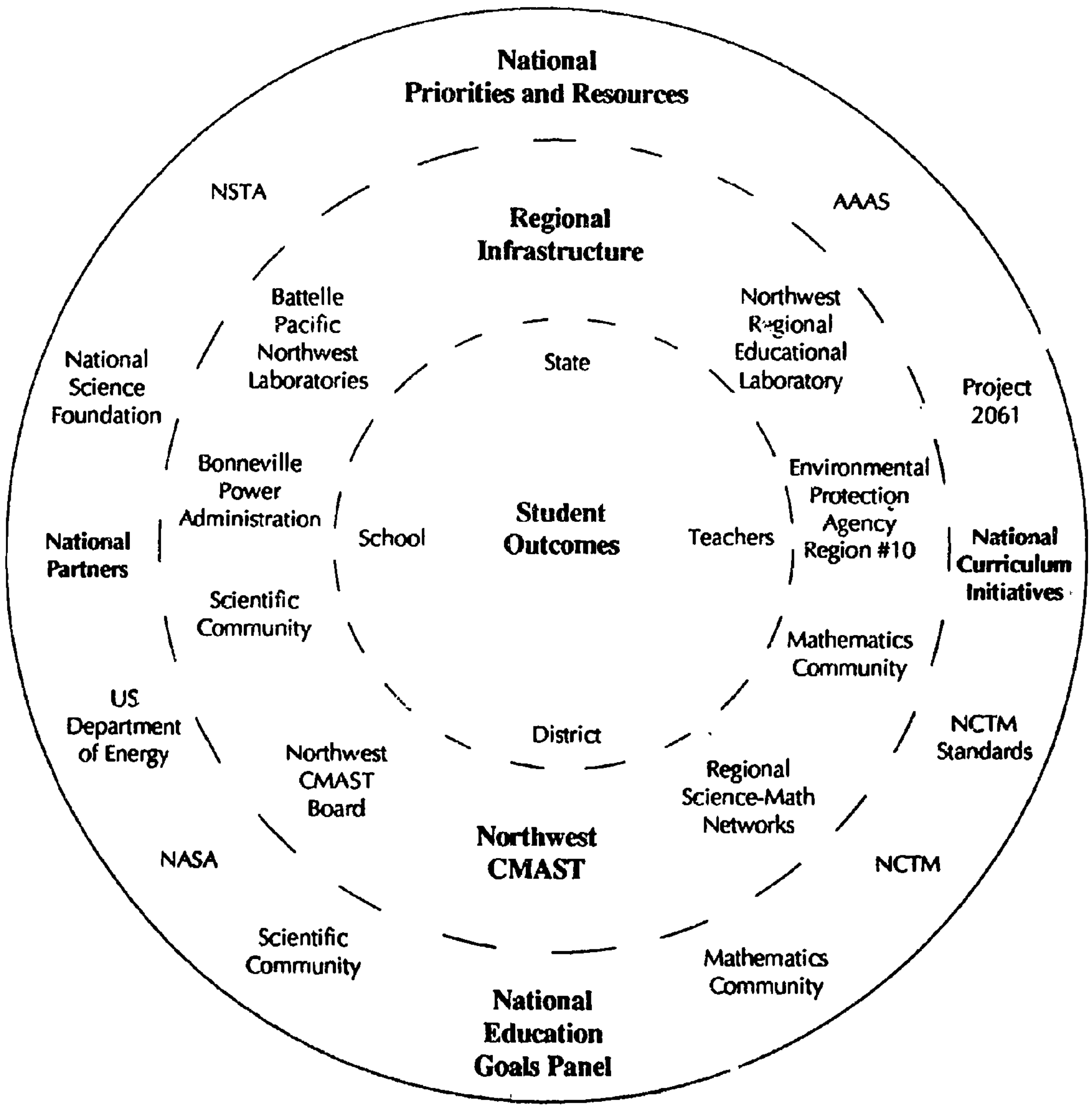
In fact, many aspects of the Northwest bind it together as a cohesive region, perhaps unlike any other region in the country. The Pacific Northwest shares a unique spirit of adventure as reflected in the rivers which weave it together, the noteworthy independence of its people, and the common environment which knows no state boundaries. Energy production and the economy are intimately connected through regional agreements while social issues interplaying with our practice of science and technology provide opportunities for school-based investigation across the region.

Policy Issues

With this "picture" of the region in mind, the region must be prepared to address the national priorities of the National Goals Panel by stimulating innovation through a regional infrastructure of mathematics and science. However, some aspects of being "first in the world in science and math" may be problematic for science education policy.

The gratifying surge of national interest in cranking up the American education system to produce a second-to-none rating for science achievement by the year 2000 cannot be attributed solely to the enunciation of the nation's educational goals by the state governors and the President, for there has been growing, for a number of years, the realization that we were lagging behind many other nations in our science and mathematics instruction and, hence, in our level of student achievement. But the announcement of the stated goal certainly stirred things up! Now that--for better or for worse--we have a clearly stated goal, what policies will most likely take us down the road toward its achievement?

Regional Context



The statement of the desired goal is commendably forthright; not so clear, however, is an understanding of the significance we really attach to achieving the sought-after preeminence. "First among nations" sounds worthwhile--even impressive. But to what ends? Only when the ends are clearly envisioned does the route to be taken become plain. It seems fairly simple to secure agreement that being 'first" would be worth striving for and achieving, but even careful analysis of the details involved in reaching that goal does not wholly clarify the next steps needed, or provide the sort of policy framework within which actual policy options might be developed.

The lack of clarity and agreement about details is illustrated by examination of two competent attempts to discern and state specifically what the rationale and motivation really is for attempting ambitious improvements in science instruction. Because the purpose of the "national goals" statement was essentially one of producing a ringing manifesto rather than one of utilizing a coherent and comprehensive program of systemic improvement, the major emphases implicit in the broad goal have to be surmised rather than reported.

For example, development of a national capability for exercising international leadership in science implies the creation of an ongoing strength in scientific research and its application so that the U.S. will continue to be an intellectual innovator rather than a mechanistic replicator in applied science fields. In addition. The relationship between science education policy and its influence on curriculum implementation suggests exploration of the goals for science teaching and learning. For example, towards what ends do we choose enhance science learning?

All of the knowledge, skills, and innovative abilities will not propel us into a leadership position without a highly educated work force capable of utilizing and applying scientific knowledge and principles in the processes of production and service with sufficient efficiency to assure our international competitiveness.

Furthermore, the scientific excellence we seek is not something which will be the sole province of scientists and workers in applied fields, but will be reflected in the populace as a whole--a scientifically-literate population which can understand and use scientific data in their participation as citizens engaged in deciding critical environmental and social policy issues and as individuals in safeguarding personal and family health. A similar claim for broader interpretation of educational priorities was recently suggested in an *Education Week* article (Viadero, 1991) entitled "Subject Specialists Decry Errors of Omission in Goals," where experts have called attention to the narrow subject-base orientation of the national goals which are based largely on economic rather than cultural needs.

The listings in the above paragraphs do not in any sense bear the imprimatur of the federal government or of the group which originally developed the "goals," but it does parallel quite closely the official position of the Federal Coordinating Council for Science, Engineering, and Technology which has, in a recent (1991) publication ["By the Year 2000: First in the World"], set forth a list of "priorities" which the Council believes should be used to direct the national agenda in seeking to achieve the preeminence goal: improving student performance; strengthening the teaching profession; ensuring an adequate "pipeline" of scientific and technical workers; and enhancing public science literacy.

This council elaborates on its priorities list by suggesting a major focus of effort on four areas of pre-collegiate education:

- Teacher preparation and enhancement;
- Curriculum development;
- Organization and systemic reform; and
- Student incentives and opportunities.

Quite in consonance with meeting the nation's specific science/technology goals, but needing special attention are additional public-policy goals affecting the entire educational enterprise. Using the impetus provided by the popular acceptance of the "#1 internationally" goal, some of the efforts needed to reach this goal may well be applicable to all of American education. Examples:

- General enhancement and strengthening of the entire teaching profession, both pre-service and in-service;
- Renewed efforts to involve women and minorities in research;
- Improving assessment practices in all subject matters;
- Tying curriculum reform and textbook revision to all relevant national goals;
- More effective use of appropriate electronic instructional technologies.

It is recognized that striving to have U.S. students rank at the top in achievement scores in science would be a commendable but probably insufficient outcome unless other goals were also reached.

If the study of science is seen by the student solely as a means of getting a job, and not also as a stimulating and intellectually satisfying personal experience, the top-of-the-heap goal is a rather empty achievement. If special incentives for teachers in these fields and appropriate training programs are limited to them only, we will have missed an opportunity to reach all teachers, and, through them, all students. If we concentrate our efforts on high-achieving secondary school students only, and neglect early-childhood and elementary education, our national supremacy may be an empty victory.

Strengthening instruction and raising the level of student achievement in science as a means of restoring American preeminence in international economic competition is a worthy goal, but while we have the momentum, we may well be able to make other related educational and social gains through regional collaboration.

From Public Policy To Goal Achievement

A policy framework which supports the achievement of a national goal must reflect both a clear understanding of the desired outcomes to be achieved and how systemic change can be undertaken to realize those outcomes. Policies which are symptomatic and piecemeal have little likelihood of success.

How can policy frameworks support systemic educational improvement?

To change a system, we must recognize and understand what the system is we wish to change. Improving science achievement does not simply mean changing the curriculum, but rather, modifying all elements of the system from the classroom to the university to the statehouse. In investigating systemic change the following considerations appear worthy:

- We must test our conventional wisdom. Will doing more of the same be better or must we do things differently? Policies which solely require more time to be devoted to a task have little impact.

- We must change the system controls. Special demonstration projects in isolated environment have little effect upon system-wide improvement. Not only do incidental projects lack scope, but they continue to operate within the traditional system. To change the public education system, you must change the controlling forces (policies, standards, etc.) which guide public education.

- We must make incremental changes in the entire system. Teacher education, graduation requirements, state curriculum standards, assessment mechanisms, resources, and curriculum materials are all inextricably tied. You can't effectively change one without changing the others. The system must be restructured.

- Restructuring policies must have built-in incentives and guarantees. The public and the education profession, alike, are tired of investing in waves of reform which are quickly abandoned. Goals are hollow if they are not backed by long-term commitment and resources. There is no quick fix.

How can policy frameworks more clearly articulate the significance of the desired outcomes?

- Public and professional support of student outcomes will only occur when those outcomes are significantly understood and valued. Policy must work to change public awareness and attitudes about science and scientists. The sub-goals of R&D capability, competitive workforce, and a scientifically literate society are steps in the right direction. The public must understand the ramifications of overdependence upon scientific and technological innovation. The public must also understand the importance of the use of applied science in our labor force as a very real and different societal need. Finally, the public must take personal responsibility for making environmental, social, and health decisions which are influenced by scientific knowledge, skills, and attitudes. Put more simply, our decisions about science education policy have very real and direct implications for us as individuals. Science is not something done to or by someone else. It affects our lives every day.

- Education policy cannot be solely driven by economic ideals. Prospective employment and economic self-sufficiency of our learners is only one goal of our public education system. It is doubtful that America could employ all of the scientists the public schools could potentially produce. There are other moral, social, and democratic ideals which we also value that drive our public education system.

- Public policy must lead public opinion toward an important, tangible goal. Being "number one" is not in and of itself a laudable goal. That goal has to be founded upon a vision of how the nation and the world will benefit in a multitude of ways. Educators and policy makers, alike, have had little recent success in shaping the public's vision of the future. Performance on achievement tests makes little practical sense as a goal for the nation. Improving the quality of life and championing an educated society, on the other hand, certainly does.

- Public policy must recognize and respect the relationship among federal, state, and local responsibilities for education. At each level, steps can be taken in different ways to achieve the national goals. No one level can do it all. We must understand that public support for science education comes from the local level, while enabling policies and resources to achieve these ends come from the state and federal levels.

In interpreting national goals, priorities and initiatives for science education, states rely upon a variety of public policy formats. To the curriculum administrator and classroom educator, policy frameworks appear most evident in the content and implementation of curriculum frameworks. These frameworks, particularly those relating to science education, may be useful to compare to ascertain state-level priorities.

These comparisons may yield insights into various interpretations of national priorities while suggesting questions and goals relevant to the region. Also, regional perspectives as seen through regional agencies (e.g., EPA, DOE), and professional science and math associations (e.g., NSTA and NCTM) may contribute to these discussion and understandings. Therefore, by providing enhanced regional communication and collaboration, the region may approach curricular and policy change through a systemic effort.

State Influence and Local Reform

An Analysis of State Science Curriculum Frameworks

Among a range of skills, attitudes and aptitudes in science education, the desire to produce a scientifically literate population seems paramount. Several goals of scientific literacy are broadly accepted by nationally recognized organizations and authors in the field. The five most frequently identified, through an analysis of twelve definitions [see An Analysis of Definitions of Scientific Literacy in the appendix] are:

- Students will understand academic knowledge in science including basic content, facts and principles, and the natural world. This knowledge should be adequate for students to pursue further study for personal or career purposes.

- Students will understand methods and practices of science. These include a view of science as a "way of knowing", an ability to "think scientifically" and use scientific values, formulate questions, use observation and computation skills and data collection methods, understand the meaning and importance of theories in science, and develop critical thinking and problem solving skills.

- Students will be able to use intellectual tools (science knowledge and processes) to make decisions on science/technology related societal issues.

- Students will recognize the nature of science in terms of the human limitations and strengths of science/technology, as well as the relationship of science to other curricular areas, and have perspective on the history of science, science-oriented careers and interests, science as a cultural phenomena, science as tentative, and the role of inquiry in the generation of science knowledge.

- Students will be able to use science in their own lives to resolve or take action on science/technology personal issues.

Using these five purposes of scientific literacy as a measure of science education in the Northwest, there is broad agreement from state-level documents on what students should learn from their experience with school science. The state frameworks or model curriculum for each state in the region identify goals for science education. The guides used for comparison have all been revised within the last three years, reflecting current purposes. All five states identify some aspect of each of the five scientific literacy goals outlined above in their framework. The emphasis placed on specific goals varies from state to state.

The *Alaska Model Curriculum Guide for Science* places major emphasis on the science, technology, and society (STS) notion of preparing students to use science knowledge and processes to make decisions on and/or take action on societal issues. There is a strong emphasis on state and local issues as well as environmental topics. The guide also has an underlying premise of "science as a way of knowing" with a goal of developing that pattern of thinking in all students.

The notion of the benefits of science education for all students is clearly evident in state of Washington too. The *Guidelines for Science Curriculum in Washington Schools* has a more traditional approach to science education in two of its four goals, focusing on content and skills. The other two major goals focus on critical thinking and the importance of science in society. The guideline's introduction mentions the importance of reaching traditionally underserved populations and limited English proficient students. The philosophy statement has a strong scientific literacy perspective. As Alaska promotes the use of environmental topics in science, Washington has developed an additional document, *Environmental*

Education Guidelines for Washington Schools with parallel goals and objectives to the science curriculum guideline. This serves as a model for using an STS style approach to science education. The Washington framework also mentions the importance of developing an awareness of science-related careers and interests as a goal.

This career awareness goal runs through the Montana framework as well. The *Tool Kit for Science Curriculum Development* contains a model science curriculum guide as part of a package which also includes pamphlets on instructional climate, curriculum development, implementation and assessment. Instructional strategies focus on thinking rather than memorization and advocates that science classes be forty percent laboratory in format. The goals outlined in the guide encompass building capable learners, acquiring science knowledge and process skills, an STS style orientation and the importance of relating science to other curricula areas.

The integration of science into other disciplines also emerges in the Oregon framework. *Science - Comprehensive Curriculum Goals* notes this approach. The model for local curriculum development has a large STS thrust to the rationale, basing the major reason for teaching science on the goal of scientific literacy. Instructional strategies promote hands-on experiences. The seven goals identified use science concepts and processes as the basis for the other five goals.

This emphasis on problem solving is the underlying premise of the *Idaho Elementary Science Curriculum Guide* in conjunction with a focus on environmental issues. The science knowledge component of the guide is organized around conceptual schemes which build on the interrelationships of science disciplines. A strong STS component runs through the curriculum as well which also recommends that science be taught every day at the kindergarten through second grade level as an integral part of the program.

Taken as a group, the state framework goals are aligned with current thinking on science education nationally, particularly in terms of scientific literacy. All elements of scientific literacy are represented in each model curriculum with unique emphasis from specific states on STS, critical thinking or the content and processes of science. All the guidelines also endorse environmental topics as ideal themes in science learning. The frameworks are designed to provide preparation for students interested in science careers. Most districts offer advanced placement or other special classes for interested students to pursue science topics in greater detail. There are isolated examples of schools or districts which offer courses designed for students who have a need for applied-science style classes. The need for this type of class is not clearly addressed in the state frameworks.

The state frameworks provide guidance for curriculum development at the district level. There is no real assurance that districts or teachers comply with the state goals. Although the state documents reflect current research and trends in science education, they are often viewed by teachers as impractical or theoretically distant from the classroom experience.

<u>Understanding Student Achievement</u>

Although state curriculum guides and model curricula provide direction for districts in developing local goals and objectives, other factors also impact the state of science education in the region. Student achievement is a critical measure of success in looking at science education. While reliance on quantitative data lacks robust indicators of actual classroom practice, scant evidence is available on the content of science education and the performance of students. Evaluation procedures in all five states is mixed and data collection is haphazard. None of the states compile data on science learning in an organized way.

Generally positive feelings about science at the elementary level indicate an interest in pursuing science learning in later schooling. For children to select classes or extra-curricular activities focusing on science they need to have their curiosity stirred and feel successful in the subject. It would be useful to know how children view science yet there is virtually no data along affective lines in science. Attitudes toward and behavior of students in science is not measured at any state level. Therefore there are no concrete indicators of interest levels or other subjective impressions of students' learning in science.

Where objective data is collected at the state level, it is generally from selected grade levels. Only Idaho uses standardized testing in science statewide. Grades 6, 8, and 11 are assessed using The Iowa Test of Basic Skills (ITBS). Many districts in Alaska, Montana, and Oregon also use the ITBS but generally the science section is not given. Washington uses the Metropolitan Achievement Test (MAT6) statewide in grades 3, 8, and 11 but again no science data is collected. Montana and Oregon plan to perform a statewide assessment in science in the next two years using grades 3, 8, and 11 (plus fifth grade in Oregon). These tests will be tailored to state level goals. Alaska tailors a questionnaire for teachers to quantify the frequency of use of the inquiry approach to teaching science. SAT scores provide a snapshot of science achievement toward the end of senior high school, but by the time scores are returned from these tests, it is too late to bridge gaps in understanding.

Many states recognize the benefits of establishing baseline data on where their students stand. Unfortunately, enormous problems exist with nationally available assessments. There are no real options for testing in science which reflect current goals of scientific literacy and higher order thinking skills. The NAEP 1990 assessment reflects these goals but is not applicable on a state level. There is interest in modifying the assessment to make it usable on a state or district level--certainly by the 1994 testing period. Several states would be interested in using this if it were available.

The National Science Teacher's Association is developing standards in science which will be philosophically congruent with the NAEP assessment, according to Lee Jones of NAEP. Oregon is developing an assessment to evaluate how districts are implementing the Common Curriculum Goals. This test will be given in 1993. Many states might benefit from using an assessment tool if it matched their curriculum goals for science; however, development is costly and of debatable benefit with the potential of national tests becoming more available. Alternative forms of assessment in classroom practice, though popular in common rhetoric, are virtually absent on any scale throughout the region. This need gains greater importance in light of the national goals.

Science Texts

Other broad curriculum-oriented factors are similar from state to state. Texts are either not restricted at all by the states or several are state-approved. Alaska, Montana and Idaho revised their curriculum guides in 1990 de-emphasizing the importance of texts and encouraging a thematic focus--crossing disciplinary and science subject area boundaries.

Standards

Course offerings are fairly standard at the junior and senior high school level. Two years of high school science is required for graduation in all states (The Educational Testing Service publication, *The Education Reform Decade* recommends three years.).

It may be useful to explore the idea that different instruction is necessary for scientific literacy among the general population, and for applications and research instruction for employment and academic careers. It may be that differentiated science offerings, focused on the expected life skill and knowledge requirements of each student may be beneficial to achieving general scientific literacy for all students and enhanced science achievement for students oriented to science careers. Similarly, careers requiring the application of science may have different skill and knowledge requirements than research careers. At this point, science instruction is generally viewed as a monolithic whole. Perhaps the desired outcomes for all students resulting from science instruction are not part of the same whole.

Montana offers "applied" courses in Biology, Chemistry, Earth Science and Physics as well as general and advanced placement sections. Elsewhere in the region, applied science courses often are taught in vocational schools. There is at least one high school (in Oregon) which addresses this applied-science perspective. The entire school has a technology or applied science focus. Students graduate with a regular high school diploma but have had greater opportunities to explore applied science topics than in a regular high school. This is a successful program and an approach worth consideration for other districts.

Teacher Role

As reported by the American Association for the Advancement of Science (1989), the teacher is central to reform. However, educational leadership and support at all levels of science education must assist the teacher in understanding and implementing reforms at the classroom level. Instructional designs, effective materials, and teaching strategies need to be supported by a dynamic and comprehensive infrastructure which enhances teacher professionalism and student outcomes in science and mathematics.

There are many model science classrooms throughout the Northwest which implement recommendations from their state curriculum with effective materials and teaching techniques to produce outstanding students in science. However, model science classrooms revolve around the efforts of successful teachers.

A high degree of discretion in science teaching in the Northwest is in the hands of teachers. The instructional strategy, resources, topic, emphasis and scope are often decided upon by individual teachers. The crucial role they play is recognized by outstanding current projects in science education such as Phase II of Project 2061, the National Science Teacher's Association's (NSTA) Scope, Sequence and Coordination of Secondary School Science, and The California Science Implementation Network (CSIN). The ongoing training, support and recognition of teachers is key to implementation of scientific literacy goals established by the states.

All Northwest states except Alaska require certification in science subject areas for secondary teachers. Misassignment of teachers to teaching classes they have not been trained in themselves is a profound problem nationally. However, this does not seem to be a major problem in our region. The misassignment levels are relatively low and stable. No states anticipate great shortages of science teachers in the immediate future.

At the elementary level, districts struggle with an inability to assess their teachers' interest or competency in teaching science. No states have special certification for science at the elementary level.

There are numerous teacher education projects available in the Northwest. State branches of the NSTA are active in disseminating information on teaching practices, and curriculum updates through newsletters, concept papers, and workshops. Projects aimed at elementary teachers tend to have less focus on content than those geared for the secondary teachers. Some projects are taught across grade-levels and have met with good success. Each state relies upon many projects focusing on specific curricula (Project Wild, Project Learning Tree).

There are programs which "pass through" the states from the federal government that have varying impact on science teaching. However, at the state level, the implementation of the National Eisenhower Program which encourages local staff development in mathematics and science staff development "is an implementation resource, not a vehicle for redefining what is taught or how to do it" (USDE, 1991). It is evident that efforts through the Eisenhower Program alone will not produce nationally-driven reforms: regional articulation must involve many segments of the educational community in assisting teachers. This assertion is certainly supported by the National Research Council's view that "vigorous national dialogue...is a prerequisite to national consensus" (NRC, 1989).

Moreover, as stated in the *Eisenhower Mathematics and Science Education Program: An Enabling Resource for Reform*, the Eisenhower "program does not chart the course for efforts to reform mathematics and science education. Rather, it offers a key resource to state, regional, and local leaders to implement reform ideas on a wide scale. In this way, the program depends on the environment of reform activity that surrounds it" (1991).

Currently, there is scant reliable data in the region available on what constitutes success of Eisenhower Programs. Some demographic data is available, however, thorough evaluation of classroom impact and successful program design is lacking in the region. It is apparent that potential for this program continues to unfold as a contributor to science teaching and learning.

Regional collaboration offers an approach to combine the strengths and expertise of the regional National Science Foundation grant projects with local Eisenhower consortia. On the one hand, the National Science Foundation grant projects address national models in curriculum reform and teacher education, while on the other hand, Eisenhower consortia implement practical and local applications of science and mathematics staff development (USDE, 1991). These two rather independent program perspectives, which often participate in isolation of one another, may be brought together in concerted regional efforts,

Through such alliance building of regional agencies and regional math/science networks, local Eisenhower projects can be encouraged to seek assistance from a variety of participating institutions, therefore, increasing the breadth of reform efforts. Through the sharing of data and information, professional expertise, cost efficiency strategies, and program designs which nurture collaboration, regional infrastructure will--in the end--stimulate opportunities for implementing innovative reform for the educators and children of the Northwest.

The State to Local School District Interface

Implementing national priorities through state curriculum frameworks and grant programs may impede systemic and lasting change. For example, economic isolation and the lack of financial resources often plague school districts as they clamor for curriculum renewal financial support. In addition, SEAs "often have small amounts of allocated funds that can be used for technical assistance, or other activities that fulfill leadership functions" (USDE, 1991). In concert with these financial constraints, reform--innovative perspectives and action in education--may also be impeded by political influences.

For example, as Firestone (1989) asserts, state roles in curriculum reform efforts may be influenced by a state's regulatory obligations, encouraging LEAs to adopt reactionary positions to state policy instruments of mandates or inducements rather than p'oactive participation in reform. Hence, "the enthusiasm for the reform is likely to be limited" (Firestone, 1989).

While the U.S. constitution assures the states with statutory responsibility for education, with local school boards accountable to local citizens, national inducements--or incentives--often drive state priorities, while state inducements often propel local initiatives. This rather hierarchical system for reform may not effectively address local needs and priorities in educational innovation.

Indeed, as attention is diverted to strategies for compliance at all levels, it may foster an acquiescence of responsibility for district, school, or classroom reflection on the content and process of improving outcomes in science education. An end result may be an educational system characterized by: (1) a need to "be fixed" by those perhaps more distant from local schooling; (2) an atmosphere of compliance rather than one of responsibility; (3) the loss of vision and educational leadership at the local level; and (4) the eventual waning of accountability.

This is again underscored by Firestone's notion of "'good apples'--that is, those who are willing to comply with the law through some sort of general sense of obligation--but not enthusiastic appliers of reform" (Firestone, 1989). There is also evidence which suggests that state mandates of science curriculum, in particular, actually inhibit reform (Wood, 1988). This political challenge calls for complementary frameworks which nurture collaborative mechanisms within the larger context of state and national reform visions. Moreover, promoting and encouraging risk-taking--the exploration of new ideas--may be nurtured best in the non-regulatory setting.

Recommendations for the Improvement of the Quality of Student Outcomes In Science

The direct improvement of student performance in science--achievement, attitudes, aspirations, and behavior--is the result of the quality of the interaction between students and teachers. The system which supports this interaction is in need of analysis and reform.

Existing regional networks, including National Eisenhower Program-grantees, state mathematics and science teachers associations, and projects led by higher education institutions and science and technology centers, play important roles in fashioning innovative approaches to science learning. In addition, public policy frameworks in support of science and mathematics, delivery and exchange of information, technical assistance, professional development and capacity building for local improvement efforts are also aspects of reform in the larger context of intra-state collaboration.

Moreover, in light of national priorities (NEGP, 1991)--and indeed the moral efficacy of offering exemplary schooling for our nation's children--it is incumbent upon the Pacific Northwest region to provide the best context for this learning to take place. The models, materials, and procedures for learning are extensive; however, the support of their identification, dissemination, selection, and implementation needs vast improvement. Moreover, reform efforts have "been hampered by the lack of a system to manage change in the structure of the schools" (DeHart-Hurd, 1986).

In the interest of improving the quality of student outcomes in science learning, it is proposed that the educational community of the Pacific Northwest collaborate in addressing the following goal:

Develop a regional infrastructure that nurtures a world-class educational system

To achieve this goal, regional collaboration must focus on:

- implementing systemic curriculum reform in K-12 science and mathematics which supports public attitudes and expectations that place a high value on scientific literacy and mathematics numeracy for all members of society

- championing the view that all children can and must succeed in school science and mathematics and that fairness and equity for all children is top priority

- promoting teacher professionalism that is first-rate

- improving the quality of curricula and the use of new technologies for the direct improvement of student performance in science and mathematics by facilitating the implementation of national curriculum standards and accountability systems for schools, districts, and states in Pacific Northwest

- identifying, disseminating, and implementing high quality instructional designs, materials, methods, and assessment tools in elementary and secondary science and mathematics

Northwest Consortium for Math and Science Teaching Design Concepts

To design a regional infrastructure that nurtures a world-class educational system, a Northwest Consortium for Math and Science Teaching, *Northwest CMAST*, would utilize innovative and effective conceptual designs which, in concert, offer a comprehensive approach to reform.

A Northwest Consortium for Math and Science Teaching holds promise in improving the quality of teaching and instruction in mathematics and science by driving a dynamic framework for systemic reform. In addition to the implementation of specific activities mentioned earlier, which address these objectives, Northwest CMAST calls for successful and innovative policy and curriculum frameworks which detail the process of curriculum renewal. The reader will note that the following frameworks seek to address the need for a regional infrastructure and operate in conjunction with one another to produce a comprehensive and dynamic map for reform. They include:

Context: the educational environment in which Northwest CMAST occurs

Activities: the specific events and strategies to be implemented

The Curriculum Renewal Structure: the process of change used

The Framework for Systemic Reform: the foundation of reform activities

These frameworks are briefly described on the following page and are discussed in greater detail at the indicated pages in this document.

Northwest CMAST Context (page 6) describes the national and regional participants involved in reform of science and mathematics education. Moreover, it is suggested that the regional role provides a "bridge" between national priorities and state and local implementation, intended to enhance student outcomes.

The *Northwest CMAST Activities* (page 20) details effective and specific activities to implement systemic reform. Research, networking, technical assistance, capacity building, and evaluation call for detailed activities at all levels of the *Framework for Systemic Reform.* These activities, implemented as the creation and maintenance of the Northwest infrastructure, require collaboration of institutions, efficient communication systems, and an effective operating framework. A Northwest CMAST Board will be responsible for articulating priorities within the scope of these activities.

The *Curriculum Renewal Structure* (page 25) highlights the mechanisms and strategies for initiating and supporting curriculum renewal recommendations found in the *Framework for Systemic Reform.* It acknowledges the complexity of systemic reform, the need for collaboration and risk-taking at organizational levels, and the efficacy of regional approaches to systemic reform in science and mathematics. Moreover, used as a "road map" to guide the process of reform, it suggests the need for implementation strategies which are comprehensive.

Of primary significance is the *Framework for Systemic Reform* (page 28). This framework clearly articulates the priorities and recommendations in the National Goals Panel for systemic change by illuminating "strategic components for systemic reform" in the context of organizational levels of educational practice: teacher, school, district, and state. It provides the foundation of national standards necessary for systemic change. Using the *Framework for Systemic Reform*, it becomes apparent, for example, that activity to change and enhance student outcomes must occur across instructional and administrative boundaries in order for systemic innovation to truly take hold. In addition, tensions so often apparent at the intersection of organizational levels in education may be minimized if the need for control is balanced with professional respect and decision making.

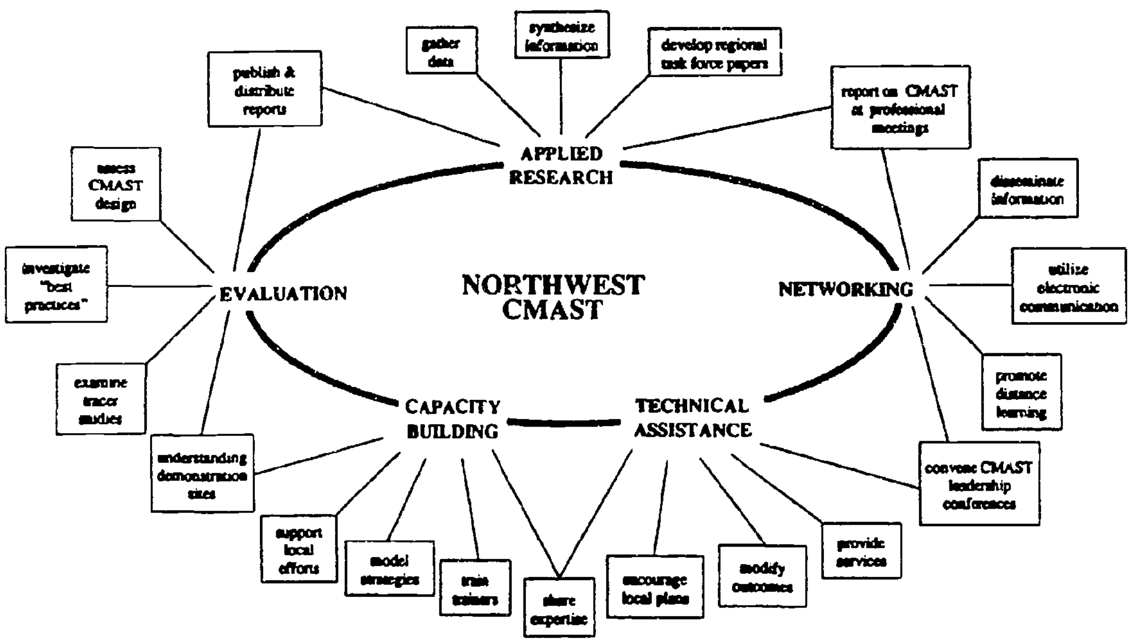
Therefore, reform efforts must be sensitive to the national *context* of renewal--the priorities of the National Goals Panel; the *content* of curriculum renewal--the *Framework for Systemic Reform*, and the nationally-recognized curriculum initiatives; and the *process* of curriculum renewal--the *Northwest CMAST Activities* and the *Curriculum Renewal Structure*.

Northwest CMAST Activities

The Northwest CMAST Activities provides for both general and specific strategies at all levels of the educational system with the intent of maximizing deep and long-range change to the infrastructure of science and mathematics education. They detail sample regional efforts to integrate the "strategic components for systemic reform." The accompanying diagram demonstrates the relationship between the *Northwest CMAST Activities*, and includes the following areas: applied research, networking, technical assistance, capacity building, and evaluation. In the narrative description to follow, examples are indicated in parentheses as samples of priorities that may be suggested by the CMAST Board and are referenced to the *Framework for Systemic Reform.*

NORTHWEST CONSORTIUM FOR MATH AND SCIENCE TEACHING

Activities



Applied Research

DeHart-Hurd (1986) calls attention to the notion that "specialists in education have been slow in synthesizing the empirical research on how students learn science and even slower in drawing implications for instructional practice." To address this concern, a significant purpose and service of the Northwest CMAST may be to provide applied research to practitioners in the region. This applied research could occur in the following formats: (1) comprehensive research syntheses; (2) topical syntheses; (3) close-ups; and (4) task force reports. The intent of using this approach is to provide knowledge-based products, produce new knowledge through evaluation and other applied research and development on educational problems, and disseminate information to regional audiences about educational research and best practice (NWREL, 1986-1991).

Comprehensive syntheses describe the full range of educational research findings. Documents will list the practices at the classroom, school, district, and state level that have a positive relationship to student performance.

Topical syntheses describe research findings in topical areas and compare findings in the topical area to findings from the general research on effective schooling and teaching.

Close-ups detail particular research-based practices in depth. Particularly effective practices are selected from the comprehensive syntheses and descriptions of the practices are enlarged to provide detail and give examples from throughout the region. Close-ups answer the questions, "What practices are effective within a certain area (e.g., staff development designs) and why are they effective?"

Task force reports, will be developed depicting the state of science and mathematics in the region. This applied research will strengthen and abet decisions and policy planning in the region while communicating valuable information throughout the region. Data for reports will be gathered on a variety of research topics as suggested by the *Framework for Systemic Reform*. For example, "track availability, quantity, and quality of staff development opportunities at all levels" (strategic component 3, state level), or strategies which foster "teacher awareness and use of assessment protocols: observation, works samples, teacher logs, sustained science projects" which implement recommendations of national curriculum initiatives and utilize recommendations of the National Goals Panel (strategic component 4, teacher level). The sharing and synthesizing of information for curricular and policy decisions will also serve to advance the understanding of the practices in the region.

Regional task forces will also explore specific aspects of reform such as regional literacy strategies to "foster curriculum development sensitive to general literacy, applied academics, and academics" (strategic component 2, district level). Task forces of the Northwest CMAST Program Board will investigate issues and report their findings at the Northwest CMAST Leadership Conferences.

The outcomes of Northwest CMAST applied research will yield, each year, topics or issues that will be identified by the CMAST Board. For example, during year one, four areas emerge as a result of consultation with regional experts. These areas may provide the focus for applied research efforts to be carried out by regional task forces. They include: (1) assessment of student performance; (2) program evaluation; (3) meeting the needs of underserved and underrepresented populations in the region; and (4) exploration of resources and materials in applied academics. Results of these task force investigations will be reported in a format which makes the information readily usable at CMAST Leadership Conferences, for dissemination through regional networks, and for capacity building activities.

Networking

Communication will be enhanced among Northwest CMAST members primarily through frequent and regular newsletters, telephone, and FAX communications. A quarterly CMAST newsletter could be targeted to educators in the Northwest working in the Consortium, providing them with information about CMAST activities. In addition, information will be more widely distributed, at no cost to the CMAST, through NWREL's monthly news bulletin, the *Northwest Report*, and an electronic newsletter, *Northwest Regional News*, on the GTE National Electronic Educator's Information Network. In concert with regular mailings to Northwest CMAST members, these two media will provide information on national and Northwest regional science and mathematics reform efforts. The *Northwest Report* is mailed to some 10,000 school districts and institutions throughout the United States.

Northwest CMAST will make use of an electronic communications system to "stimulate use of electronic telecommunications to foster collegiality, resource sharing, and maintaining of educational systems" (strategic component 5, school and district level). In addition, the ability to disseminate information efficiently and maintain frequent contact with collaborating agencies, with a minimum of travel, will be enhanced. Moreover, electronic communication will also be utilized to connect members of the science and mathematics research communities with science and mathematics educators, and for networking Northwest CMAST with other funded regional networks throughout the country.

The value of electronic mail for increasing the convenience and efficiency of communications among colleagues in a variety of locations who operate on a variety of time schedules is well known. Many such systems also support bulletin boards, databases, and electronic conferencing. Several factors will make electronic communications an effective mechanism for:

- Participating organizations distributed over a wide geographic area
- A major focus of common interest which motivates frequent contact among the participants
- Issues, questions, or requests to be addressed which do not require face-to-face meetings
- Information for dissemination to all participants which will be generated both locally and centrally on predictable topics
- Resource information collected over time and organized for quick reference which will be used by participants, and for which additions will be generated by the participants and others during the project

Several options exist for a suitable system, some locally operated and some commercially supported on a regional or national basis. Compatibility with statewide telecommunications systems already in place in three of the five states will be an important consideration in choosing a system for this project. At the beginning of the project, an analysis of the options will be conducted and a choice of system will be made.

The initial requirements will be:

- Electronic mail for routine messages between participating individuals and organizations, including information and assistance requests and responses
- Bulletin boards for timely information sharing in specified topic areas such as task force correspondence and information exchange
- A database of research reports, professional articles, and other documents relevant to project work and of interest to participating agencies
- The ability to connect to other networks in the region and nation for information sharing with groups and individuals in other regional centers or other related projects

- The potential to provide for distance education efforts such as satellite conferencing, courses and information sharing

Northwest CMAST will convene two Leadership Conferences annually to: (1) identify, disseminate, and share program designs, materials, and strategies for mathematics and science learning; (2) discuss national reform efforts with specific regard to Northwest concerns; (3) disseminate and review documents pertinent to curricular reform in science and mathematics; and (4) provide ongoing communication on project development and success. Strategic components from the *Framework for Systemic Reform* will be reviewed with priorities and activity timelines emerging as practical and calculated responses to national priorities and local need. Among the many other purposes central to Northwest CMAST, the Leadership Conferences will bring together participating institutions and agencies in the Regional Math-Science Network to "encourage testing and assessment that reflects nationally defined learning goals and standards" (strategic component 4, district level).

Each of two Northwest CMAST Leadership Conferences will be three days in length, involving the Northwest CMAST Board for days 1 and 2, and the Regional Math-Science Network directors for days 2 and 3. This extended-time design of meeting twice during the project year will facilitate ongoing communication between the two groups while enhancing accountability on interpreting and implementing reform at the local level. Moreover, participants will share task study reports on topics relevant to mathematics and science curriculum reform in the Northwest. The driving aim of this approach is to secure support for regionally-designed and locally-interpreted articulation of national priorities for reform of mathematics and science education.

Outcomes for the Northwest CMAST Network activities include the operational use of a telecommunications network that will be established among member agencies and projects. Four Northwest CMAST newsletters will be produced each year and distributed. Information about Northwest CMAST activities will be included regularly in NWREL's *Northwest Report* newsletter and the *Northwest Regional News* electronic newsletter, as well as other electronic bulletin boards and databases. In addition, contact and communications among agencies and projects will be enhanced by the two three-day Leadership Conferences to be convened annually.

<u>Technical Assistance</u>

A strategy for supporting the delivery of technical assistance involves site-based support of state and local effort. Technical assistance activities are intended to modify outcomes and, for example, "facilitate long-range strategic planning" for reform in mathematics and science (strategic component 1, district level). Activities for technical assistance will: (1) focus on outcomes of successful practice for all students; (2) consider locally expressed need and environment for reform; (3) accommodate established frameworks and exemplary practice of reform implementation; (4) involve locally driven ongoing assessment; and (5) encourage local improvement plans through capacity building and the sharing of expertise.

In year one of Northwest CMAST, in-depth technical assistance will be provided as a service to five sites, one per state, based on need and the intent of supporting program formats which demonstrate promise of successfully implementing national reform efforts in mathematics and science education. Technical assistance will primarily involve direct support to modify student outcomes and encourage the development of state and local plans to foster improvement at the teacher and student levels. In this regard, successfully applied aspects of the NWREL District Level Strategic Improvement Program model (see appendix) will be used to foster consideration of science and mathematics reform with school improvement efforts. This need is particularly apparent due to the lack of district-level science and mathematics coordinators in the region, as mentioned earlier.

The Northwest CMAST Board, with recommendations from the Project Director and state education officials, will select sites for technical assistance. The following two considerations will guide the Northwest CMAST process in selecting demonstration sites which receive technical assistance: (1) expressed need and enthusiasm for implementing systemic reform in mathematics and science education, and (2) evidence of program framework and willingness to be a "risk-taker" in program innovation and implementation of reform.

Outcomes for technical assistance include the development and enhancement of state and local projects, and cross-state coordination in science and mathematics efforts. Quantitative and qualitative data regarding implementation of applied research-based efforts, intended and actual change, and dissemination of national and regional priorities will be investigated. This information will be reported as part of the evaluation report.

Capacity Building

The capacity building efforts of Northwest CMAST may focus, for example, on "facilitating district initiatives in staff development utilizing national curriculum initiatives" (strategic component 3, district level). Activities may include the training of trainers (multiplier design) to create a Regional Math-Science Network to share and model staff development strategies. The support of local efforts may also encourage inservice staff development in appropriate assessment techniques as modeled by the NCTM (1989), (strategic component 3, district level).

Understanding demonstration sites and championing "best practice" will provide Northwest CMAST with valuable insights and data on the level of current reform implementation. In encouraging and studying effective practice at all levels of the reform effort, Northwest CMAST will publish ongoing "snapshots" of effective practices as they are actually implemented at the state and local level. Snapshots will detail information about how practices are being used in a given setting and their effectiveness. For example, a snapshot might highlight an effective staff development strategy used by an Eisenhower project, or a state policy which has demonstrated a positive impact in school districts. Snapshots are intended to highlight regional success by practitioners and be shared with other educators in the region.

This learning from local projects and sites will include how comprehensive evaluation schemes will be employed to monitor and enhance communication of goals and practice in the region (strategic component 1, state level). Through capacity building, state and local efforts will be strengthened in their resolve to participate in reform, while Northwest CMAST will provide a forum to share exemplary practice and seek greater understanding of reform strategies through comprehensive and ongoing evaluation.

Outcomes in Northwest CMAST capacity building include the identification and publication of exemplary practice in the region, the increase in the region's capability to reflect and implement innovative and exemplary practice, and the increase in knowledge about accessing assistance in science and mathematics reform. Moreover, this documentation of state and local practice will foster and encourage growth in projects and sites by promoting exemplary standards in science and mathematics.

Evaluation

The evaluation of the Northwest CMAST will focus on the processes, outcomes, and impact of the consortium's leadership efforts to contribute to the quality of the science and mathematics instructional interaction of students and teachers. Specific evaluation activities will address the leadership of the Northwest CMAST to influence public and policy frameworks associated with science and mathematics instruction, to facilitate the delivery and exchange of relevant information among consortium participants and beyond, to provide and encourage appropriate technical assistance and training necessary to improve science and mathematics instruction, and to encourage professional development and capacity building among science and mathematics teachers.

Early in the Northwest CMAST efforts, evaluation will primarily address the operational processes of the consortium. During this critical start-up period, the role of evaluation will be to document and provide information at critical decision points to consortium leaders and participants. As the Northwest CMAST matures, evaluation will expand to assess the outcomes of consortium efforts in identifying, implementing, and supporting instructional reform efforts in science and mathematics. While process evaluation activities will be ongoing, outcomes evaluation will document the quantity and quality of activity that contributes to the realization of the consortium's primary goal of enhancing the quality of the interaction of students and teachers in science and mathematics.

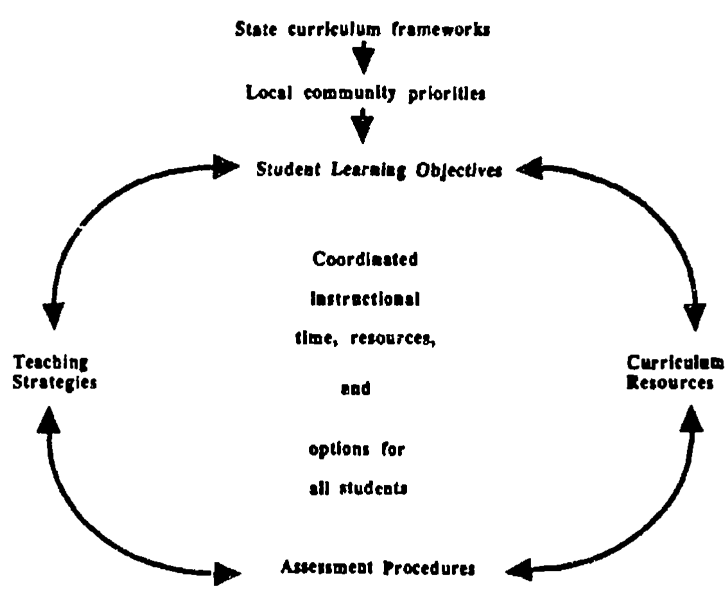
Impact evaluation activities will address the depth of influence of the Northwest CMAST activities in influencing science and mathematics instruction. Tracer studies of the impact of product and activity will be conducted to identify the depth of influence through networks directly supported and indirectly served by the consortium.

Through these three levels of evaluation activities, the effect and influence of the Northwest CMAST activities will be monitored and provided to the consortium leadership to inform critical decisions about the consortium's organization and activities.

Curriculum Renewal Structure

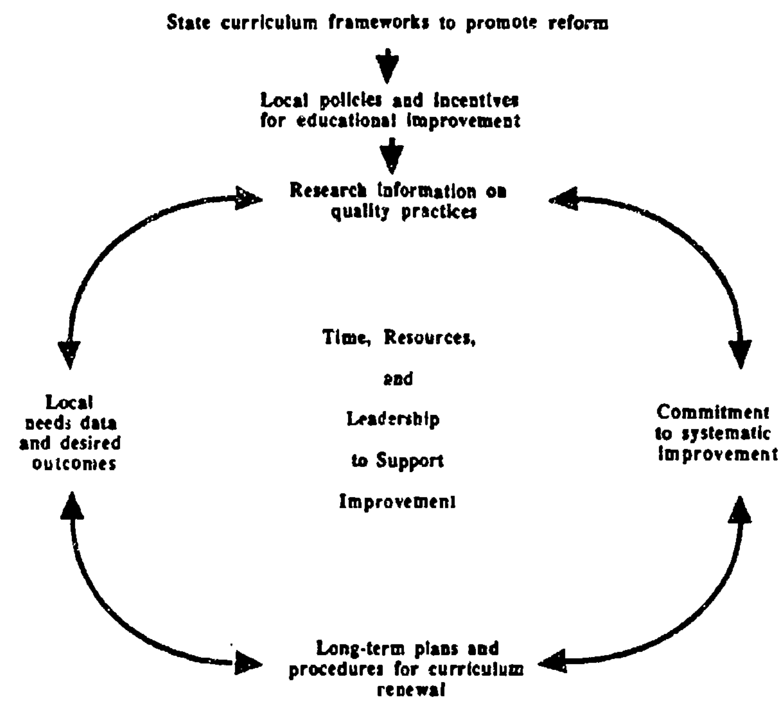
Curriculum reform in mathematics and science requires more than the development and dissemination of effective instructional materials. Curriculum structure must be more broadly viewed as the integral relationships among curriculum frameworks suggested by state policy and the professions, on the one hand, and local community priorities and desired student outcomes, on the other hand. These desired student outcomes can be achieved through coordinated instructional time, resources, and options for all students. Such options to address needs of all student include, but are not limited to, aligned learning objectives, teaching strategies, assessment procedures, and curriculum resources as seen in the *Framework for Systemic Reform*.

<u>Components of the Curriculum Structure</u>



This broader view of curriculum does not, however, address the manner in which renewal and restructuring takes place. A second dimension is necessary for reform: the mechanisms for initiating and supporting curriculum renewal itself. Again, state policy frameworks are needed for promoting reform through leadership, technical assistance, standards, and incentives. These state reform policies can be linked to local policies and incentives for supporting educational improvements. Lastly, at the local level, curricular reform can take place when time, resources, and leadership are available to support ongoing improvement, including local information on the needs and desired outcomes for learners, access to research information on quality practices, clear and consistent commitment to systematic improvement which results in long-term plans, and procedures for curriculum renewal.

Components of the Curriculum Renewal Structure



This means that we must not only have a clear view of where we are going in mathematics and science curriculum reform, but also a strong resolve to dedicate the resources and mechanisms for moving toward that vision. Pieces of this puzzle are already in place. Federally, resources are available to draw local attention to mathematics and science improvement through the priorities of the National Education Goals Panels. Nationally, efforts have begun to create a vision of the structure and outcomes of mathematics and science reform as articulated with nationally recognized curriculum initiatives of *Project 2061* (AAAS, 1989) and the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). At the state and local levels, a variety of projects have been undertaken and provide models of exemplary practice. Northwest CMAST can help to capitalize upon and support these efforts by providing leadership through research, networking, technical assistance, capacity building, and evaluation to:

The Evaluation of Regional Efforts

The evaluation of a regional infrastructure provides an opportunity to assess the effectiveness of regional activity towards enhancing the quality of student outcomes in science and mathematics instruction. Several issues of a regional approach to influencing public policy, instructional improvement and curriculum renewal in science and mathematics need to be addressed by evaluation activity. The following evaluation questions focus on these issues:

1. Organization and Operations
   - How effective is the infrastructure in developing networks that create and nurture a world-class education system in science and mathematics?
   - Does the infrastructure involve the appropriate members in the infrastructure, or are there additional important members necessary to attract?
   - Does the infrastructure operate in an efficient and effective manner to accomplish the stated objectives?

2. Curricular Reform
   - How was systematic curriculum reform implemented?
   - How was encouragement and support provided to teachers, schools, districts, and states in the Northwest for systematic curricular reform?

3. Student Achievement and Participation
   - In what ways, and to what depth, did the regional infrastructure influence the view that all children can and must succeed in school science and mathematics?
   - Did the regional infrastructure contribute to increased student science and mathematics achievement and participation?

4. Teacher Professionalism
   - What teacher development activities and encouragement were most effective in promoting increased teacher professionalism and improved science and mathematic instruction?
   - Did teachers implement and share new instructional practices?
   - What was the depth of change associated with teacher development and encouragement?

5. Curricula Quality and Use of Technology
   - Were criteria for identifying and developing effective practices for implementing the national curriculum standards identified from appropriate knowledge bases and uniformly applied to consortium activities?
   - How effective were the regional infrastructure efforts in identifying and developing effective programs?

6. Implementing Effective Practices
   - How effective were the infrastructure activities in disseminating and implementing effective programs?
   - What was the depth of influence on improved instruction in science and mathematics?

This comprehensive view of evaluation addresses the needs for process information as the organization and procedures of the regional infrastructure are developed and monitored. It allows for the identification of specific outcomes realized by the activities, and it focuses on the level of impact on the instruction of science and mathematics within the Pacific Northwest region.

Towards Scientific Literacy and Applied Academics

Scientific literacy has been raised repeatedly in recent years as a national goal. The term "scientific literacy" is a phrase which encompasses a range of notions with varying underlying assumptions, objectives, and implications. The critical elements and scope of topics included in scientific literacy are still under consideration.

Thomas Huxley began the debate in 1880 with his lecture on "Science and Culture" (Miller, 1983). Through the writing and speeches of Huxley and others, science training became a regular part of the collegiate program at major universities. Over fifty years later the value of developing scientific literacy in the general public was recognized and initial efforts to delineate the "scientific attitude" were made by writers and educators such as John Dewey (1934) and Ira C. Davis (1935).

Since World War II, technology has become increasingly integrated with science and science more responsive to social needs. Each field has become dependent on the other as the two fields grow (Shapley & Roy, 1985). Technological advances have expanded the need for science education "to reflect the contemporary relationship between science and technology" (Bybee, 1985). The enormous accumulation and growing generation of scientific knowledge has made understanding how science and technology affect our lives increasingly difficult. The integration of technology with culture has created numerous situations where solutions to problems give rise to additional problems (Wenk, 1986), and the general population is at a loss to interpret either the science or technology.

An Analysis of Scientific Literacy

Over the last decade, national committees and prominent figures in the field of science and science education have set forth a variety of definitions of scientific and technological literacy. Leaders in education, science, technology, economics, and politics each bring unique perspectives to their definitions of the topic. The authors' interpretation of the role science plays in society has a direct impact on the emphasis of their definitions. Concerns from the spectrum of writers on the topic are captured in four trends in scientific literacy. The first focuses on the need to integrate current issues in science and technology with acquiring science knowledge and problem-solving skills. Second, some leaders recognize the critical need to prepare more students to pursue science-oriented careers. Business and industry articulates a growing need for employees with basic science and technology skills. The third concern emphasizes the importance of including currently under-represented groups in the science "pipeline" (the group of people with a background enabling them to go into science careers). The fourth trend compels educators to expand the science knowledge and background of all students, providing a citizenry better able to participate in discussions on science-related topics.

These four trends have been articulated in dozens of reports. Advocates of science education reform look for ways of including these ideas in their reform efforts. Many authors from a variety of backgrounds propose coursework relating science and technology to human affairs as a means of developing scientific literacy. This interdisciplinary approach using real-life problem solving of science, technology, and society (STS) issues is seen as a means to develop knowledge and decision-making skills (DeHart-Hurd, 1985; Johnson, 1990). In addition, recent recommendations from *The Task Force on Women, Minorities, and the Handicapped in Science and Technology* (1989) suggest steps the nation should take to avoid a shortfall of scientists and engineers by the year 2000. The disproportionately low number of minority students receiving degrees in science and engineering points to an enormous loss in the potential pool of people in terms of employment, research, and social impact. Several intervention programs for minority students are aimed at increasing the number of students obtaining bachelor's and doctorate degrees in science and engineering (Collea, 1990). Changes in demographics and the nature of the workforce make emphasis on policies which encourage inclusion of all students essential. Ongoing innovations in national science curricula stem from the need to make science more accessible to all students (Aldridge,

- Connect isolated efforts into a broader framework of systemic change to integrate and coordinate effort in the region

- Strengthen the ties among mathematics, science, and other essential living skills to integrate these learning experiences with other desirable student outcomes articulated by the National Goals Panel

- Broaden the view of the mathematics and science outcomes desired for all students to provide for a balance necessary to prepare a nation of researchers, productive workers, and responsible, literate citizens

Framework for Systemic Reform

The Framework for Systemic Reform (pp. 28-30) is a template of clearly articulated priorities designed to address Goal #4 of the National Education Goals Panel (1991). The framework draws upon *Measuring Progress Toward The National Education Goals: Potential Indicators and Measurement Strategies* to extract regional targets consistent with national reform efforts. It is, first and foremost, the guiding emphasis for comprehensive action toward change in the current infrastructure of mathematics and science education. Moreover, it presents action across traditional administrative boundaries designed to enhance the science outcomes of students in the region. In this regard, the "strategic components for systemic reform" act as organizing themes of priorities, permeating organizational levels and provide the substance of the reform effort, while the activities provide the format, or process, to implement change.

Regional Collaboration and Action Equity Concerns: Serving Needs of Underserved and Underrepresented Populations

It is incumbent on the region consortium to address the needs of underserved and underrepresented children of the Northwest. Aside from current demographic and economic rationale, to serve the science and mathematics learning needs of all children, with equity and fairness, is not only a foundation of democracy, but a moral obligation of a decent and worthy educational system. Moreover, the equal and available access of opportunities in science and mathematics learning must, ethically, be central to innovation and reform. These children not only include the 240,000 minority students, but also the rural, the poor, and the isolated who must overcome low community expectations of performance.

It is proposed that Northwest educators address and meet the needs of underserved children while monitoring the progress and attainment of this priority. The following specific activities could be implemented towards this end: (1) research syntheses and task force investigations of minority and equity issues in the Northwest; (2) investigation and dissemination of exemplary projects which serve the needs of minority children; (3) ongoing expert information about minority and equity issues through newsletters and reports to members of the Regional Math-Science Network; (4) implementation of the "strategic components for systemic reform" as seen in the *Framework for Systemic Reform*, with particular emphasis on minority and equity issues; and (5) strengthening networks with minority programs (such as MESA, and AISES, and Project EQUALS) to increase awareness of issues and opportunities.

NORTHWEST CONSORTIUM FOR MATH AND SCIENCE TEACHING

Framework for Systemic Reform

National Education Goal: By the year 2000, U.S. students will be the first in the world in science and mathematics achievement

Northwest CMAST will: Develop an infrastructure that nurtures a world-class education system.

Strategic Components for Systemic Reform	Teacher	School	District	State
1. Supportive public attitudes and expectations that place a high value on scientific literacy and mathematics numeracy for all members of society.	• Encourage recognition of effective practice. • Promote teacher-community collaboration. • "Foster student self-perception with regard to learning potential/success." • Encourage a variety of active and authentic learning experiences in science, math and technology integrated into school curriculum. • Foster the pursuit and construction of knowledge driven by natural curiosity of children. • Encourage children to be responsible for their own learning. • Encourage production of science projects. • Promote parental involvement and support for mathematics and science learning.	• Promote school as basic change unit of educational and community development. • Encourage understanding of change. • Foster business-education partnerships which directly involve scientists, mathematicians, and engineers. • Encourage a spirit of experimentation in science and math education which encourages creativity and innovation.	• Assist in articulating education context of district priorities. • Facilitate long-range strategic planning. • Encourage inter-district collaboration. • Promote value and importance of science and math on personal/global basis. • Stimulate respect for science and math as the highest priority.	• Enhance communication of goals and practice. • Enhance data collection on: --value of science and math --personal and global importance of science and math --reasons for science and math achievement --likelihood of an individual's success in science and math --perceptions on science and math curriculum for students. • Strengthen science and math curriculum for students pursuing associate or baccalaureate degrees in areas other than science and math. • Strengthen and monitor overall undergraduate curriculum in science and math.

Components	Teacher	School	District	State
2. Widespread belief that all children can and must succeed in school science and mathematics. Fairness and equity for all children.	• Increase access to curriculum that addresses minority, gender, and geographic equity. • "Encourage teachers to construct teaching situations in which students will learn mathematics and science." • Foster in each student a fluency in the language and culture of math and scientific habits of the mind.	• Increase access to curriculum that addresses minority, gender, and geographic equity. • Stimulate innovative efforts in equity issues. • Encourage high achievement for all students through school organization and structure: courses, time allotted, organization of instructional time. • Encourage the elimination of the predictive powers of sex, race, and ethnicity with regard to successful math, science, and technology learning.	• Facilitate articulation of philosophy. • Encourage research-based programs to serve underrepresented children. • Foster curriculum development sensitive to general literacy, applied academics, and academics. • Promote equity in teaching resource pool and hiring. • Stimulate inquiry into ethnic and gender differences in science and math.	• Enhance access to rural, urban under-represented and underserved children. • Stimulate policy analysis exploring science and math literacy, applied academics, and academics. • Facilitate equity in teacher education. • Foster reporting that allows "dissaggregation of gender, ethnicity, socioeconomic status, primary language, and disabling conditions." • Enhance data collection in: differential expectation along racial, gender lines in science and math.
3. Teacher professionalism that is first rate.	• Enhance teacher content knowledge and pedagogical content knowledge. • Foster professional development. • Network teachers to encourage collegial support and reduce isolation. • Promote role of teacher as primary change agent in educational leadership.	• Encourage incentive programs for schools. • Foster self-determination of work group norms. • Enhance school-level staff development and support. • Foster use of instructional design teams to guide curriculum implementation.	• Promote effective personnel policies and incentives to recruit high-quality teachers. • Facilitate district initiatives in staff development utilizing national curriculum initiatives. • Encourage in-service staff development in appropriate assessment techniques.	• Foster innovation in graduation, course, and credit requirements. • Encourage certification of teachers with skill in use of appropriate assessment techniques and reporting. • Promote pre-service education of teachers which equips teachers to implement national standards. • Encourage ways to measure qualitative aspects of pre-service teacher education. • Track availability, quantity, and quality of staff development opportunities at all levels. • Encourage the production of more science and math teachers. • Strengthen undergraduate science and math curriculum for students in science and math and for those preparing to be teachers. • Track availability, recruitment and induction of teaching force across schools and districts

Components	Teacher	School	District	State
4. National curriculum standards for schools, districts, and states. Tests, assessments and accountability systems that measure the valued knowledge, skills, and processes promulgated by the national curriculum standards.	• Facilitate appropriate alternative assessment techniques and strategies. • Encourage awareness of, and use of, national standards. • Foster teacher awareness and use of assessment protocols: observation, work samples, teacher logs, sustained science projects. • Encourage authentic examinations and assessments of knowledge.	• Share strategies to enhance the school as a basic reporting unit. • Develop understanding of accountability and authentic assessment strategies. • Encourage testing and assessment that reflects nationally defined learning goals and standards. • Stimulate standards of learning where science, math, and technology play a critical role. • Encourage awareness of, adoption of, and use of national standards as measured through classroom observation.	• Enhance accountability and reporting of curriculum implementation. • Foster system-wide reporting of standards. • Encourage awareness of, adoption of, and use of national standards. • Encourage case study documentation to support data sources. • Encourage testing and assessment that reflects nationally defined learning goals and standards. • Facilitate aligning large-scale assessments with learning goals and standards in science and math to support reform efforts.	• Encourage state assistance in implementing National Goals. • Foster system-wide reporting of standards and evaluation. • "Provide a context for understanding the sources of national differences in academic achievement." • Access data sources necessary to provide information to set standards. • Encourage testing and assessment that reflects nationally defined learning goals and standards. • "Collect data through on-going surveys on policies for state and district testing, and information on the nature of assessment or test being used."
5. Instructional materials and equipment and other learning tools.	• Increase access to exemplary materials and resources. • Foster innovative classroom practice which explores what is taught and how it is taught. • Encourage use of technology for collegial networking and in instruction.	• Increase access to materials, management strategies and curriculum effectiveness. • Foster enhancing of instructional conditions including school organization, curriculum materials, and instructional practice. • Encourage use of technology to enhance resource use and instruction. • Stimulate use of electronic telecommunications to foster collegiality, resource sharing, and maintaining of educational system.	• Promote cost effective rise of resources and budget tracking. • Foster information exchange. • Encourage clear and concise reporting of classroom practice. • Enhance availability and resources in tests and assessment protocols. • Promote use of technology to improve education systems. • Stimulate use of electronic telecommunications systems to foster resources sharing and monitoring of educational system.	• Promote effective strategies in resource allocation. • Enhance system-wide monitoring material and program effectiveness. • Encourage use of distance learning techniques in science and math. • Encourage access to electronic telecommunication systems.

1989a). Bill Aldridge, Executive Director of The National Science Teachers Association, points out that 95% of the United States' secondary students are not "sufficiently literate to participate effectively in our scientific and technological world" (Aldridge, 1989b).

The notion of effective participation in our scientifically- and technologically-oriented society appears to be at the core of scientific literacy. This participation is predicated on an ability to adapt to change in our society (DeHart-Hurd, 1985). The parameters of how we develop scientifically literate students who can actively participate in a rapidly changing society are drawn through an array of performance objectives to be met. To identify key characteristics of scientific literacy it is beneficial to compare definitions proposed by a spectrum of organizations and writers in the field. In sampling definitions of scientific and technological literacy, there is broad agreement in some areas as well as unique nuances to each committee's or individual's components.

Issues in Scientific Literacy

Table 1 summarizes common capabilities identified within selected definitions. The characteristics are drawn from papers over the last decade which sought to clarify the meaning of "scientific literacy." In some cases, specific objectives were prioritized by the author(s). Author rankings of objectives were not a factor, however, in extracting the commonalities. The capabilities are listed with more detail in Appendix ii. If the objective was itemized or clearly included in the author's definition, it has been identified with a "bullet" in Table 1 In some definitions the topic is mentioned several times from different perspectives or broken down more finely than other authors chose to do. In this case, more than one bullet may appear, indicating each mention of the objective. Therefore, the number of bullets suggests the importance of the objective to the author.

The one characteristic of a scientifically literate student, recognized by all surveyed papers, was an "understanding of academic knowledge." This category captures the idea of science content as well as knowing science facts and principles. Some authors recognize this as a prerequisite to further study for a science-oriented career as well as being essential to pursuing personal needs or interests on science topics. This category also encompasses familiarity with the natural world. All papers mentioned academic knowledge either directly or indirectly as an indicator of scientific literacy. This is the only objective with 100% agreement, although interpretations and relative importance of academic knowledge vary. The idea of understanding basic facts, principles, and theories of science is pervasive in the literature.

Two performance objectives were both most frequently identified as second in importance. One is an "ability to make decisions using intellectual tools (science and technology knowledge and processes) on science-related societal issues." This is an application-oriented skill where students are able to use their intellect to arrive at decisions related to societal issues such as waste management or health. This is identified as an objective by all but two of the papers reviewed, indicating strong consensus in the field on this characteristic. The other objective which appeared as frequently is an ability to "understand methods and process of science (an ability to 'think scientifically')." This includes skill in formulating questions or forming hypotheses, data collection, using observation, inference and computation skills, understanding the meaning and importance of "theories," and developing critical thinking and problem-solving skills. Both of these characteristics focus on the importance of logical reasoning and interpreting findings.

Seven of the twelve papers recognize the importance of "the nature of science/technology" as a critical objective. This is generally depicted as an ability to recognize the human limitations and strengths of science/technology. This objective captures the human fallibility aspect of the study of science. It anticipates that students will recognize the influence of real people with capabilities and weaknesses in science.

Table 1

Scientific Literacy Definitions

Performance objectives for a "scientifically literate" person. Student should be able to:	NSTA, 1981 Project Synthesis N. Kahl, R. Yager	NEA, 1982 Education in the 80's M. Rowe	NSB, 1983 Educating Americans for the 21st Century	Daedalus '83 Achieving Sci. Literacy A. Arons	NSTA, 1985 Exeter II Conference R.Brinckerhoff R. Yager	NAEP, 1988 The Science Report Card	NAEP, 1989 Science Obj. 1990 assessment	AAAS, 1989 This Year – Scientific Literacy A. Champagne	AAAS, 1989 Project 2061 Science for all Americans	NCISE 1989 NETWORK & BSCS R.Bybee,etc.	AAAS, 1989 Conference paper J. Miller	Science Ed 1991 R.Bybee, etc
Use science in own life	•		•		•			•	•			•
Make decisions using intellectual tools (science and tech. knowledge and processes) on science-related societal issues	•	•	•		•	•		•	•	•	•	•
Understand academic knowledge (science content) •science facts and principles •background for further study •be familiar with natural world (diversity and unity)	•	•	•	• •	•	••	•	•	• •	•	•	•
See variety of career options (in science and technology)	•		•		•							
Nature of Science/Technology: •recognize human limitations and strengths of science/technology		•		••••	•		•		•	•		•••
Have a perspective on: •history of science •science as a cultural phenomenon •science as tentative, (it changes over time) •role of inquiry process in generation of science knowledge		• •		•• • • •			•		•	• • •		• •• •
Understand method and processes of science (able to "think scientifically") •formulate questions •use observation and computation skills, data collection •understand meaning and importance of theories •develop critical thinking and problem-solving skills	•		• •	•• •	•	•	•	•	•		•	•
•assess science material for value judgments, methods, data		•	•			•		•				
Think creatively			•									
Learn about science, life-long •have a natural curiosity					•			•		•		
See interdependence of science, math, and technology									•			

4 45

Half of the surveyed definitions also mentioned two other components of a scientifically literate student. The first is an "ability to use science in one's own life." Although this overlaps with an "ability to make decisions on science-related societal issues," the six authors who identified the objective all made a distinction between the two. The other characteristic mentioned as often was, "having a perspective on science" in terms of knowing some history of science, recognizing it as a cultural phenomena, its changing nature over time, and the role inquiry plays in the generation of science knowledge. Generally, authors who mentioned this included several of the aspects of the overall objective.

A few of the other characteristics are interesting to examine. In three of the early reports (until 1985) "seeing the variety of career options in science and technology" was itemized as a priority. However, this is not singled out as a specific goal in more recent years. Two characteristics are each mentioned in only one paper. The first is an ability to "think creatively." Although many authors would likely validate its importance, it was singled out only by the National Science Board in *Educating Americans for the 21st Century*. The second is an "awareness of the interdependence of science, math and technology." Once again, many authors would agree on the importance of this characteristic but only the AAAS report, *Project 2061*, prioritized it as a key feature of a scientifically literate person.

The Scientifically Literate Citizen

A compilation of selected definitions casts some light on a broadly accepted definition of scientific literacy. In general terms, a scientifically literate person has a basic understanding of science knowledge and an ability to "think scientifically." That knowledge can be used to make decisions on science-related societal and personal issues. In addition, the individual recognizes the influence of culture, time, and human limitations on science.

With this understanding of the objectives of scientific literacy, some implications for revising science education are apparent. This profile of the need and capabilities of the scientifically literate student points to the importance of four components of the science curriculum:

- Educators need to make science content and knowledge more widely accessible to more students.
- Students should also focus on developing logical reasoning skills.
- Real-life (Science-Technology-Society) issues need to be addressed with opportunities to acquire and apply knowledge.
- In conjunction with these goals, students need to develop an understanding of human and cultural influences on science.

Current Practice in Applied Academics

Across the Northwest and the nation as a whole, teachers are reporting that many of today's youth (those at risk, the "neglected majority," and the gifted alike) fail to see relevance in their curriculum. This may be due to the fact that many subjects including science, math, history, economics, and language arts are taught in isolation with little or no reference to how these subjects are applied in the workplace and other areas of life or how they fit with other school subjects. This is occurring at the same time that jobs are requiring higher proficiency in basic skills and technological understanding. As a result, billions of dollars are being spent by business and industry each year to correct the deficiencies that many employers feel should have been addressed while students are still in high school and jobs are being shipped overseas.

In the regional study of entry-level workers in the Northwest and Pacific (Owens, Lindner, & Cohen, 1988) employers reported a growing gap in the level of basic skills needed by employers and those available in the applicant pool for entry level positions. Mentioned most often were serious deficiencies in reading, writing, mathematics, communications, and problem solving skills.

Teaching decisions were once guided by a hierarchy suggesting that students must first learn the facts and skills and later learn to apply them. Yet many educators now recognize the limitations of this steppingstone view of education. A different pattern of generative teaching and learning, where learning content and procedures and how to use this learning for specific purposes occur interactively. When students engage in activities that require them to use new learning, both their knowledge of content and skills and their ability to use them develop productively together" (p.40).

There is very little opportunity in most secondary schools for students to pursue science for applied or vocational reasons. Most such opportunities appear to occur in community colleges or vocational schools. Although we know of efforts to introduce new applied science courses, we have an accounting of courses titled "Applied Biology" or "Applied Physics." (The CCSSO study refers to such courses, but only Montana and Idaho responded to their query.) We have very little data from the region on the proportion of secondary students who move into applied science and tec:. ology courses in community colleges. Most jobs require applied science rather than academic or research preparation, and many jobs require only a high school diploma or at most an A.S. certificate.

There is little attention to the possibility of enlarging or restructuring the secondary curriculum with applied courses for those students who are more interested in employment in technical fields after secondary school or community college. Some experiments with new secondary courses to address those needs are under way, but the focus of most applied science appears to be in the community college curriculum.

"Applied academics" is a generic name given to curricula developed over the past decade that show the work relevance of subjects such as physics, math and language arts. These curriculum packages are aimed particularly at the middle 50% of students who often find "general" and "college bound" classes irrelevant. These curricula are often developed through multi-state consortium efforts by companies such as the Center for Occupational Development (CORD) and the Agency for Instructional Technology (AIT). The curriculum packages usually include hands-on laboratory activities for students as well as high interest videos to draw student attention to the real world applications of the concepts taught.

Principles of Technology

Principles of Technology-often called just PT-has now been implemented in some 1200 schools nationally. The materials were cited as the best technical physics curriculum available by the American Association for the Advancement of Science in their 1988 review of materials. PT was developed by a consortium of 47 states and two Canadian provinces. It is a high school course in applied science aimed particularly at vocational-technical students. For them, a theoretical course designed for college-bound students did not seem to meet their need to better understand the behavior (and misbehavior) of modern technology.

The curriculum covers 14 units of study in a two-year period--though many schools choose to offer only the first seven in a one-year course. The 14 units nf study include: force, work, rate, resistance, energy, power, force transformers, momentum, waves and vibrations, energy converters, transducers, radiation, optical systems, and time constraints.

There are several unique features of this "packaged" curriculum:

- a teacher's guide spells out exactly what each unit covers and what the instructor needs to know and do

- each unit opens with a video (78 in all) that motivates students to consider that particular principle as it applies in mechanical systems, fluid systems, electrical systems, and thermal systems

- students then observe a teacher demonstration and use their own text to work at a lab station shared by 1 to 3 other students

- math skills are carefully assessed at each step; math labs are part of each unit to assure that students can handle the computations required for each activity

PT is being taught by science teachers, vocational teachers and by teams in some schools. Some special training is required and time is needed to make sure each laboratory exercise is set up correctly for each unit. High schools may choose to offer students elective credit in science, vocational education and/or math depending on local and state policies.

Applied Math

With the financial assistance of 42 state vocational education agencies and the guidance of mathematics and vocational educators, CORD also developed 25 units of Applied Mathematics. The materials were designed to meet the needs of students in the middle fifty percent of the high school population. The 25 units consistently use hands-on activities and work applications to transform abstract concepts into concrete experience. In the 1988-89 school year nearly 250 schools in 42 states taught Applied Mathematics to an estimated population of 7000 students.

The overall course includes material that focuses on arithmetic operations, problem solving techniques, estimation of answers, measurement skills, geometry, data handling, simple statistics, and the use of algebraic formulas to solve problems. The materials are designed to be used in a one-year course for academic credit toward high school graduation. Alternatively, they may be used in part and infused, as needed, into existing vocational courses. They are written generally at an eighth-grade reading level. The materials are deemed appropriate for high school students in grades 9 through 12 who are not necessary baccalaureate-bound.

Applied Communications

Applied Communications has been developed by the AIT as a practical curriculum to teach students the communications skills that the workplace demands. It was developed in conjunction with state departments and provincial ministries of education, instructional technologists, and educators in 42 states and provinces. The learning materials are divided into 15 instructional modules and include a total of 150 lessons. They can be used to broaden existing courses or used as the basis for a year-long course. Each module includes a series of ten 40-55 minute lessons incorporating a variety of learning activities and experiences.

Lessons 1 through 7 of each module provide instruction and practice in communications skills as they are generally used in the workplace. Lessons 8 through 10 feature activities designed to develop and refine communications skills in five major occupational areas: agriculture, business/marketing, health occupations, home economics, and technical/trade/industrial. Each module features two video programs. The student work-text for each module supplies the material for student activities-individual task sheets with lists of goals and objectives, background information, observation checklists, self-evaluation forms, worksheets, schedules, letters, and charts.

Applied Biology/Chemistry

The Applied Biology/Chemistry curriculum is in the early stages of development by CORD in conjunction with state directors of vocational education, state science consultants, and vocational and academic teachers. The prototype unit "Natural Resources" was pilot tested in September and October, 1989. The curriculum was a modular, competency-based instructional system that can be presented as a separate course or infused into existing courses. It was designed as a two-year course of instruction with the first year being developed and field tested prior to development of the second year. It may be used in any of grades 9-12 but is not intended to replace traditional biology, chemistry, or vocational courses. It will present the concepts and processes of science and technology in the context of concrete applications in society and work. Biology and chemistry will be integrated in a unified presentation. The curriculum will employ the science process skills of observing, classifying, using space-time relations, using numbers, communicating, measuring, inferring, predicting, interpreting data, controlling variables, defining terms, formulating hypotheses, experimenting, and developing models in hands-on laboratory and problem-solving activities. It will include up to 12 units, each with two to six instructional modules. Themes will deal with structure, function and classification with applications drawn for agriculture, trades and industry, home economics, technologies, health occupations, and environmental.

Modules planned include: natural resources, synthetic materials, air and other gases, water and other liquids, community of life, plant life processes, plant nutrition, animal life processes, animal nutrition, continuation of life, disease and wellness, and waste management. The prototype unit was pilot tested in September with 70 schools across the country.

According to CORD, each of the above three applied academic materials has the following similarities:

- Formatted as modularized student units
- Incorporate teacher-empowering guides for each unit
- Constructed with competency-based objectives
- Enhanced by instructional video for each unit
- Stress effective validation through field-testing
- Written at an estimated eighth-grade reading level
- Target secondary vocational students as primary audience; also useful in post-secondary adult training sites
- Emphasize holistic learning
- Can be infused into vocational courses or taught alone as a credit course by either vocational or academic instructors--or a team that includes both
- Not meant to replace "traditional" academic courses for the top 25% of the student population

Materials Science Technology (MST)
The MST curriculum is a course initially developed by Steve Piippo, an industrial arts teacher at Richland, Washington in cooperation with scientists and technical specialists from Battelle Pacific Northwest Laboratories and local volunteers. MST focuses on emerging materials that have a profound impact on products and processes in today's manufacturing works: polymers, ceramics, composites, and alloys. However, traditional woods, metals and plastics can also be addressed using the MST process. The essential ingredient at the Richland and subsequent sites has been a partnership between educators and industry experts supplemented by volunteers from other fields such as jewelry-making. Students are required to keep scientific journals of their activities to practice notation skills used by scientists. Seven new sites in Washington and Oregon field tested the curriculum in 1989-90 and new sites have come on line annually since then. Battelle is making plans for national dissemination in summer, 1992.

While it would be helpful to have well documented student impact data supporting the gains made by students in applied academics classes, such conclusive results are not yet available. Third year findings of some of the schools participating in applied academics programs through the Southern Regional Educational Board Consortium are showing that such students are getting higher grades in the respective subject areas covered than they received in prior years and that they are more likely after having had a course like Applied Math to go on to take more advanced math and science classes.

Recommendations for Systemic Action

> "There has been little study of the transitions in society and the emerging requirements for knowledge that must undergird the constructions of coherent policies of education reform." Paul DeHart-Hurd, Stanford University, 1986

Seymour Sarason's thought-provoking question (1990), **"Why should we expect that what we will now recommend will be any more effective than our past efforts?"** compels honest inquiry as a hallmark of reform intent. Beyond rhetoric, we must push conceptual boundaries and see science education in the Northwest with deeper insight.

The countless reform efforts over the past century have done little to change our cultural conception of what science education is and how we might design a dynamic system for education which is responsive to individual and cultural needs. Indeed, little reliable and accurate data exists about science education in the Northwest. Reform efforts continue to emanate from largely parochial interests and fail to address the patterns and connections of individual and organizational relationships.

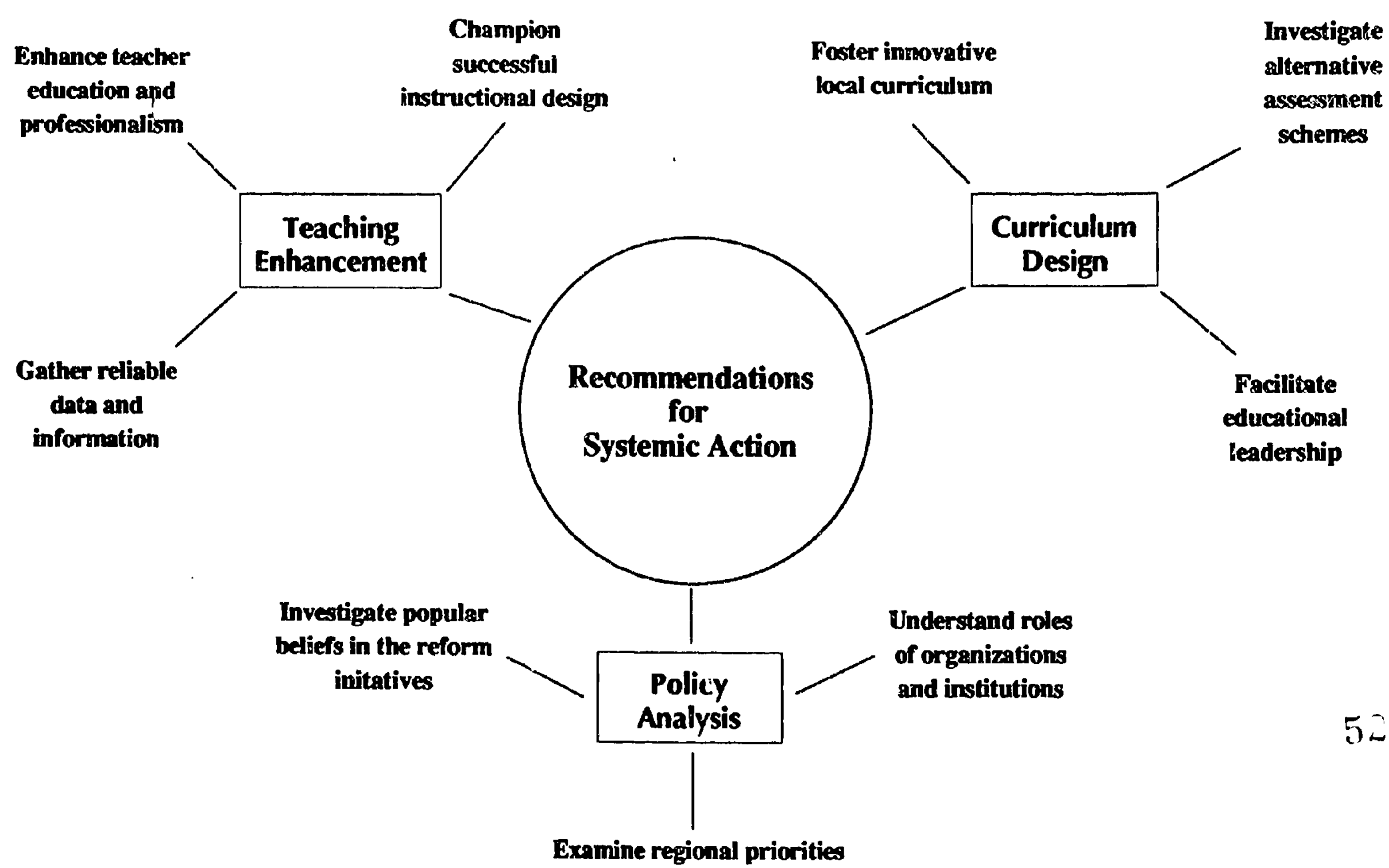
DeHart-Hurd (1986) advocates educators' discussion of beliefs and values on science education as "professional soul searching, rather than as persuasion by external authorities." It has also been underscored by others (Atkin & Atkin, 1989; NRC, 1989) that wide participation in conceptualizing reform through professional dialogue would indeed be a strong method of engendering change, or, indeed, determining if and where change is needed. Sarason (1990) calls for sensitivity to relationships between policy and curriculum players by claiming that "any educational reform that does not explicitly and courageously own up to issues surrounding changing patterns of power relationships is likely to fail. That prediction is based on the feckless consequence of educational reform in the past half-century." These perspectives imply that through concerted efforts, Northwest educators need to not only examine the current status, successes and challenges in science education, but that we illuminate the patterns among and between the conceptual and tangible parts of the science education system.

In beginning to conceptualize recommendations for systemic action it became increasingly apparent that design questions continued to emerge. The challenge was to respect the complexity of system-wide analysis, while recommending starting points for action.

The organization of concepts and ideas also presented a challenge in that one idea always led to and was intimately tied to another, making it difficult--and indeed somewhat short-sighted--to "place" an idea under an exclusive heading. This suggested a static rather than dynamic relationship, limiting insight and promoting acceptance at the expense of scrutiny. Complexity does not always lend itself to clean organization.

The following narrative and concept web suggests a starting point for system-wide recommendations for action. The reader is invited to explore patterns of connections and roles of salient organizational and systemic concepts in the science education system. In a manner similar to a student constructing conceptual understanding in science, connections are put forth to demonstrate intricate patterns between three broad, not exclusive aspects of the science education infrastructure of the Pacific Northwest: Curriculum Design, Policy Analysis and Teaching Enhancement. This approach encourages the reader to explore and challenge apparent relationships, to analyze this mental model in light of organizational and systemic perspectives, and to contribute to general understanding.

Enhancing a Regional Infrastructure to Nurture a World-Class Education System



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Curriculum Design

It is recommended that educators in the Pacific Northwest foster locally-driven. innovative curriculum sensitive to developing both citizenship and general scientific and technological literacy. Moreover, curricular innovators should seek opportunities in teaching and learning to apply academic understanding in real-life situations for all children. This includes. but is not limited to, relevant experiences in the school setting and experiences promoting needed life-long and workplace skills and attitudes. This calls educators to assist children in constructing meaning in developmentally appropriate settings in the context of commonly held conceptions of scientific and technological understanding.

Of increasing importance to curriculum innovators and policy makers is to gain understanding of assessment strategies in science and mathematics education in the Pacific Northwest. This need to investigate alternative assessment schemes is seen at many levels: (1) designing alternative forms of classroom assessment in science and mathematics learning; (2) analyzing the interplay between local needs and the articulation of state and national priorities: and (3) gaining deeper understanding of the desired educational outcomes for the regional science and math educational system.

Facilitating educational leadership at all levels is paramount. If we expect that children grow and develop in their understanding of science and its relevance in our culture, then creative and invigorating experiences in science and technology should be available to all who are responsible for nurturing such an environment. Appropriate levels of curricular decision-making should be encouraged to foster responsibility and accountability and to covey the value of science and technology education. Exploring power relationships in curricular decision-making may also yield insight into these leadership elements and policy frameworks.

Policy Analysis

The understanding of the roles of organizations and institutions calls educational leaders and participants to see their contribution and expectations in a larger context. This is vital to a dynamic and evolving educational system and assists organizations in understanding the manner in which they utilize their resources. encouraging collaboration and resource sharing. Moreover, through promoting organizational capacity. strength in decision-making is developed at the local level.

It is recommended that science educators explore regional priorities in light of national initiatives. This necessitates acquiring reliable and accurate data. articulating a vision larger than parochial views. and analyzing specific and appropriate contributions to the larger system. Identifying and recommending aspects for systemic improvement may then proceed to longer-range aims to enhance student outcomes, replacing short-term "fixes" which often impede deeper improvements in science education. In addition. by exploring system controls. policy analysts may gain insight into current relationships which inhibit true reform efforts (Sarason, 1990).

The investigation of popular beliefs in reform initiatives is vital to gaining accurate information of where we are and where we are going. Policy analysis is often plagued by the politics of popular rhetoric, rather than making sound decisions based on reliable data and information. Without reliable and accurate data and information. science education improvement is reduced to short-term and short-sighted trends, leaving needed restructuring of policy a frustrating political football. DeHart-Hurd (1986) has called for us to gain insight into the manner in which we construct "coherent policies." Testing our current conventional wisdom is recommended as a sound starting point to enhance the outcomes of science education and science teaching.

Teaching Enhancement

Teaching enhancement refers to those aspects of the professional science teaching and learning process. In this area, as well, the development of a reliable data and information base is needed to understand the demographic changes in teaching, the perceptions of science teaching and learning throughout the Northwest's educational system, and to the exploration and anticipation of workplace needs.

Enhancing teacher education and teacher professionalism is key to developing a cadre of educators who believe in their roles and contributions while recognizing the challenges they face. Research is needed to identify why science teachers choose to enter the field, and what are the causes of science teacher attrition. This involves the review of pre-service education at the local school level in light of changing science content, instructional challenges, and leadership needs in science education.

To champion successful instructional designs fosters increased understanding of what has proven to be successful, how we know it is successful, and why or why not it may be successful in a variety of settings. Aside from curriculum, the quality of the teacher is central to student outcomes in instruction. It is therefore recommended that Northwest educators and policy makers foster research-based and practical inservice education for science teachers as an integral aspect of the teaching and learning experience. Moreover, strategies to encourage civic responsibility with appropriate and relevant application of science is strongly encouraged.

Beginning a course of action

In revisiting Sarason's compelling question (1990), "Why should we expect that what we will now recommend will be any more effective than our past efforts?", we are reminded to examine the system and context for science education in the Northwest. In beginning a course of action, where do we begin? We begin by taking tangible steps, which we know are essential for planning systemic reform.

1) Mobilizing alliances of educators, concerned with science education, across a broad range of policy and practitioner role groups;

2) Forging common understanding, while respecting diversity, in articulating outcomes for science education in the Pacific Northwest;

3) Gathering reliable and accurate data and information about the region's current performance in achieving those science outcomes.

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Appendices

Appendix i

Testimony of
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Sandia National Laboratories

Before
Subcommittee on Elementary, Secondary, and Vocational Education
Committee on Education and Labor
U.S.House of Representatives

When President Bush and America's governors set forth national education goals in October 1989, Sandia National Laboratories in New Mexico took notice. We listened further to a challenge from the Secretary of Energy, Admiral James Watkins, that the national laboratories become more involved in education. Because Sandia conducts scientific research for the U.S. government, we have a keen interest in the educational system that develops future scientists, engineers and mathematicians. We decided to rise to this challenge by initiating several new programs. In the past, much of Sandia's thrust has been directed toward programs at the post-secondary level; but a significant portion of the new emphasis is directed toward elementary and secondary education. All told, Sandia is investing $12 million in its numerous projects.

In support of these new efforts, the New Initiatives Division of Sandia's Systems Analysis Department is conducting a wide ranging analysis of local, state and national educational systems to determine where Sandia can maximize its contribution. Sandia is located in Albuquerque, New Mexico, and is one of the largest employers in the region with over 7,000 employees; so, in addition to focusing on education in the nation generally, the study looks at education in New Mexico. A group of three systems analysts is focusing on the following areas:

HISTORICAL PERFORMANCE
- Dropout - Retention Rates
- Standardized Tests
- College and University Data
- Expenditures for K-12 Education
- International Comparisons
- Status of Educators

FUTURE REQUIREMENTS
- Workforce Skills
- Changing Demographics
- Education Goals

The study is producing interesting results. It has greatly changed Sandia's initial perceptions in several of the areas and reinforced others. Overall, it provides an objective "outsider" perspective on the status of education in the United States.

To ensure the accuracy of their findings, the analysts are subjecting their lengthy report to critical peer review with representatives from the U.S. Departments of Education and Energy, the National Science Foundation, The Office of Technology Assessment, and numerous state and local educators and researchers. The following is a brief summary of the major findings in the report.

Dropout - Retention Rates

America's on-time high school graduation rate has been steady for 20 years at roughly 75% to 80%. However, some students require more than four years to complete high school and many dropouts avail themselves of opportunities to reenter (GED, night school, etc.), resulting in an overall high school completion rate for young adults of over 85%. This rate is improving and is among the best in the world.

The analysts note, however, that merely reporting gross national numbers can mask underlying problems. The "fine structure" indicates that the most significant dropout problems are among minority youth and students in urban schools. Nearly 80% of white students complete high school on-time, and roughly 88% do so by age 25. Minorities do not fare as well. Only 70% of black students and 50% of Hispanic students graduate on-time. By age 25 roughly 82% of blacks complete high school (only 6% less than whites), but only 60% of Hispanics do so. Finally, dropout reports indicate that urban students, regardless of race, drop out at very high rates.

The report shows that recent immigration of under-educated Hispanic young adults who are beyond high school age is significantly inflating dropout figures for that population. Further analysis of this phenomenon is essential to properly understand the educational needs of this growing population.

Standardized Tests

The analysts evaluated student performance on both The National Assessment of Education Progress (NAEP) and the Scholastic Aptitude Test (SAT). They found that performance has been steady or improving on the NAEP with the greatest gains in basic skills. Furthermore, these gains have not been at the expense of advanced skills.

The analysts also discovered that the much publicized "decline" in average SAT scores misrepresents the true story about student SAT performance. Although it is true that the average SAT score has been declining since the 1960's, the reason for the decline is not decreasing students performance. They found that the decline arises from the fact that more students in the bottom half of the class are taking the SAT today than in years past. Since 1971 the median test taker has dropped from the 79th percentile in class rank to the 73rd percentile. Additionally, every ethnic group taking the test is performing better today than it did 15 years ago. More people in America are aspiring to achieve a college education than ever before, so the national SAT average is lowered as more high school seniors in the 3rd and 4th quartiles take the test. However, as in the dropout data, analysis of the "fine structure" indicates that minority youth continue to lag far behind their white peers on the standardized tests. For example, in spite of a 50 point improvement over the past decade in average SAT score, black students still average nearly 200 points lower than whites. Similarly, Hispanic and Native American scores lag white scores by more than 100 points.

College & University

Nearly 60% of today's youth attempt post-secondary studies at accredited institutions, and two-thirds of these (40% of all youth) enroll in 4-year institutions. Eventually, one in four of today's youth will obtain at least a bachelor's. These rates are the highest in the world.

Of significant importance is the changing population on today's college campuses. The number of women enrolled in college has been increasing steadily for 30 years while male enrollment has remained steady. Female enrollment surpassed male enrollment in the mid 70s. College populations are aging as more people enroll in post-secondary studies later in life. Additionally, four out of five college students nationwide are commuters, and over 25% hold full-time jobs while in school. As a result of these and other changes in student demographics, many universities are evolving from traditional, residential 4-year institutions to a more flexible environment which better meets the needs of today's population.

As a National Laboratory, Sandia is particularly interested in possible shortages in technical degree attainment. The analysts found that roughly 200,000 U.S. students earn technical bachelor's degrees in the Natural Sciences and Engineering each year, up significantly from 20 years ago, but representing a fairly steady rate of 4-5% of U.S. youth. The United States grants a large number of advanced technical degrees to non-U.S. citizens. Nearly 50% of engineering PhD's and 25% of science PhD's are awarded to non-US citizens annually. However, statistics show that about half of these recipients remain in the United States.

The analysts also point out that female and minority technical degree attainment continues to lag far behind their white male peers. This is in spite of impressive growth in technical degrees for women and minorities in the past two decades.

Expenditures for Education

In their investigation of educational expenditures the analysts learned that most of the increase over the past 20 years has been in special education. According to their calculations, roughly 20-35% of all K-12 expenditures today are directed to the 10% of the student population who qualify for special education.

Real increases in K-12 "regular" education expenditures during this period have been modest and are the result of decreased pupil-to-teacher ratios and modest salary increases for teachers. The salary increases consistently follow increases in average household income in the U.S.

Compared to sixteen other industrialized countries, the analysts found that U.S. spending for "regular" education is about average when adjusted for purchasing power parity, though how it ranks with specific countries is heavily dependent on the method of accounting.

International Comparisons

As was the case in other areas investigated, the analysts found little credible data regarding international comparisons. The most complete data are found in the International Assessment of Educational Progress (IAEP) report. The results of most international studies indicate that average U.S. student performance continues to be low in both math and science compared to other participants. However, the analysts discovered that many educators discount the value of an international assessment of 13-yr-olds. Quite often the major differences in educational systems across countries render such single point comparisons invalid. Additionally, many educators question the utility of the IAEP for instructional improvement. Reporting only the average performance of a large, heterogeneous population provides little insight into the quality of educational services provided to various subpopulations (urban students, ethnic groups, etc.).

Other international indicators of education system performance reflect well on the U.S. Only Belgium and Finland exceed the U.S. in the percentage of 17-year-olds enrolled in school. The U.S. continues to lead the world in the percentage of young people obtaining bachelor's degrees and the percentage of degrees obtained by women and minorities. This is true for both technical and non-technical degrees.

The analysts' comparison of technical workforces also reflected well on the U.S. educational system. Although the U.S. lags behind other countries in certain specialities (such as industrial engineering), the overall technical degree attainment by the workforce and population as a whole is unparalleled in the world.

Status of Educators

Our analysts found that direct, quantitative measures of teacher status are very difficult to obtain.

Indirect measures (e.g., interviews, opinion polls, etc.) indicate that the status of educators is low both within and outside the profession. The analysts have interviewed nearly 400 individuals to date, and low self-esteem among teachers is a common theme. The analysts believe that the foundation for this low self-opinion and poor public perception is based on misinterpretations of simplistic data such as average SAT scores and international comparisons. This unfortunate cycle of low self-esteem followed by unfounded criticism from the public raises the specter for a downward spiral in future educational quality.

Workforce Skills

Of late, much of the education debate has focused on the system's inability to produce students with adequate "skills" for the workforce. According to many, this is a primary cause for a perceived decline in U.S. international economic competitiveness.

However, the analysts' review of the limited research in business education and training practices found that very few companies point to inadequate academic preparation of new employees but rather focus on social "skills" such as punctuality and personal appearance. They found that much of the negative data circulating in New Mexico is anecdotal, and they suspect that the same is true on the national level. The business community is not uniformly responding to any forecasted "crisis" in workforce skills. Nationally, nearly 90% of business training dollars go to college educated employees (managers, professional sales, etc.) and skilled laborers, and very few business training dollars are dedicated to academic remediation. Finally, the analysts emphasize that much of the current "basic skills" training is directed at older workers and immigrants, not recent graduates.

Additionally, the analysts emphasize that even if the K-12 educational system markedly improves the "skills" of its students, this reform will not impact the workplace for 10-20 years. Thus, limited contribution, even in the long-term, to improving the economic competitiveness of U.S. businesses.

Changing Demographics

Perhaps the dominant influence on future education requirements is the changing demographic makeup of the student body. Immigration was higher in the 1980's than any other decade this century except the 1920's. Coupled with slow native-born birth rates, this is creating significant changes in the demographic makeup of today's classroom. It is estimated that up to 5 million children of immigrants will be entering the K-12 in schools nationwide, and figures nearing this number occur in single large districts.

Also, the American family structure is changing, and teachers are encountering more children from single parent homes and homes where both parents work. These demographic changes are real, persistent, and accelerating. They will drive change in education, and other social institutions as well, especially since we continue to accept the challenge to educate all of our youth. More and more, society is turning to the schools to be engineers of social change by becoming increasingly involved in meeting students' non-academic needs.

Education Goals

With respect to leadership in educational improvement the analysts found that the call for educational reform is truly widespread and includes many new voices. The President and Governors have articulated goals for education by the year 2000. However, the analysts believe that some suggested initiatives to achieve these goals may be in conflict. They believe that implementation of several programs without proper coordination or a clear understanding of desired outcomes could result in little or no gain and possibly even setback the impressive gains of the past two decades.

The analysts believe that American society has not clearly articulated the changes required to meet future goals. In fact, they assert that forming a consensus on required changes may be the greatest challenge facing education today. However, the concept of a national consensus is itself debatable. The analysts point out that the U.S. education system was built on the foundation of local control, state influence, and federal interest. The nearly sixteen thousand independent school districts nationwide attest to this concept. Forming a national consensus will be difficult and may even be undesirable.

Summary of Issues

Based on their work to date, the analysts believe the following issues are the greatest challenges to education in the 1990s:

- Forming a national consensus and finding leadership in educational improvement
- Improving the performance of minority and urban students
- Adjusting to demographic changes and immigration
- Improving the status of elementary and secondary educators
- Upgrading the quality of educational data

The analysts also believe that the following impediments to educational improvement must be overcome:

- "System-wide crisis" rhetoric
- Misuse of simplistic measures with dubious value
- Preoccupation with the link to economic competitiveness
- Focus on forecasted "shortfalls" in technical degrees

Sandia National Laboratories is using these challenges as the foundation for its increasing involvement in education at local, state, and national levels.

Appendix ii

Scientific Literacy: Sample Definitions

Harms, N. C., & Yager, R. E. (Eds.). (1981). *What research says to the science teacher (Project Synthesis)*. Washington, DC: National Science Teachers Association.

A Scientifically Literate person should be able to:

- Develop a picture of the structure of science and its relation to society to insure that the scientists of the future see the social context of science;
- Acknowledge the ambiguities of science and somehow develop a mechanism to accommodate them to insure that the scientist of the future sees the potential pitfalls of science as operated in society (e.g., analytic vs. synthetic; objective vs. subjective);
- Acknowledge the elements of science considered to be most troublesome by some, and relate them to the career of his/her choice (e.g., the uncertainty principle, optimization and self-correction); and
- Give examples of how scientific and technological advances have been used and abused by society.

Learning Outcomes of Science Education: Science education should:

- (Personal needs) Prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world.
- (Societal Issues) Produce informed citizens prepared to deal responsibly with science-related societal issues.
- (Academic Preparation) Allow students who are likely to pursue academically as well as professionally to acquire the academic knowledge appropriate for their needs.
- (Career Education/Awareness) Give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

Mullis, I. V. S., & Jenkins, L. B. (1988). *The science report card: Elements of risk and recovery*. Princeton, NJ: Educational Testing Service.

Five levels of proficiency for science assessments:

Level 150 Knows Everyday Science Facts
Level 200 Understands Simple Scientific Principles
Level 250 Applies Basic Scientific Information
Level 300 Analyzes Scientific Procedures and Data
Level 350 Integrates Specialized Scientific Information

The National Assessment of Educational Progress. (1989). *Science objectives, 1990 assessment: The nation's report card.* Washington, DC: The National Assessment of Educational Progress.

"Understanding the nature of science is the foundation of scientific literacy and thus of the assessment framework itself..."

Understanding the nature of science requires an understanding of:

- The methods and processes of science
- The principles underlying scientific work
- The nature of scientific knowledge

In addition students should:

- Be cognizant of the major developments in science history
- Apply technology to problem solving

Christianson, D. (1982). Understanding science as a cultural phenomena - Mission for the 80s. In *Education in the 80's: Science.* Washington, DC: National Science Board Commission on Precollege Education in Mathematics, Science and Technology.

Scientific Literacy should yield an educated public with:

- Knowledge of potentialities and limitations of science.
- Perspective on history of science.
- Working knowledge of science content.
- Intellectual tools needed to appreciate science as a cultural phenomena, and,
- Ability to assess science material for value judgements and use moral reasoning.

American Association for the Advancement of Science. (1989). *Project 2061: Science for all Americans, (Summary)* (p.4). Washington, DC: Author.

Focus on connections rather than boundaries between disciplines. Emphasize thinking rather than vocabulary/memorized procedures.

Adapted Recommendations:

- Familiarity with natural world (diversity and unity)
- Understanding of key concepts and principles of science
- Awareness of interdependence of science, math and technology
- Knowledge of human limitations and strengths of science
- Capacity for scientific thinking skills

- Apply scientific knowledge to individual/societal purposes

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. (1983). *Educating Americans for the 21st Century: A plan of action for improving mathematics, science and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995*. (Report to the American People and the National Science Board). Washington, DC: Author

Goals of Science Education:

- Formulate questions
- Develop critical thinking and problem solving
- Develop creative thinking
- Awareness of breadth of science and technology careers
- Foster academic knowledge for science careers
- Develop academic knowledge for civic responsibility, personal health, and effective use of technology
- Ability to evaluate (meaningfully read) science articles

Arons, A. B. (Spring 1983). Achieving wider scientific literacy. *Daedalus*, pp. 91-122.

The person who has acquired scientific literacy will possess the ability to:

- Recognize that scientific concepts...are invented or created by acts of human intelligence...
- Recognize that ... a scientific concept involves an idea first and a name afterward
- [Make]...distinction between observation and inference....
- Distinguish between the occasional role of accidental discovery in scientific investigation and the deliberate strategy of forming and testing hypotheses.
- Understand the meaning of "theory" in [science]...
- Discriminate...between acceptance of... unverified end results...and when something is being taken on faith.
- Understand...[that] scientific concepts and theories are mutable and provisional...
- Comprehend the limitations [of] scientific inquiry...
- Develop enough basic knowledge and understanding in some area (or areas) of interest to allow intelligent reading and subsequent learning without formal instruction.
- Be aware of... instances in which scientific knowledge has had direct impact on intellectual history...

- Be aware of...specific instances of interaction between science and society ...
- Be aware of...certain modes of thought in natural science and in other disciplines such as history, economics,...

Brinckerhoff, R. B.,& Yager, R. E. (Eds.). (1985). *Science and technology education for tomorrow's world.* Exeter, NH: Exeter II Conference on Secondary School Science Education.

The science teachers supported the following goals of science education:

- Prepare students to use science and technology in understanding and improving their daily lives.
- Prepare students to deal responsibly with science-related societal issues.
- Encourage in students an inquisitiveness about the natural world and an understanding of scientific explanations of natural phenomena.
- Encourage in students an awareness and understanding of the nature of science ...
- Develop in students an awareness of science and technology-related careers.

Champagne, A., Lovitts, B. E. et al. (Eds.). (1989). Scientific literacy: A concept in search of definition. *This Year in School Science 1989, Scientific Literacy.* Washington DC: A.A.A.S.

Scientific Literacy definition depends on where emphasis lies in different aspects of science and citizen's role in society.

Scientific Literacy focii:

- Application of science knowledge and reasoning skills to solving problems and making decisions in personal, civic and professional affairs.
- Ability and interest to continue learning about science—lifelong (appreciation of science/ability to read and understand science-related material).
- Knowledge and intellectual skills in science (whether or not they're used).

Bybee, R., Buchwald, C. E., Crissman, S., Heil, D. R., Kuerbis, P. J., Matsumoto, C., & McInerney, J. D. (1989). *Science and technology education for the elementary years: Frameworks for curriculum and instruction.* Washington, DC: National Center for Improving Science Education.

Science and Technology Education: Recommendations

Primary Goals for science education in the early years:

- Develop the students' natural curiosity.
- Broaden the students' procedural skills for investigating the world, solving problems, and making decisions.
- Increase the students' understanding of the nature of science and technology.

- Develop the students' understanding of the nature of science and technology.

- Ensure the students' understanding of the limits and possibilities of science and technology in explaining the natural world and solving human problems.

Bybee, R. W. (January 1991). Integrating the history and nature of science and technology in science and social studies curriculum. *Science Education Journal*, pp. 143-155.

- Understands the nature of modern science, the nature of scientific explanation, and the limits and possibilities of science.

- Understands the nature of technology, the nature of technological solutions to human problems and the limitations and possibilities of technology.

- Understands that the nature of science and technology as well as their interrelationships have changed over time.

- Understands that science and technology are products of the cultures within which they develop.

- Understands that the roles and effects of science and technology have differed in different cultures and in different groups within these cultures.

- Understands that technology and science are human activities that have creative, affective and ethical dimensions.

- Bases decisions on scientific and technological knowledge and processes.

Miller, J. D. (1989). *Scientific literacy*. Paper presented at the Annual Meeting of the American Association for the Advancement of Science, San Francisco, CA.

Scientific Literacy demands:

- An understanding of the process or methods of science for testing our models of reality,

- A basic vocabulary of scientific and technical terms and concepts, and

- An understanding of the impact of science and technology on society.

DeHart-Hurd, P. D. (1985). A rationale for a science, technology and society theme in science education. In *NSTA Yearbook Science Technology Society 1985*(pp. 94-102). Washington, DC: National Science Teachers Association.

Adapted from pp. 99, 100

A Science Technology and Society context for science teaching will enable students to:

- Participate in exploring "real" problems to develop an awareness of their own purposes, beliefs, and ideals...

- Recognize humanistic factors in technical knowledge.

- Develop intellectual skills (problem solving, decision making, ethical judgment, and knowledge synthesis).

- Apply knowledge of science and technology.
- Draw social and personal implications from knowledge.
- Have perspective of science and technology as they function in research and are applied to human affairs.
- Recognize integrated nature of sciences, humanities, arts, mathematics, life outside school environment.
- Motivated to use knowledge and skills for planning the future.

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- Developing and disseminating effective educational products and procedures
- Conducting research on educational needs and problems
- Providing technical assistance in educational problem solving
- Evaluating effectiveness of educational programs and projects
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