THE REALITY OF THE K-12 SCIENCE PUBLIC EDUCATION SYSTEM

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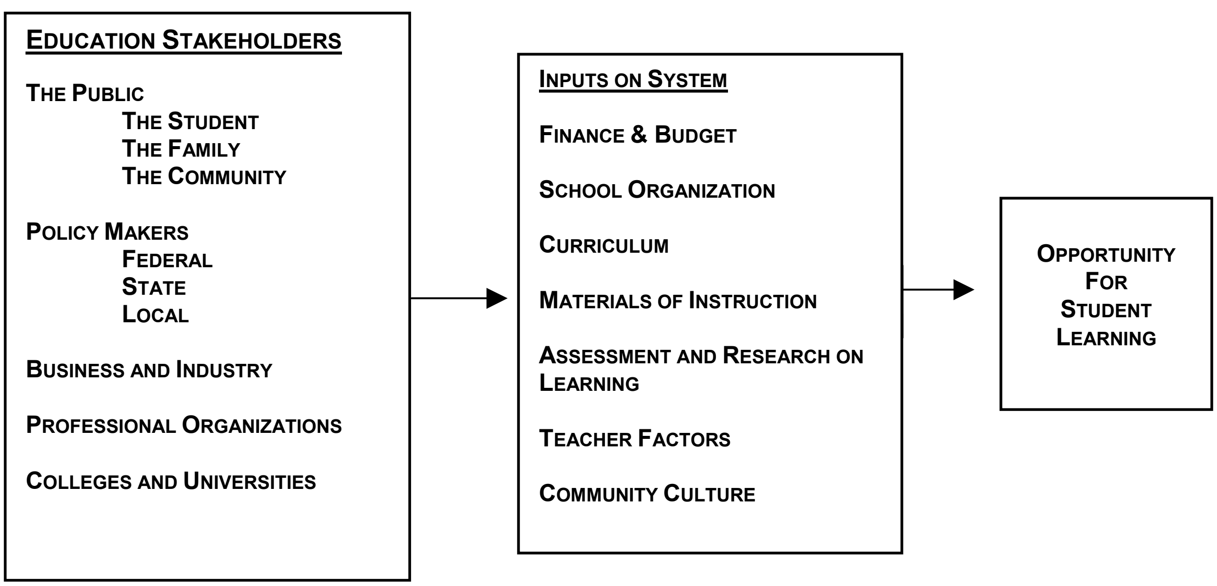
PUBLIC EDUCATION IS A SYSTEM

The American Association for the Advancement of Science (AAAS) suggests that a system may be thought of as a collection of things and processes (and often people) that interact to perform some function (*Benchmarks for Science Literacy*, 1993). Public education is a system. The purpose of this system is to ensure science literacy of students as they emerge from high school and to prepare them for advancement into careers or advanced study. What are the parts of this system? What are factors that influence the system and how do they interact to affect the scientific literacy of our secondary school graduates? The system is complex and has levels of organization. *Blueprints for Reform* (AAAS, 1997) lists factors that impact student learning. These may be thought of as categories of inputs to the system. The figure below[2] illustrates a model that may be used to examine the K-12 Public Science Education System, from stakeholder influences to the desired system outcome—student learning.

Figure 1: Model for U.S. education system showing influences of stakeholders, inputs to the education system and the principal desired outcome from the system.



POLICY

Policy on the national, state, and local levels dictates the structure and organization of the system. In January 2002, President Bush signed the ***No Child Left Behind (NCLB) Act of 2001***, reauthorizing the *Elementary and Secondary Education*

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[2] Adapted from a framework developed by the National Research Council's Committee on *Understanding the Influence of Standards in K-12 Science, Mathematics, and Technology Education* (2000) chaired by Iris Weiss of Horizon Research, Inc.

Act "*to ensure that all children have a fair, equal, and significant opportunity to obtain a high-quality education and reach, at a minimum, proficiency on challenging state academic achievement standards and state academic assessments.*"[3] This sweeping federal legislation touches and interacts with virtually every area of education policy. To qualify for funding under NCLB, the state must meet specific regulatory requirements and procedures including:

- Stronger Accountability for Results
- Expanded Options and Choice for Parents
- Emphasis on Teacher Quality and Teaching Methods that Work
- High standards for all students and at a minimum attain proficiency or better in reading and mathematics by 2013-2014.
- Proficiency for All Limited English Proficient Students
- Highly qualified teachers for all students by 2005-2006
- State assessments administered to all students in all public schools in the state. Beginning with the 2007-2008 school year, states must administer a science assessment annually in at least one grade in each of the following grade spans: 3-5, 6-9, and 10-12.

WHAT IS THE REALITY?

NCLB has the education community turned upside down! All policy (national, state, and local) now emanates from this federal legislation. There is a laser focus on reading and mathematics- the first areas to be assessed and report adequate yearly progress (AYP). No longer can achievement of subgroups be hidden within the statistics of the general school population. Data must be disaggregated and reported by subgroups including economic status, special services, and ethnicity. Because science is not slated for testing until 2007-2008 and at this time not required to report AYP, many of those who create policy have relegated science to the backburner- directing the majority of resources to reading and mathematics. Jodi Peterson, Legislative Director for the National Science Teachers Association (NSTA), reports, "very serious concerns that science will erode from the curriculum and that science teachers won't get continued federal funding for professional development."

FINANCE & BUDGET

Most states have a district-driven finance system. Districts raise money and determine how it is spent on schools; states and the federal government distribute money to districts. Schools receive resources - teachers, books, and transportation - but they rarely receive money[4]. In Maryland, the *Bridge to Excellence in Public Schools Act* describes two approaches: the **Professional Judgment Approach**, in which panels of educators determine the kinds of resources needed to achieve a particular set of objectives in prototypical schools. These resources are then "priced out" based on salary levels and other factors to determine the per pupil base cost and weighted adjustments for at-risk students. The **Successful Schools Approach** examines the "basic" spending of those schools that meet performance objectives established by the state, where basic spending excludes transportation, special education, compensatory education, or other

[3] Public Law PL107-110, *No Child Left Behind Act of 2001*

[4] Odden, A. (1995). *Critical Issue: Redesigning School Finance: Moving the Money to the School*. North Central Regional Educational Laboratory. Naperville, Illinois.

spending targeted to special student populations. A foundation program provides state and local aid to school systems based on general enrollment and "base cost" per student. When fully phased in, Local Education Agencies (LEAs) will receive a minimum per-pupil state foundation grant of 15%.

The per pupil expenditure in the United States varies. The range is shown in the table below.

Table 1: 2002 Fiscal Year Range of Per Pupil Expenditure on U.S. PreK-12 Education[5]

State	Number of students	Number of teachers	Pupil/teacher ratio	Per pupil expenditure
United States	47,575,862	2,988,379	15.9	$7,524
District of Columbia	68,449	5,235	13.1	11,009
New York	2,920,000	215,000	13.5	10,725
Connecticut	570,145	41,263	13.8	10,517
Tennessee	938,162	58,059	16.2	5,470
Arizona	903,518	45,959	19.7	5,445
Mississippi	491,686	32,757	15.1	5,230

Sixty percent of the instructional dollar is spent directly on instruction. This includes employee salary and benefits. An additional 8-10 percent is spent on curriculum development, professional development, and student services. The remaining 30 percent is spent on operations, transportation, food services, and administrative costs.

WHAT IS THE REALITY?

Teachers report a constant need for resources including money for textbooks and science materials of instruction. In districts I am familiar with, district administrators (not necessarily those intimately involved with the Science Program of Studies) allocate resources. Resources are especially lacking in the elementary program. Schools may have little or no textbooks or materials of instruction for students to "do science." In some states, some grant funds are available for purchase of materials if the district is able to provide matching funds. For Maryland, the district provides matching funds in a ratio of 3:1. Some districts are able to take advantage of this grant program (Maryland Equipment Incentive Fund). In 2002-2003, in Anne Arundel County, a district of about 75,000 students the amount to be shared by mathematics and science was about $20,000.

In the past, Eisenhower Professional Development Funds were specified by legislation for professional development activities in science. With the elimination of the Eisenhower Program, and folding of the Eisenhower-like Program into Title II of NCLB, funds are more discretionary and states and districts can direct funds to the immediate priorities- reading and mathematics.

Some district-level science supervisors in Maryland report they have no funds for professional development. Some districts are more forward thinking and do allocate such funds in the core areas of instruction, including science. For Title II B (Department of Education Math Science Partnerships), the funds allocated for Maryland are $1.2 million for 24 districts. This is a source of funds for math science partnerships in

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[5] National Center for Education Statistics. (2003). Retrieved October 2003 from http://nces.ed.gov/pubs2002.

collaboration with higher education. The informal direction given from state officials was that proposals directed towards mathematics would be favored (and in fact my personal direction was "science need not apply"). This is in spite of the addition of funds in response to direct lobbying by Gerald Wheeler, Executive Director of the National Science Teachers Association (NSTA). The snowball effect is that science may not be taught at all in the elementary grades.

Teacher salary is another huge financial consideration. Teachers earn less than many other college graduates with similar literacy skills; however, adjusting for inflation, education majors have fared better than other recent college graduates in terms of growth in earnings. In 1992, teachers had literacy skills similar to those of many other college graduates, including private-sector executives and managers, engineers, physicians, writers and artists, social workers, sales representatives, education administrators, and registered nurses. However, they often earned less. The average annual earnings for teachers (prekindergarten through secondary, public, and private) employed full time were $26,000 in 1991, compared to $38,500 for all persons with a bachelor's degree who were employed full time.[6]

In the *Quality Teacher Workgroup Final Report* (February 2003), presented to the Maryland State Board of Education, the committee states, "Salaries in teaching must be highly competitive with other professions in our state and neighboring states in order to attract quality individuals into the teaching profession. Without the appropriate salary incentives, public education will continue to have difficulty in recruiting and, more importantly, retaining quality teachers, so that students will be able to meet the standards for Adequate Yearly Progress (AYP)." The salary portion of any district's budget may be the largest outlay of funds. In Anne Arundel County Public Schools, the salary and wages portion of the 2004 Operating Budget accounted for 61.49% of funds (close to 394 million dollars in a district of 75,000 students and 3,407 educators).

Teachers represent 4 percent of the entire national civilian workforce. (Ingersoll, 2003). Employee data from the Bureau of National Affairs[7] shows a percent annual turnover rate for all employees of 11 percent. All teachers have a percent annual turnover rate of 14.3 percent. For math and science teachers, the rate is 16 percent. Among reasons for teacher turnover, 48 percent of math and science teachers cite job dissatisfaction (including poor salary, poor administrative support, student discipline problems, lack of faculty influence and autonomy, poor student motivation, poor opportunity for professional advancement, inadequate time to prepare, and intrusions on teaching time).[8]

RESEARCH ON STUDENT LEARNING IN SCIENCE

There is a lack of research in specific areas of how students learn about specific topics. *Benchmarks for Science Literacy* (AAAS, 1993) describes specific areas missing from the research base. Some of them are:

- How elementary students learn about the nature of science
- The relationship between mathematics and science and mathematics as a tool for modeling and understanding science and the use of models

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[6] National Center for Educational Statistics. (1996). Findings from "The Condition of Education 1996." *Teachers' working conditions*. December 1996.
[7] Bureau of National Affairs. (1998). BNA's quarterly report on job absence and turnover. *Bulletin to Management*. Washington, DC: Bureau of National Affairs.
[8] Rhoton J. and P. Bowers, eds. (2003). *Science Teacher Retention. Mentoring and Renewal*. Arlington, VA: NSTA Press.

- What students understand about processes that shape the Earth
- Teaching interventions in physical and Earth sciences
- Abstract ideas such as the atomic/molecular nature of matter
- How energy flows through the environment

WHAT IS THE REALITY?

Without this research base, science-teaching practices have huge areas that remain uniformed about the most effective teaching strategies. We know little about student misconceptions in specific subject areas or how long misconceptions, once developed, follow a student—do they persist through college? Do they persist as students enter the teaching profession? How do a student's interest and other non-cognitive factors influence science literacy and what are the implications for participation in science, technology, engineering, and mathematics careers? What is the snowball (collateral) effect on public support of science and science related issues?

The *Math and Science Partnership* (MSP) Program offered by the National Science Foundation addresses the mandate to strengthen K-12 science and mathematics education. The *MSP* promotes a vision of education as a continuum that begins with our youngest learners and progresses through adulthood. The program supports partnerships that unite K-12 schools, institutions of higher education, and other stakeholders in activities that ensure that no child is left behind. Recognizing the need for research, *MSP* has created the *MSP Learning Network*, "designed to deepen our understanding of how students learn, how to create supportive learning environments, and how to prepare and support teachers."

TEACHER FACTORS

The link between student achievement and teacher quality is well documented in educational literature. In his work on the Tennessee Value-Added Assessment System, William Sanders has found that teacher effectiveness is, "the single biggest factor influencing gains in achievement, an influence many times greater than poverty or per-pupil expenditures."[9] After synthesizing the past 35 years of research, Robert Marzano has come to a similar conclusion.[10]

The implications for jurisdictions are enormous. The mandates under NCLB will drive the development of an organizational infrastructure to identify, monitor, and report the numbers of "unqualified" teachers, as well as the need for resources, development, and support of teachers who do not meet the standard. This law provides three choices for teachers to comply with the mandates: take course work, pass a test, or undergo a uniform state evaluation.

WHAT IS THE REALITY?

In testimony to the U.S. House of Representatives, May 14, 2003, Gerald Wheeler, Executive Director of the National Science Teacher Association (NSTA), described issues facing mathematics and science education.

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[9] Weglinsky, H. (2002). How schools matter: The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archives*, 10, 12.
[10] Marzano, R. What Works in Schools. Translating Research into Action. Reston VA: ASCD, 2003.

- National and international tests show American students do not compare with their counterparts in other countries: Findings from the Third International Mathematics and Science Study (TIMSS) in 1995 show that while U.S. fourth grade students scored above the international average in science and mathematics, eighth grade students scored far below international counterparts, and 12th grade student scores were abysmal. The 1999 TIMSS update study, TIMSS-R, showed no significant changes in these achievement levels from 1995 to 1999. Scores from the National Assessment of Educational Progress (NAEP) show that less than one third of all students in grades 4, 8, and 12 performed at or above the proficient level in mathematics and science.
- Too many teachers of science and math do not have baccalaureate degrees in these subject areas**.** Serious shortages exist in high poverty schools where students have less than a 50 percent chance of having a science or math teacher who holds both a license and a degree in those subjects.
- The need for qualified science and math teachers is increasing, especially in urban areas. In 2000, the Council of Great City Schools and Recruiting New Teachers surveyed 40 top urban school districts, and asked them if they faced a teacher shortage. Ninety-eight percent of these districts reported an immediate need for science teachers, and 95 percent reported an immediate need for mathematics teachers. This is more than 10 percent of the nation's public school enrollment.

The Maryland committee reporting on teacher quality (*Teacher Quality Workgroup Final Report*, 2003) heard considerable testimony, *"suggesting that working conditions for teachers have significantly worsened. Teachers are struggling with crushing workloads"*. In the most recent statistics[11], the average amount of time a full-time teacher is required to spend at school is only about three-quarters of the teacher's workweek. In school year 1993-94, full-time public school teachers were required to be at school for an average of 33 hours-per-week to conduct classes, prepare lessons, attend staff meetings, and fulfill a variety of other school-related responsibilities. The average was similar whether they worked at the elementary or secondary level. In addition to the required time at school, a full-time public school teacher worked an average of 12 additional hours-per-week before and after school and on weekends. Teachers spent three of these hours in activities involving students and nine hours in other school-related work, such as grading papers, preparing lessons, and meeting with parents.

When compared to other countries, United States teachers spent considerably more time teaching and they carry higher pupil-teacher ratios. At the primary level, in 1992, the average time-per-year public-school teachers spent teaching (excluding other school responsibilities) was 858 hours (average of 15 countries, mostly European), with a low of 624 hours in Sweden to a high of 1,093 hours in the United States. Moreover, in public schools, at the secondary level, pupil-teacher ratios in the United States are higher compared to those in other developed countries. U.S. secondary classrooms on average have three more students than those in 16 other countries (compare 16.7 to 13.8).

Maryland Science Supervisors (2003-2004 school year) report that teacher class size may range from 20+ in the primary grades to well over 35 in the secondary grades.

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[11] National Center for Educational Statistics. (1996). The Condition of Education 1996. *Teachers' working conditions*. Washington, D.C.

Hours spent on students outside classroom time increase as pupil-teacher ratios increases.

Maryland's *Teacher Quality Workgroup Report* also states that teachers experience less support from administrators who are equally overworked; and they enjoy far less autonomy, and can be far less creative in their teaching, as the result of mandated testing and curriculum requirements. A reasonable workload is essential to accomplishing the desired outcomes of student achievement as well as a greater retention rate for teachers. Until working conditions for teachers are substantially improved, it will continue to be difficult to attract and retain the best and brightest to teach in our schools.

WHAT LIES AHEAD FOR K-12 SCIENCE PUBLIC EDUCATION?

If the United States is to retain its position of leadership in the global economy, then producing a citizenry literate and supportive of science, *and* developing our own students into scientists, mathematicians, and engineers the need to support our national agenda is critical.

All science, technology, engineering, and mathematics (STEM) stakeholders must make a full-scale commitment. A laser-focused, coordinated and sustained research and implementation effort is essential in order to reverse our current trends and accelerate student achievement. These efforts require the most influential and prestigious of stakeholders to come together to set, commit to, and invest in an agenda to address the nation's needs in the STEM areas.

Create a task force of key stakeholders to advance science achievement in terms of NCLB - professional organizations, higher education, business and industry, and the K-12 education community.

1) Develop an action plan to address current issues in science education with identified stakeholders responsible for specific parts of the plan
    a) Initiate procedures for development of research in identified areas including best practices for teaching in STEM areas
    b) Develop a model for school system/business/higher education partnerships and set expectations and specific goals
    c) Set standards for teacher career practices—working conditions and salary to be commensurate with professionals of similar educational background in order to attract and retain highest quality teachers; include models for ongoing professional development linked to partnerships
    d) Create steps in a career path for master educators in STEM areas with appropriate community recognition and salary advancement so that master teachers do not need to become administrators in order to move to the top of the education salary scale
    e) Establish a focused and ongoing campaign to educate the public about the benefits of and nations' need to support science and technology; address myths, stereotypes, and negative public attitudes in our culture towards science and technology professionals; focus on creating positive attitudes towards the teaching of STEM subjects as a career in the student community and the public at large.
    f) Design a financial package for implementation of the action plan. Include the national experts in banking and finance as well as industry to develop funding for implementation of initiatives. Without funding, an action plan is just words.

We are bound by a complex and cumbersome structure in which many individuals and communities are working as competitors for research dollars and resources rather than cooperators. TIMSS and NAEP data show, we are, at best, at a standstill. The 2007-2008 science assessments and the gap in student achievement among sub-groups remain. Looming larger than that is the ability of our country to successfully compete in the global economy across all socio-economic sectors. Envision an effort such as the one that allowed us to land a man on the moon. Build on the strengths of each of the key players; avoid duplication of efforts in each organization, state and district. Unless we can set the national agenda and ignite the stakeholders to move STEM forward, we will continue to be, as TIMSS has shown, a below average nation!

Figure 2: Block diagram illustrating proposed taskforce membership and national agenda elements.