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Reaching Teachers: The First Step in Teaching Students

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Abstract

A 1984 American Association of the Academy of Sciences study of more than 150 successful science in-service programs developed a list of their characteristics, which included:

- Strong academic component in mathematics, science, and communications, focused on enrichment rather than remediation
- Academic subjects taught by teachers who are highly competent in the subject matter and believe that students can learn the materials
- Heavy emphasis on the applications of science and mathematics and careers in these fields
- Integrative approach to teaching that incorporates all subject areas, hands-on opportunities, and computers
- Multiyear involvement with students
- Recruitment of participants from all relevant target populations
- Opportunities for in-school and out-of-school learning experiences
- Parental involvement and development of base of community support
- Specific attention to removing educational inequalities related to race and gender
- Involvement of professionals and staff who look like the target population
- Development of peer support systems (involvement of a critical mass of any kind of student)
- Evaluation, long-term follow-up, and careful data collection
- "Mainstreaming" - integration of program elements supportive of women and minorities into the institutional support programs

I will illustrate these points with ongoing teacher-support programs in progress in the Chicago area.

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Introduction

The state of teaching of mathematics and science in our schools is at a critical stage: Admiral James Watkins' report to Congress in January 1991 *By the Year 2000: First in the World* accompanied the President's education budget request and pointed out some of these crises: 20% of new teachers leave the profession in their first year; more than half leave before their sixth year; for every mathematics and science teacher entering the profession, thirteen are leaving it; the number of college students majoring in education in four-year colleges today is 55% of the number in 1972.

A report[1] by the Committee on Education and Human Resources (CEHR) of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) in March 1991, pointed out the necessity of providing support to improving the mathematics, science and technology education in graduate schools, in undergraduate schools, and in our high schools and elementary schools. Their implementation priorities for precollege education, in order are:

- Teacher preparation and enhancement
- Curriculum reform, research and development in learning, dissemination and technical assistance
- Organizational reform and system operation
- Student support, incentives and opportunities

A recent study of the Association for the Advancement of Science (AAAS) found that very few teachers have adequate preparation for teaching mathematics or science. The following table shows the percentages of elementary school teachers reaching an established standard of course-work preparation:

Subject	Elementary school	Middle school
Mathematics	18%	14%
Science	33%	22%

High school science teachers show similar inadequacies with only 12% of physics, 31% of chemistry and 29% of biology teachers reaching the set standards.

The National Science Teachers Association (NSTA) defined two major goals of an effective science education for all kindergarten through twelfth grade (K-12) students[2]:

1. **Scientific Literacy**: Our nation must have a citizenry that is prepared to understand and deal rationally with the issues and opportunities of a scientific and technological world;

2. **Human Resources**: Our nation must have enough qualified scientists, engineers, teachers and

related professionals to compete successfully worldwide in science and technology.

The NSTA set of five broad areas for **Initiatives to Improve Science Education** closely parallel those of the CEHR above:

- Commitment to science education
- Curriculum development
- Instructional support
- Preparation and staff development
- Research support

(See appendix A for a more complete description of the relevant parts of the NSTA proposals)

A recent conference workshop[3], **New Challenges in Educating Engineers**, workshop on **K-12 Preparation for Science and Technology**, at the Illinois Institute of Technology in Chicago, June 10-11, 1991, focussed on these needs. A key realization at the conference especially for the needs for K-12 science education, but also in the education at college and graduate levels, was the importance of leadership from higher education institutions: they are the legitimizing agencies for K-12 education. In addition, they educate the teachers who will be responsible for achieving the goals of successful K-12 science education.

The leadership role can only be effective if it enhances the lines of communication between higher education institutions and the K-12 educational world. The traditional gap must be bridged by developing a community of all interested and involved stakeholders in science and technology education.

We focus here on the needs to train and support science teachers for the K-12 grades, and use some of our Chicago experiences as examples. This first point of developing a coordinated community of professional scientists and engineers, of university educators and scientists, and other professional educators and the teachers, principals and parents is a critical one. Each part of the community has to develop a respect and understanding of the abilities of the other parts. For example, university scientists and educators rarely set foot inside elementary or secondary school classrooms that are not associated with their own children; elementary and secondary science teachers rarely visit scientific labs or university classrooms. A mutual understanding of the different sets of problems can bring immediate steps forward in helping to work together.

The establishment of the **Academy for Mathematics and Science Teachers in Chicago** was a major attempt for a cohesive approach to the problems of science teachers in a large urban school system[4]. The Academy was envisioned as a place in Chicago where all the components of the science education community would play a part. Initial strong Federal support for an integrated program of enhancing Chicago Public School Teachers was important as a catalyst for success based on the tenets given in the abstract above. Admiral James Watkins, Secretary of the U.S. Department of Energy led the drive to obtain other federal support from the National Science Foundation, the U.S. Department of Education, and NASA, the National Aeronautical and Space Administration. State support came through the Illinois Science Education programs, and through in-kind contributions from the Chicago Board of Education. Personnel from the local Federal laboratories, Argonne and Fermi, gave support. The

Presidents of fourteen local-area universities and colleges formed the board and funded an umbrella organization, The Chicago Education Federation, to administer the Academy. This Academy was conceived in July 1989, first funded in June 1990, opened in July 1990, and started its first teacher-training program just one year ago in January 1991. Its first year budget of $5 million enabled it to give intensive training to most of the teachers in ten of the 596 Chicago Public Schools.

Further increased support and enhanced programs will be necessary for the Academy to have a real impact on education in this enormous educational system for 400,000 students. That is the real goal of the Academy programs - to build such a large community of interest that will automatically provide the necessary support for revitalizing approximately 18,000 elementary and secondary teachers of science. The major question facing us is - **CAN IT BE DONE!!**; is upwards of $30 million per year too much money to save the lives of the technological future of one of the biggest cities in America! And if it cannot be done in Chicago, perhaps it cannot be done anywhere else. The opportunity, and its corollary - failure, are keys to the future of human life in the urban environment of twenty-first century America. The President of the United States' plans for **AMERICA 2000** will come to nought if the urban teachers, and thus our urban youngsters, are denied the chances for a meaningful future. Appendix B lists some of the goals and initiatives of the Chicago Academy.

I give below some of the specific proposals for attaining effective science and mathematics instruction in our elementary and secondary education classrooms. These are largely taken from the report[3] from the conference on **New Challenges in Educating Engineers**. However, I will first describe in an illustrative way the aims of effective science instruction. I do this because most of the people listening here today are the converted who know the problems, and have applied no insignificant parts of their expertise, time and energy to helping in the ongoing revolution in science-teaching techniques.

Illustrations of Learning

A key point in the training of teachers at the Academy is the integrated approach to learning and teaching. Teachers must learn the subject matter - science - in the same way as they teach it. Hence, training of methods and subject understanding must be coordinated and achieved together. This is not generally the case for most university teacher training programs, where typically, science department faculty rarely speak to each other, let alone conceptualize and organize course schedules and content for our future pre-college teachers. The following examples indicate how important this integration is.

1. Early Learning

Everyone is a scientist - a seeker after new knowledge on how the world works - from the earliest age. Take the example of a 10 month old baby crawling across the carpet, seeing a piece of fluff to one side. The baby crawls over to investigate - she picks up the fluff, squeezes it in her fingers, smells it, licks it, puts it in her mouth, and then eats it.

Here we have the explorative process, a natural one, existing long before it is removed by unimaginative early grade school teachers. In addition, note that the baby uses all her senses (no sound in this one) to learn about the new experience and relate it to previous experience. If the baby chokes, she probably will not repeat the trick of eating the fluff.

This baby was female, and I hope the sex identification surprises you. Most professional scientists are white males. White males form a very small proportion of our inner-city public school students, less than 10% in Chicago. Yet, if an audience is asked to write down the name of one scientist each, the selection is typically 95% white male responses, plus a few females. I challenge you to write down the names of 5 hispanic scientists, or 5 african-american scientists.

2. All Together

We must learn science as an integrated subject with mathematics, physics, chemistry, biology, etc, being learned in a comprehensive and coordinated classroom. The TIMS (Teaching Integrated Mathematics and Science) program[5] utilizes these concepts and the exploratory, hands-on techniques for science teaching in the early grades. The program fits well with the MathTools program[6], both of which are part of the Academy's initial teacher training program.

For example, on getting up in the morning, we do physics by using gravity to take us down the stairs, we use mathematics to count how many eggs we will fry, we use chemistry to cook the eggs. We then use physics to get the car cylinders firing on our way to work, and we probably so some biology by interacting with other people at work. In fact our life integrates all these individual scientific acts, and that's the best way for classroom learning.

3. The Joy of Learning

Learning is most rapid when the student enjoys the act of learning. We all know that in times of stress our minds become closed to new ideas, to the suggestions of others, etc. This extreme is balanced by the other extreme when learning seems effortless because we are enjoying the experience. The electric power companies are aware of these relationships. A remarkable picture "High-Powered Offense" by Art Shay in the April 7, 1991 Chicago Tribune (Figure 1) shows the learning of linemen. To reach a necessary level of comfort while hanging alone, high near the top of a telephone pole, supported by a single waist strap, could be difficult. Turning the learning process into a game of "poleball", would-be linemen playing on a court of about 10 poles, brings joy to the learning

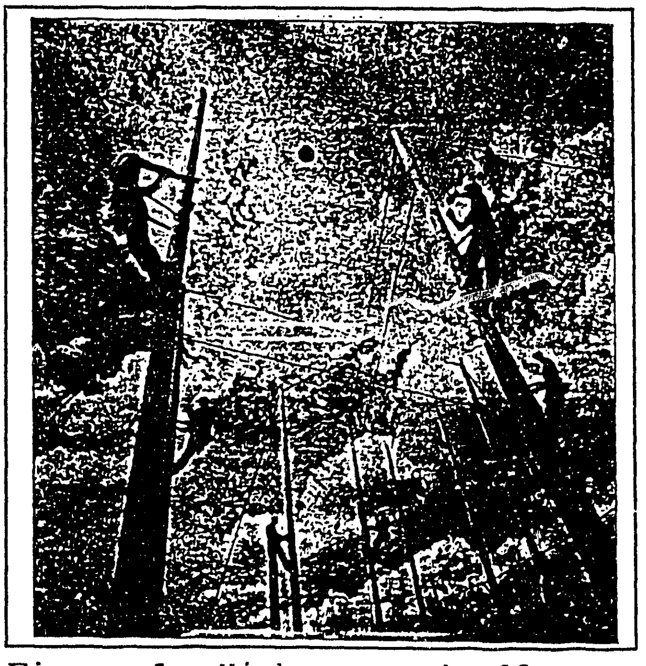

Figure 1 *High-powered offense.*

process. Medical experiments shows physiological differences in the brains of people learning under stress and without stress. Background music, symphonic if you like, rock-and-roll if you prefer, is proposed to help develop a relaxed "atmosphere for learning". For children and adults living in stress, the learning classroom should become such a haven.

4. Different Ways of Learning

Everybody learns differently, and the learning skills also depend on what the student already knows. Many people will say that learning mathematics was a joy until they reached the dreaded "word problems". They were probably forced to use newly acquired concepts of algebra to produce equations, which were then solved in the unique manner previously explained by the classroom teacher.

A Southern Illinois teacher recently illustrated the needs to let the student use any technique for problem solving, and particularly to utilize his/her own experience. She posed the following word problem to 8th grade, 4th grade and 1st grade students.

A farmer (who grows mainly corn and beans) has twelve animals. (S)he knows the animals are cows and chickens, but (s)he doesn't know how many (s)he has of each. (S)he counts the number of legs to be 30. How many of each?

The eighth graders, this being an algebra class, write down the two equations with the two unknowns, and try to solve them:

$$N(Cows) + N(Chicks) = 12; \qquad 4*N(Cows) + 2*N(Chicks) = 30$$

The 4th graders, not having had algebra just guess a number of cows, say 6, and multiply out, then try again, etc. This guess method is the way most grownups will try to solve the problem.

The first graders don't know how to multiply, but they do know about drawing pictures. Every animal has a body, so the first step is to draw 12 bodies (Fig. 2a). Both chickens and cows have at least 2 legs: so now add 24 legs, counting as one draws them (Fig. 2b). The last step is to add 2 legs to each animal until the count reaches 30 (Fig. 2c). Hence the answer 3 cows and 9 chickens.

These 1st graders were not afraid of this word problem. Most word problems can be solved with drawings (we scientists call them graphs, other "grownups" call them drawings). I challenge you to find a word problem that cannot be solved using a drawing! The occasional student will ask about 3-legged cows and 1-legged chickens: they should be encouraged to realize that their experience can lead them to different answers, and these are not necessarily wrong answers. The importance is in the thinking about it. A discussion of the topics just learned in class should be an integral part of the learning process. The Russian educator Vygotsky in the 1920's, and his school taught that this explaining or application is a completing part of the learning process. We don't know what we have learned until we have explained it to someone.

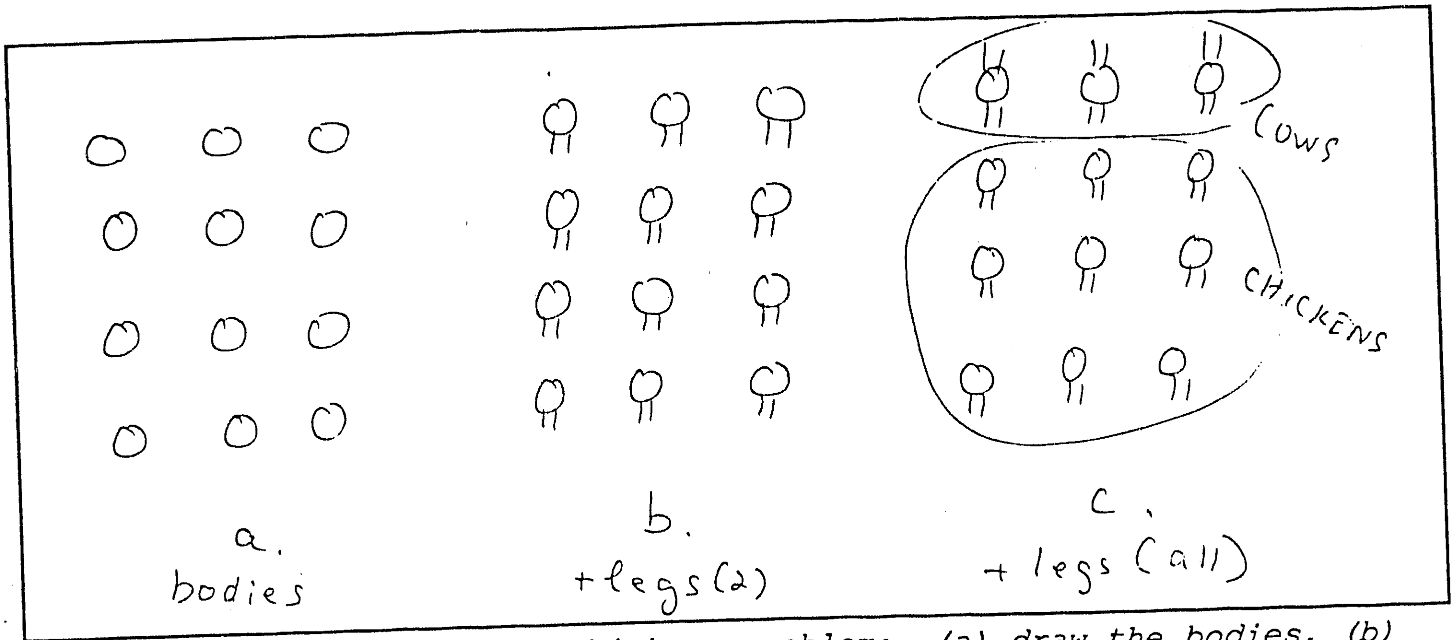

Figure 2: *The cows and the chickens problem: (a) draw the bodies, (b) draw 2 legs on each, (c) add the remaining legs.*

Specific Recommendations (taken from reference 3)

1. Hands-on Learning of Science

A survey has shown that 50% of 3rd graders do not like science, 80% of 8th graders do not like science. Most students never know what real science is and have never had science (they only had text book science). It is not taught correctly because those science teachers were never taught science.

- Science text books are heavy and very thick, getting thicker by the year, plus, they tend to promote rote learning - Classes need to concentrate on thinking skills, and give room for creative thinking.
- We need to develop a concept-based curriculum which teaches the why instead of the how.
- Students enjoy exploring for themselves, seeing the outcome, and experiencing the "surprise ". The "eureka moment" of discovery gives them an experience they understand and remember!

In science laboratories, students should be encouraged to find solutions to problems through scientific investigation. Students asked to develop their own procedures and materials needed like this approach (direct student involvement) much better than passive involvement. Needed is the related leadership by the teacher to introduce new topics, encourage synthesis of ideas through discussion, and generally take advantage of the opportunities for cognitive development provided by hands-on learning.

We propose a magnet school for future teachers, especially for attracting minority and female teachers of science and mathematics.

There is a crucial need to develop relations between teachers and students: for example, teachers (especially science teachers) call on boys more often than girls. We need to be aware of and remove this gender emphasis. The Society of Women engineers is working to remove the white male stereotypical scientist/engineer image often imposed in the earliest years of K-12 education. Programs must actively "mainstream" women and minorities into science and technology.

Courses for materials-based, hands on learning were developed in the 1960s (the often-called NSF era). Unfortunately, they lasted only 2 to 3 years, materials not replenished, then teachers dropped the classes and went back to the old style. In a few districts, science centers were formed to take care of (1) teacher support, (2) continuing inservice of these programs. Schaumburg, Illinois, has a good example of a continuing program (under the direction of Larry Small).

Many excellent new science and mathematics-based hands-on curriculum modules have been developed during the 1980s. They are exhibited regularly at NSTA meetings throughout the county. For example, the NSTA initiative, *Scope, Sequence and Coordination of Secondary School Science*, and *Project 2061* from the American Association for the Advancement of Science (AAAS). So why the lack of implementation in our K-12 schools? Two of the answers are given above - lack of teacher support and lack of materials. But another key ingredient is the lack of communication between classroom teachers and these programs. The teachers are hungry for the information, but there is no time in the average teacher's school year for further education.

College outreach programs in K-12 are vital connections in developing the sense of a science education community: e.g. the WISE program at IIT (and other campuses) is a career day involving parents, students and teachers to show them what scientists do. In Toledo, a Saturday morning Academy (taught by faculty on a volunteer basis requires parents to accompany their child. Six major topics in the University of Toledo program are: 1. Teaching fundamentals; 2. Use of computers etc; 3. Creativity, thinking skills; 4. Communications, satellites, etc.; 5. Learning in teams; 6. Teaching students to learn how to learn. Such programs must include parental involvement and develop a base of community support.

In summary, the skills and knowledge needed for K-12 science and mathematics education are:

Mathematics: the emphasis should be on problem solving, it should be project oriented, connected to other disciplines, and contain lots of applications.

Science: There needs to be a basic grounding in all the sciences, and especially to be inter-related, problem focussed, project focussed, with case studies, and providing contexts for applications to real life.

Technology: Learning in the use of tools, and in design.

What is best practice? Examples which recent research is showing to be most effective include:

- Hands on learning
- Developmentally appropriate

- Interdisciplinary
- Aim at all children
- Community/home support of learning
- Cooperative learning (for teachers as well as children)
- Preconceptions (knowing that children have them and then specifically addressing the preconceptions: e.g. the classic example of the relative motions of the sun, moon, and earth)
- Integrated role for instruction and assessment.
- Use the children's natural curiosity about their surroundings
- Be interdisciplinary including reading, writing and technology

Barriers to best practice include:

- Skills (lack of) that teachers bring to the classroom
- Lack of understanding of how to address individual needs
- 19th century organization of school (structure of classes, structure of school year, little or no use of modern technology)
- No integration of in-school and out-of-school learning
- No meaningful assessment of student progress and readiness for college

2. Cooperative Learning

Most thinking in industry is not isolated, but involves team work. Students can learn to work in teams and cooperate with each other to solve problems. We must train teachers how and when to use cooperative learning as one more appropriate strategy to the teachers' array of expertise. Cooperative learning can lead to more effective development of individual skills. Unfortunately, most teachers have not been trained to work in such a classroom. Also, students may have to learn a new learning process. However, the underlying thesis of such learning is the application of many different strategies for learning, each strategy being adapted to fit the child. Success can only come when the teachers are able to recognize the strengths and understanding of the individual children - a factor not present in many American schools.

3. Computers and Communication

The computer's role in a classroom is supplemental - to introduce, review and enhance lessons. New data access techniques allow it be give students a much broader experience in their area of learning. The computer's role in communication provides an extra science window on the world. However, the access for large numbers of students to effective computers remains very expensive.

Well-integrated use of computers in classrooms centers on eliminating much of the rote-learning of the past. Computer communication can effectively link learning to images of the student's own world, and to the world outside the student's normal community. The enhancement of the learning process through the enjoyment of the learner is now well established: it is the basis of several *accelerated learning* projects.

The use of games in education is still controversial. But the action and stimulation involved must be an essential part of lifelong learning. Computer-based learning can be a very effective tool to provide a learning process in the classroom which parallels the learning processes outside the school, in the student's home and community.

Another value of computer-based learning can be in enhancing the individual interactions between teacher and student. The computer allows each student to learn individually, but also can be the intermediary in allowing the teacher to interact with each student during the process of learning. Peer interactions are also enhanced through effective computer use. Who has not seen a crowd of students huddled around a monitor, each giving directions towards solving a problem?

4. Evaluation

Evaluation, assessment and accountability are becoming key words in comparative studies of educational excellence. It has become clear that present standardized tests do not test laboratory experience; in order to do so, they must have a performance component. Standardized written tests emphasize the recall of facts. However, we value the ability to "do science", which can be tested using "authentic assessment". This performance-based testing is beginning to gain credibility in the U.S.A. The British APU testing in the 80's has shown that it is possible to test students on the values held by the British system - measurement, experimental design, doing an open ended experiment, observation, controlling variables, classification, observation, as well as application of concepts. Current efforts to develop performance based assessment frequently focus on the manipulative rather than the cognitive. The Lawrence Hall of Science (and others) are exploring a number of approaches including item banks such as a new **Plastics in Your Lives** module. A lot of thinking and work is needed and is going on in this area.

Any testing should become the servant of the science curriculum. The curriculum should clearly define the goals, attitudes and behaviors, and the test should determine how well you have taught them. Note the shift from how well they learned to how well you taught them and how well they learned. We have a shared responsibility with the students to both communicate what it is that we value, align our instruction to reflect those values and test for the knowledges, behaviors, skill and habits of mind that we value.

We must tell all colleges that the SAT, ACT and other similar tests are not good indicators. GRE and college GPA show no correlations: as one example, it has been noted that right-brained people all leave engineering (a remarkable indicator of the way we teach science and engineering in college). We propose that student portfolios be used as the principal inputs into judging high school students entering college. If a large enough group of colleges announce their abandonment of the use of the ACT, SAT and other standardized tests in favor of the portfolios, a large step in the abandonment of *teaching-to-the-test* will be achieved.

5. New programs and Networking

No broad ranging programs exist today. There are industry and college programs, usually very small and both lack the knowledge of how to work together and what they could do for each other and for the students. There are student teaching programs that have little coordination between the college faculty and the supervising teachers and absolutely no commonly agreed upon goals for the student teacher that relate in any way to their professional teacher preparation classes. Here is an area where great strides are possible. It will require a new relationship between the college methods/professional classes and the school-based supervising teacher. We propose a strong relationship between the supervising teacher and the college teacher, presently nonexistent.

At the typical education college, there is little curriculum coordination with the science and engineering/technology departments. The methods classes do not inter-relate to the special needs of the classroom. There is no comprehensive assessment of the student teachers' skills related to the classroom instruction. There is no program of helping that student teacher gain the skills on a systematic basis. We propose developing a strong partnership between the two "learning environments". Content and pedagogy must be learned together in the same way the teacher will be teaching students in the schools.

We propose that colleges and universities give tenure for teaching abilities: for example, for (1) being a good teacher or (2) helping in the education environment of the local community. The old dichotomy of content versus pedagogy must be balanced: science researchers are bored by discussions of educational psychology; science teachers are not real scientists - i.e. researchers. We need to remove this barrier.

We propose more linkage between teacher colleges and the schools. Student teaching is one example. In general, teachers have no time to develop a curriculum: there must be support from other agencies: for example, college education and science and engineering professors, the national labs scientists, etc.

The sense of community lacking at the secondary and elementary level, principally due to the isolation of the science teachers can be overcome by the active participation of science and education college faculty and other professional scientists and engineers.

This sense of community is also needed at the elementary school level. For example, a Wisconsin elementary science teachers association was started just 2 years ago in 1989, and now has 600 members.

Business and industry have their feet in one camp or the other but never in both. They are left out of the loop. They are looked upon as a source of resources, both money and people to serve our schools, but not as full partners in teacher training. We have a very long way to go to develop a coherent and coordinated teacher development program, which can include business participants at both the precollege and college levels.

6. Support for Education

No college faculty recommend teaching as a career for their brightest students.

Revolution in the educational system requires a **firm commitment** made to the **importance** of every child's education. This commitment must come from the government, the school system, the parents, and the teachers. There will not be any kind of change until there is commitment made to the **value** of children, all children, in our society. While society talks about the problems in education and the problems with our kids, **we lose a generation of potentials**. Children must feel they are valuable and can succeed. Financial commitment, parental involvement and teacher dedication will cause change whether evolutionary or revolutionary.

Would you believe --

1. By the year 2000, all children in America will start school ready to learn.
2. By the year 2000, the high school graduation rate will increase to at least 90 percent.
3. By the year 2000, American students will leave grades four, eight and twelve having demonstrated competency in challenging subject matter including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so that they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.
4. By the year 2000, U.S. students will be first in the world in science and mathematics achievement.
5. By the year 2000, every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.
6. By the year 2000, every school in America will be free of drugs and violence and will offer a disciplined environment conducive to learning.

These lofty educational goals were set in September 1989 at a historic Education Summit of the Nation's Governors. We are now in 1991. Has the framework established at that meeting been supported in any way? We must remember that the Federal involvement in education is low. The federal budget request for science education for 1992 is $660 million for the whole country, far less than, for example, the total school budget of $2.4 billion for Chicago. The $660 million includes new funding of $146 million, an increase of 28% over the previous year's federal support for precollege mathematics and science education.

There is a lack of enthusiasm for the recent education initiatives of President Bush and Secretary of Education Alexander. The suggestion for national examinations runs counter to our present conclusions. Support for private schooling may be the death-knell for many urban area public school systems which already lack the necessary state and federal support for minority and/or below-poverty-level children.

The National Coalition of Women Scientists has produced an alternative formulation to the President's *Year 2000* initiative. The President's plan lacks the financial commitment needed for long-range improvement in the science and mathematics teaching in our schools. The Bush/Alexander plan is unrealistic in expecting such large-scale change in the short time of nine years. The lack of effective implementation even of programs that work continues to be a *federal* problem.

7. Conclusions

Science and mathematics teaching is in great need of support from engineers, scientists, and technologists at the college level and in the professional community. The development of a community which is committed to helping improve science education is essential to produce a nation of scientific literates and enough qualified engineers, scientists and related professionals, including science teachers.

The engineering and science faculties must take the lead in developing this community awareness of the importance of science and technological education. Their initiatives can be the key to providing:

- Hands-on science and technology teaching in elementary and high schools
- Development of cooperative teaching techniques
- Training of teachers in both science/technology content and teaching/learning styles
- Coordination of education and science/engineering department faculty in the training of pre-college teachers
- Development of a college/pre-college science education community
- Development of a commitment to teaching and research on an equal basis
- Development of new technologies applied to education in pre-college classrooms to enable them to use the new 21st century technologies, for example in computers and communication.
- Support the concepts of the responsibilities of state and federal governments to provide scientific literacy for all the nation's populace
- Support a new commitment to involve business and local industry in developing the concepts of modern technology in education
- Development of performance evaluation testing
- Elimination of the use of standardized tests (SAT and ACT) for college entrance requirements, and replacement with student portfolios

We strongly support the need for annual conferences to discuss the progress of these initiatives and to help propagate their conclusions throughout the pre-college, college and graduate school education and scientific and engineering communities.

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FIGURES

1. High-powered offense. Linemen learn to manoeuver on Consumer Power's Pole Ball Court in Marshall, Michigan. Photo by Art Shay, The Chicago Tribune, April 7, 1991.

2. The cows and the chickens problem: (a) draw the bodies, (b) draw 2 legs on each, (c) add the remaining legs .

APPENDIX A

The NSTA Lead Paper in Science and Technology Education for the 21st Century

Philosophically, the K-12 preparation of engineers was addressed as one of two major goals in a paper issued by NSTA in January 1990. Summaries of the topics of the statement, a "lead paper", designed to guide the organization's programs for the next decade, follow:

The NSTA takes the position that two major goals of science education are *to achieve scientific literacy for all citizens* and *to ensure an adequate supply of scientists, engineers and science teachers.* Major reform must occur in order to meet these goals.

1. **Scientific Literacy**

   Our nation must have a citizenry that is prepared to understand and deal rationally with the issues and opportunities of a scientific and technological world.

2. **Human Resources**

   Our nation must have enough qualified scientists, engineers, teachers and related professionals to compete successfully worldwide in science and technology.

Initiatives to Improve Science Education

Initiatives are needed in five broad areas:

1. **Commitment to science education**

All American students should spend more time in quality science instruction in elementary, middle and high schools to equalize the opportunities of all students in this nation with those of other industrialized nations where science is given a high priority in grades K-12.

Recommendations

- Schools should give science a central role in K-5 instruction.
- Create awareness that research evidence shows that all subjects are enhanced through effective science instruction.
- Create awareness that science education stimulates the natural curiosity of children.
- Stress motivation and development of positive attitudes toward science and scientists - critical in developing scientific literacy and interest in careers in science.

- K-2 students should have at least 100 minutes of science per week; grades 3 & 4 should have 100 minutes per week; middle level students should have 45 minutes of science per day; high school students should have science courses which meet every day of each school year.

2. Curriculum development

The impact of science and technology on society has created the necessity for reconceptualizing and restructuring science curricula. The need for young people to keep up with rapid changes impact on career decisions, their personal welfare, their responsibilities as citizens, their quality of life, and the economic and political status of their country has not been met by the traditional science subject matter offerings.

Recommendations

- Develop curricula that provide opportunities for all students and adults to study real-life, personal, and societal science and technology problems.

- Develop a K-12 science curriculum framework that is integrated or correlated in terms of science, technology, mathematics, humanities, and the social sciences

- Develop and implement science curricula that will prepare students to pursue a career in science and engineering and respond to the growing demand for women in physical science and engineering.

- Develop awareness of science career opportunities

- Develop and implement science curricula that integrate appropriate technology

- Develop and use evaluation and assessment tools that reflect the goals of science education

3. Instructional support

In many places, teachers receive little or no support for teaching science. Equipment and supplies are sparse and no laboratory space is available, making the use of a variety of teaching strategies impossible. Supplies and equipment and how they are delivered are a great concern for effective science teaching.

Recommendations

- Develop materials and programs for instructional administrators, policymakers, and lay people (e.g., principals, superintendents, school board members, and parents) that would provide better understanding of the goals of science instruction and the facilities, equipment, supplies and personnel needed to achieve these goals.

- Construct, equip and supply appropriate science teaching facilities.

- Establish science supervisors, coordinators, and consultants in school districts to give leadership in curriculum and instruction; and provide ways of getting equipment and supplies to teachers.

- Provide appropriate electronic technologies to science teachers at all grade levels.

- Develop regional science education centers within each state that would make the following available to local teachers and administrators:
  - models of effective science teaching
  - science updates
  - research opportunities
  - media and technology
  - science equipment and supplies

4. Preparation and staff development

Rapid changes in science and technology mandate professional development programs for teachers. Findings from research on effective teaching also contribute to the need to keep teachers up to date. Often, issues such as AIDS create needs for immediate teacher updates. These concerns solidify the need for staff development programs.

Recommendations

- Mandate and support ongoing staff development programs for teachers of science to enhance their science knowledge and science teaching skills.

- Implement research-based teacher preparation programs that are designed cooperatively by education faculty, scientists, and practicing classroom teachers of science.

- Recruit and retain more qualified and competent individuals into science teaching.

- Support increased use of collegial teams within and among schools as well as networking among teachers to enhance instructional decision making.

5. Research support

Science and technology can only progress through intensive research and development efforts. Science education must have support for researching problems inherent in science teaching and learning.

Recommendations

- Establish long-term funding for regional science education centers that would conduct and disseminate results of research.

- Assemble a special task force to evaluate the crises identified in this position paper and develop a priority list of researchable problems that research centers could attack.

OUTCOMES

1. The unifying objectives of the recommendations and initiatives discussed above are to:

- Produce a scientifically literate citizenry
- Ensure an adequate supply of qualified scientists, engineers, and science teachers for the 21st century.

2. The recommendations and initiatives, if accompanied by general overall improvement and support for education, will help ensure that all citizens participate in decision-making in the world of the future. The scientifically literate citizen must

- Acquire a substantial knowledge base and understanding of the methods, framework and nature of science,
- Understand the relationships between science, technology, and society,
- Recognize the richness and challenges of the natural world,
- Recognize the limits of science and use appropriate science in decision-making.

3. The reforms requisite to produce a scientifically literate citizenry also address the problem of the supply of qualified scientists, engineers, and science teachers. These reforms will

- Expand the pool of potential scientists and science teachers to include more women and members of minority groups
- Establish patterns of lifelong curiosity and learning, essential for the changing work place of the 21st century
- Produce competent individuals prepared to pursue careers in science and engineering, after exposure to enriched curricula and opportunities to pursue individual interests,
- Ensure support for the needed infrastructure to sustain the scientific and engineering establishments for the challenges of the 21st century.

4. A scientifically literate population will serve as a foundation of both a scientifically responsible and intellectually sophisticated science and engineering community to ensure the vitality of our nation in the 21st century. This is the spirit of the recommendations, with the promise that science teachers will cooperate fully as we, as a nation, strive to achieve such vitally important goals.

APPENDIX B

Goals of the Academy for Mathematics and Science Teachers in Chicago (A partial list, adapted from reference 4)

The Academy is envisioned to:

- Provide advanced training of teachers to insure thorough mastery of subject matter and instructional skills. This applies to both new and current CPS teachers at the elementary and secondary levels.
- Focus on the school as the locus of change, including the principals, Local School Councils, as well as science and mathematics teachers to upgrade the learning environment at the school.
- Conduct a research-based program which leads to the development and implementation of new mathematics and science curricula and instructional methods, including programs which are effective for urban students with a wide range of backgrounds.
- Work with education departments in area universities and colleges to restructure undergraduate training programs for mathematics and science teachers.
- Facilitate the involvement of scientists and mathematicians in the activities of the Academy. They will come from national laboratories, universities, colleges, museums and private sector research laboratories. The activities will include staff development, materials development (hardware and software,) and far-ranging interdisciplinary study of the science teaching process. Extensive use of sabbatical leaves to the Academy will be necessary.
- Provide a focus through workshops, meetings and a curriculum and resource center to foster the collegiality of teachers, scientists, principals, museum directors and, in short, all parts of the mathematics and science education community.
- Provide a strong assessment and evaluation program, with rapid feedback directly to the Academy director to assist in program improvements and management decisions.
- Be an agent for change in the Chicago Public Schools. The Academy, which captures the spirit of school reform, can become a model for making achievement the highest priority of the total CPS.

It is our belief that we can create a learning environment which will positively impact all CPS students, from the underachiever to the most gifted. In the earliest years of school, the teaching of activity-based mathematics and science opens the door to the joy of learning and the growth of interest in scientific, engineering and mathematical careers.

It is our belief that a study of science, in the best of classrooms, stirs the imagination. The story can be in a frog, in a test tube reaction or in a photograph of the night sky. Any of these can be used to expose to the naturally inquisitive young mind, aspects of the awe, wonder and beauty of the Universe revealed by human thought.

It is our belief that mathematics and science education is valued because of urgent national needs and that inner city students, so far vastly under-represented, are a major potential pool of science literates.

It is our belief the Academy will serve as a permanent support base for teachers of mathematics and science, a place for nurturing a culture of collegiality, for on-going renewal of content, for continuous contact with the on-going revolution and development of significant delivery methodology and technology. It is a place where scholars and scientists from the national laboratories, the private sector, universities, community and teachers' colleges can interact with CPS teachers to create a rich, intellectual environment combining the excitement of learning and the pleasure of teaching.

It is our belief that vast intellectual resources, led by Fermilab, Argonne and including private sector research institutions, the universities and colleges in the city, the high schools and elementary schools, can be marshalled to create this unique institution designed to radically restructure and redesign the teaching of mathematics and science by focusing on the more than 15,000 CPS teachers who have mathematics and science teaching responsibilities.

Teacher Enhancement

A premise of the Academy teacher education program is that the teacher is a lifelong learner and that society must recognize this premise and support teachers as they continually upgrade their knowledge of content and instructional skills, both in and out of their schools. All parts of the program will be based on a view of teachers and their students as able, active learners.

In the first phase of the program, each teacher receives instruction in content and methodology. During Academy classes effective teaching practices are modeled and discussed, including the special needs of urban students. Utilization of inquiry-based, problem-solving, hands-on activities will be stressed. Questioning strategies that promote thinking skills are demonstrated and practiced. Participants apply the latest developments in learning theory and learning strategies that impact mathematics and science education.

Teachers learn how current and future technology can be used to support instruction, including the use of computers to perform simulations, to measure and manipulate data, and to produce output. Academy staff demonstrate the uses of interactive laser disc and CD ROM technology to bring an enormous database of information into the classroom to supplement science and mathematics instruction.

Program implementation support also include instruction on materials acquisition, storage and distribution strategies. Management skills necessary for teachers to teach mathematics and science effectively are a part of the program.

FOLLOW-UP

An extremely important part of the Academy's program is follow-up in the schools. An Academy outreach person will continue to work for half to one day per week in each Academy school for up to a year after the school's participation in the intensive program. The table below was developed to illustrate the importance of implementation in the classroom of programs taught through a variety of in-service techniques. The tests of understanding were taken immediately after the in-service periods, the implementation study was taken one year after the in-service periods.

Table. Effectiveness of in-service, with different support systems. [Reference: Joyce, B. and Showers, B. (1982). The Coaching of Teaching. *Educational Leadership, 40*(2), 4-10.]

OPERATION	UNDERSTANDING (%)	IMPLEMENTATION (%)
Theory	10-20	5-10
Theory + modeling	35	5-10
Theory +model +practice	70	5-10
All + feedback	80	5-10
All + **FOLLOW-UP**	80-90	80-90

Only when follow-up in the classroom of the teacher is included does the change become effective. Associated with this follow-up is the change of the **attitude** of the teacher towards the ideas being communicated in the in-service program. The other vital ingredient of the in-school presence is the support provided to the teacher as he/she institutes something new into the classroom.

END

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