

NSF Forum on Educational Competitiveness**+Introduction**

- +Today, I am going to put aside my
 - +hat as a university president and take a
 - +somewhat broader perspective. As a
 - +member, both of the National Science
 - +Board and the National Academy of
 - +Engineering, I have been heavily involved
 - +in recent years in a number of efforts to
 - +assess the challenges facing this nation as
 - +we approach the 21st century. The
 - +dominant theme of these activities, of
 - +meeting after meeting, of study after study,
 - +is the growing crisis our nation faces in the
 - +development of its human resources and in
 - +the education of a work force that will be
 - +competitive in the global economy of the
 - +century ahead.
- +“Science Under Scrutiny” (NYT, 1/7/90)
 - +In international comparisons, US high school
 - +seniors ranked 14th among 14 nations in
 - +science performance.
 - +College science enrollments are at an all-time
 - +low.
 - +Of those who enter college intending to major in science,
 - +40% drop out after first course.
 - +60% drop out by graduation
 - +Foreign nationals now comprise 60% of engineering doctorates,
 - +50% of physical science doctorates
 - +40% of mathematics doctorates
- +Let me be frank with you. I am very
 - +worried--worried about the future of our
 - +nation, worried about the future of our
 - +state, worried about the future that my
 - +children will inherit, and worried about
 - +both your future and mine--since it is clear
 - +that everyone of us is at great risk because
 - +of our serious underinvestment in the
 - +quality of our human resources.
- +Today I would like to share with you
 - +my concerns. In a sense I will only be
 - +reading some of the writing on the wall.
 - +But, beyond that, I am going to be so bold as
 - +to make several suggestions about what
 - +might be done about the state of public
 - +education in America. In particular, I wish
 - +to issue a "call to arms" to you as teachers, parents,
 - +and as citizens to take action before it is too
 - +late.
- +A Changing America
 - +Few seem to realize the enormous
 - +changes our society is undergoing as it
 - +approaches the 21st Century.
 - +We are becoming more diverse, more pluralistic
 - +as a people. Indeed, almost 90% of the new
 - +entrants into our workforce during the 1990s
 - +will be people of color, women, or immigrants.
 - +Our economy and commerce are becoming every day
 - +more interdependent with other nations as

- +the United States becomes a world nation,
 - +a member of the global community --
 - +as this past year's events in China, Russia,
 - +and Eastern Europe make all too apparent.
- +And we are rapidly evolving into a new post-industrial
 - +society, in which the key strategic resource
 - +necessary for prosperity and social well-being
 - +has become knowledge itself.
- +Indeed, we are entering what might be called
 - +an "Age of Knowledge" in which educated people
 - +and their ideas will play the role that in the past
 - +were played by natural resources or geographical location
 - +or labor pools...
- +In the pluralistic, knowledge-intensive, global
 - +future that is our destiny, it is clear that the
 - +quality of and access to education
 - +are rapidly becoming the key factors in
 - +determining the strength and prosperity
 - +of our nation.
- +The Challenge of the 1990s
 - +Needless to say, these same challenges of pluralism,
 - +of globalization, and of this age of knowledge
 - +that is our future will pose great challenges and
 - +demand changes in our state and our nation.
- +The America of the 20th Century that we have known...
 - +was a nation characterized by a rather homogeneous,
 - +domestic, industrialized society...
 - +But that is an America of the past.
- +Our children will inherit a far different nation...
 - +a highly pluralistic, knowledge-intensive, world nation
 - +that will be the America of the 21th century
- +Of course, these themes of the future,
 - +Are actually not themes of the future
 - +...but rather themes of today...
 - +...in a sense, I have simply been reading the handwriting on the wall...
- +In fact, it is here in Michigan...in the heart of the "Rust Belt"
 - +that the impact of these extraordinary changes are
 - +most clearly seen...
- +We all know that past decade was a period of
 - +great difficulty for our state...
 - +Industries of great economic importance to our
 - +nation such as steel and automobiles have
 - +fallen victim to intense competition from abroad...
 - +Plants have closed...we still have many people chronically
 - +unemployed...or under employed...
 - +There are many indicators of the impact of this
 - +transition on our state...
- +Over the past decade, Michigan has slipped badly
 - +in several key indicators of quality of life:
 - +• 30th in per capita income
 - +• 41st in overall employment
 - +• 48th in business climate (perceived)
 - +• 48th in high school graduation rates
 - +• 50th in return on federal tax dollars
- +Oh, we still rank near the top in some things...
 - +For example, we rank...
 - +• 12th in property tax burden
 - +• 14th in teenage unemployment rate
 - +• 13th in incarceration rate (and rising rapidly)

- +• 13th in percentage of children in poverty
- +• 10th in infant mortality
- +• 4th in public aid recipients
- +• 1st in mortality from major disease
- +There is still one other category of indicators of some concern, and these reflect our willingness to invest in the future. Michigan ranks
 - +• 37th in support of HE per student
 - +• 45th in support of HE during 1980s
 - +• 40th in support of K-12
- +It is clear that our state and our nation are in the midst of a profound transition...
 - +...from an industrial economy based upon the abundance of natural resources, unskilled labor, and, to some degree, constrained, slowly moving domestic markets...
- +To a knowledge-based economy, characterized by intensely competitive world markets, rapid change, and--most important of all--educated people and their ideas.
- +This has not been...and will not be...an easy transition to make.
- +The truth is that the outcome is still very much in doubt!
 - +producing jobs and improving our quality of life.
 - +Whether we will emerge from this transition as a world economic leader once again...with a strong, prosperous--albeit new--economy
 - +Or whether we will fail to heed the warnings...
 - +...to make the necessary investments and sacrifices today necessary for strength and prosperity tomorrow...
 - +And become an economic backwater in the century ahead.
- +It is clear that we face a watershed--a fork in the road ahead.
- +My central theme is that education, broadly defined, will be the pivotal issue in determining which of these two alternative futures will be Michigan's...and America's.
- +Indeed, I am absolutely convinced that the dominant issue of the 1990s will be the development of our human resources.
- +Previous economic transformations were closely associated with major public investment in infrastructure such as railroads, canals, electric networks, and highways.
 - +In the coming economic transition, an equivalent infrastructure will be an educated population.
- +The actions we must take today...
 - +...and the investments we must make...
 - +...will clearly determine our capacity to respond to this future...
- +The S&E Pipeline Problem**
 - +Today an unprecedented explosion of knowledge heralds the onset of a new era.
 - +Since people are the source of new knowledge, our nation is relying increasingly on a well-educated and trained workforce to maintain our competitive position in the world and our standard of living at home, as well as to harness the power of this new knowledge for the good of our planet and for all of mankind.
- +Yet, here we are in real difficulty
 - +because we are simply not educating enough new people to keep our economy competitive.

- +Further, there are serious signs that the education of the
 - +present American workforce is seriously
 - +inadequate to meet the demands of the next
 - +century.
- +This has become known as "the pipeline problem"
 - +since it involves the full spectrum of education
 - +from preschool through K-12, through higher education,
 - +to lifelong education.
- +K-12 Education
 - +The Scorecard
 - +Graduation Rates and Literacy
 - +The United States today spends more on
 - +education than any nation on earth, \$328
 - +billion, more than for any public service,
 - +including national defense. Yet, functional
 - +illiteracy in this nation currently runs
 - +between 20 percent to 30 percent, compared
 - +to a high of 5 percent in most other
 - +industrialized nations. Fully 25 percent of
 - +Americans now fail to complete high
 - +school. Each year 700,000 students drop out
 - +of high school and 700,000 more graduate
 - +without functional literacy.
 - +An Example: John Porter, Superintendent of Detroit PS
 - +...15,000 in 9th grade
 - +...6,600 will graduate (44%)
 - +...1,000 are "job ready" (7%)
 - +...500 are UM ready (3%)
 - +Achievement Measures
 - +Our first tendency is to think that K-12
 - +education is merely failing with minorities
 - +and at-risk students. However, other
 - +comparisons demonstrate that this is not
 - +the case and that the weakness of our
 - +educational system extends throughout all
 - +of our society. Even if we exclude those who
 - +drop out, we are presently only educating 15
 - +percent to 20 percent of our students to an
 - +intellectual level capable of functioning
 - +well in the everyday world. In recent
 - +assessment tests it was found that only 20
 - +percent of high school seniors could write
 - +an adequate letter. Only 12 percent of high
 - +school seniors could take a group of six
 - +fractions and put them in order of size. And
 - +only 5 percent of high school graduates
 - +today enter college ready to begin college
 - +level mathematics and science courses or to
 - +approach the reading of technical
 - +material.
 - +Indeed, last week we had even more
 - +evidence that there has been little progress
 - +in Michigan with the announcement of
 - +recent assessment tests in which it was
 - +noted that: i) over 70 percent of students
 - +failed the reading section; ii) over 60
 - +percent failed the science section; and, iii)
 - +over 30 percent failed the mathematics
 - +section.

+International Comparisons

+At every level of education, American
+children rank near the bottom in their
+knowledge of science and mathematics
+when compared to peers in other advanced
+nations. For example, compared to students
+in fifteen other nations, U.S. high school
+seniors scored among the bottom quarter on
+calculus and algebra achievement tests.
+Our seniors ranked fourteenth among

+

+learning was fine for training our industrial
+workforce, organized hierarchically into a
+structure in which only those in top
+management needed to analyze, think
+critically, and make decisions. But today's
+world is a very different place requiring
+different skills, more initiative, and
+creativity.

+What we need to do is stop thinking
+about how to fit teachers, students, and
+parents into an old fashioned factory. Even
+modern business is abandoning the factory
+model. Instead, we need a structure in
+which the students become the workers. In
+this sense then the teacher is not the person
+who pours knowledge into the student; the
+teacher is rather a manager with the same
+concerns that a manager of any company
+would have: How do I get my workers
+(students) to come here wanting to work
+(learn)? How do I get them to do the work
+(learn)? How do I get them to manage and
+be interested in the quality of their own
+work (learning)?

+The "Blue-Collarization" of the Teaching Profession

+It seems clear that teachers are--or at
+least should be, regarded as--among the
+most valuable members of our society, since
+in a very real sense they are creating our
+future. And yet how do we treat them? We
+give them low salaries, low status, and few
+rewards. We give them little opportunity
+for control of the curriculum and drown
+them in a mire of bureaucracy. We assign
+them the challenge of dealing with
+children from disintegrating families,
+impoverished backgrounds, dulled by the
+impact of television. And then we criticize
+them for not doing their job!

+Just think of the image of the teaching
+profession that this creates in the minds of
+a talented undergraduate. Why would any
+college student--particularly those
+struggling through difficult majors such in
+the sciences or mathematics--want to enter
+what has, in essence, become a "blue collar
+career"? Why would a strong student want
+to join a union, earn low wages, struggle

- +with excessive administrative
- +bureaucracies and meddling school boards--
- +when the alternatives are investment
- +banking, engineering, medicine, or law (at
- +least, "LA Law" style...)? And could you
- +blame them?
- +The sad fact of life is that the teaching
- +profession, at least as it is presently
- +configured, is simply not capable of
- +attracting our best students. And America--
- +and our children--are much the worse for it!
- +The Conflicting Missions of Our Public Schools
- +Once we believed that our schools were
- +primarily for learning. However, over the
- +past several decades, we have assigned to
- +our public schools a broader array of social
- +roles for which they were unprepared,
- +thereby undermining their primary purpose
- +of education. We have shifted our schools
- +attention from the intellectual
- +achievement of their students and more to
- +concerns about social adjustment, individual
- +realization, and group consciousness.
- +Indeed, we have lost any coherent vision of
- +the precise role that our schools should
- +play in our society. And, of course, part of
- +this trend toward a broadened role for our
- +public schools has arisen from our
- +abdication of our responsibilities as
- +parents.
- +Family Attitudes
- +A recent survey conducted both in
- +America and in Japan of mothers whose
- +children were not performing up to
- +expectations found some very revealing
- +differences: American mothers
- +immediately assumed their children were
- +not smart enough; Japanese mothers
- +thought that their children were not
- +working hard enough. A rather revealing
- +example of the difference in family
- +attitudes, is it not?
- +Perhaps it is the lack of commitment of
- +the American family to the education of
- +children that most distinguishes us from
- +other countries. We seem too busy to help
- +our own children in their studies or to
- +participate in their activities.
- +Of course, there are many situations in
- +which we cannot blame the family.
- +Because for many children, the family
- +simply doesn't exist!
- +The Disintegration of Our Social Fabric
- +Roughly one-half of the students
- +enrolled in K-12 education come from what
- +we used to call "broken homes." Except
- +that in today's society this situation has
- +become the norm rather than the exception.
- +To this we must add the full range of other

- +social ills, ranging from the mind-numbing
- +impact of television, to poverty and the
- +disintegration of the family, to drugs and
- +crime. Of the class of 2002 that started
- +kindergarden this past year, 25 percent are
- +living below the poverty level, 15 percent
- +have physical or mental handicaps, 15
- +percent have been born to teenage mothers,
- +and 10 percent have illiterate parents.

+Public Attitudes

- +The real power to influence education
- +lies at the local level. Yet here our schools
- +face a very serious challenge, since few of us
- +are willing to step forward and become in
- +volved with public education.

- +Sure we all complain about our schools
- +a great deal. But how many of us are
- +willing to run for schools boards with the
- +objective of achieving real change? How
- +many of us are willing to support the tax
- +millages necessary to build strong schools or
- +the other tax measures necessary to achieve
- +equity in school financing? How many of us
- +as citizens have stepped up to our political
- +responsibilities and demanded that our
- +publicly-elected officials respond to the
- +seriousness of our deteriorating system of
- +education?

- +In fact, when it comes right down to it,
- +how many of us are really willing to insist
- +on quality in our schools in the face of the
- +political pressures and costs which such a
- +quality commitment will trigger? How
- +many of us realize that what is at stake
- +here is not just the future of our children, but
- +the future of our nation and our way of life,
- +not to mention our own personal well-being?

+The Failure of Our Universities

- +While I am taking pot shots at various
- +groups, let me also aim a few as well at
- +higher education. Many of the problems
- +faced by public education these days are our
- +doing. For years in most of our institutions
- +the education of K-12 teachers was ranked
- +among the lowest of our priorities. Indeed,
- +in some institutions--including the
- +University of Michigan--during the period
- +of serious financial pressure in the early
- +1980s, we have proposed that our schools of
- +education should be eliminated!

- +Further, we have perpetuated the
- +smokestack assembly-line approach to
- +education, both in our instructional
- +programs and in our accreditation
- +activities. We have not insisted on the
- +highest standards and best preparation of
- +those we admit to our teacher education
- +programs. And we certainly have not
- +adhered to the highest standards for our

+own graduates.

+We've allowed our schools of education to become

+diploma mills:

+The 3 largest teacher factories in the US are

+in Michigan:

+EMU: 2,603

+MSU: 1,993

+WSU: 1,939

+In fact, 5 of the 10 largest are in Michigan

+WMU: 1,621

+CMU: 1,517

+Michigan produces over 7,000 teachers

+per year...and yet only has positions for

+about 2,000!

+Political Minefields

+Ross Perot was quoted as saying, "The

+hardest thing I ever did was the year I

+spent trying to improve the Texas public

+schools. It was the hardest, meanest,

+bloodiest thing I ever tried to do." It is not

+surprising then that we continue to be

+paralyzed in our efforts to come to grips

+with school finance reform or the major

+structural changes necessary to achieve

+quality in public education.

+One of the great curses of the American

+experience has been our preference for

+ "quick fixes," simple solutions to complex

+problems. Too often we go for the slickly

+marketed patent medicine that not only

+doesn't provide a cure, but actually

+aggravates the problem. The classic

+example of this tendency toward

+gimmickry is the state lottery, which, in

+effect, robs from those most in need of state

+assistance to subsidize those already well

+supported. Despite the fact that lottery

+revenues have flowed at ever-increasing

+rates into the state treasury, state support

+of K-12 education has languished for many

+years, in sharp contrast to other state

+priorities, such as prison construction.

+Hence, it seems clear that rather than

+support education, lottery revenues have

+gone to support other state priorities, such

+as corrections. Since those participating in

+the lottery tend to be from the more

+impoverished parts of our population, it is

+clear that the lottery is having the

+perverse impact of transferring funds from

+those who are deprived to subsidize those

+who are prosperous.

+Undergraduate S&E Education

+College Education

+While our colleges and universities are the envy of the world, here

+too we face major challenges.

+Demographic Factors

+Dominant factor controlling BS degree supply is the size of

+the college-age population, which will decline until the late 1990s

- +Traditional source of S&E college students is declining
 - +25%-30% falloff in HS graduates by 1992
 - +Assuming that same fraction (4.8%) choose to enter S&E,
 - +and assuming constant demand (very conservative),
 - +drop will be from 197,000 (83) to 152,000 in 1996;
 - +there will be a cumulative shortfall of 675,000
 - +by 2000!
- +To put it another way, fraction of students choosing
 - +S&E majors will have to increase by 40% to maintain
 - +even present level of graduates.
- +Composition of college age population is also changing...
 - +In 1966 44% of college freshmen were women; today 52%.
 - +By 2020 30% will be composed of Blacks and hispanics...
 - +students who have not traditionally chosen S&E careers.
 - +Indeed, by the turn of the century, over 50% of K-12 students
 - +will be Black or Hispanic.
 - +Less than 15% of new people entering the
 - +labor force of the 1990s will be white males.
 - +The fastest growing pool of youths has the lowest
 - +participation rate in college and the highest dropout
 - +rate in high schools -- not the mention the least
 - +likelihood to study science and math.
 - +Indeed, while Blacks and Hispanics account for 20% of
 - +total population, they account for less than 2% of
 - +scientists and engineers!
 - +Blacks: 2.5% of engineers and scientists
 - +Hispanics: 2% of all scientists and engineers
 - +Women: 15% of all S&E
 - +At all the key decision points during a student's career,
 - +blacks, hispanics, and women fall away from the sciences,
 - +math, and engineering at a steeper rate than the rest of the
 - +population.
 - +We must reverse this now, because women and minorities
 - +are the key human resource of our future.
- +Interest in Science and Engineering Majors
 - +ACE-UCLA Cooperative Institutional Research Program (CIRP)
 - +survey of entering college freshmen (Kenneth Green)
 - +Freshman interest in undergraduate science majors has
 - +dropped dramatically--by almost half--over the past
 - +23 years.
 - +Freshman interest in technology careers has also
 - +dropped over in past 6 years--engineering falling
 - +by 25%, computers falling by 75%.
 - +Over past 20 years, proportion of college freshmen planning
 - +on majoring in BPM has dropped from 11.5% to 5.8%.
 - +Mathematics: 4.6% to 0.6%
 - +Physical Sciences: 3.3% to 1.5%
 - +Biological Sciences: 3.7% to 3.7%
 - +(but most of these are premed)
 - +Engineering: 12% to 8.6% over past 6 years
 - +Computers: 8.8% to 2.7% over past 6 years
 - +Women: 8.8% to 5.1%
 - +Where have the students gone?
 - +Business: 10.5% to 23.6%
 - +The disciplinary-training of secondary school science
 - +teachers has declined dramatically over the past
 - +two decades. Today very few aspiring science and
 - +math majors plan to pursue careers as high school
 - +teachers.

- +A high proportion of freshmen who enter college
 - +planning to major in these fields either change
 - +their minds during entry-level courses, drop
 - +out later, or reluctantly complete their programs
 - +rather than “waste” the investments of time,
 - +energy, and money.
- +Summary: Longitudinal studies of freshmen preferences indicate
 - +that a tremendous number of aspiring science majors
 - +ultimately “defect” to other non-science fields. Indeed, the
 - +sciences have the highest deflection rates and lowest
 - +“recruitment” rates of any undergraduate fields.
- +Attrition Among Undergraduate Science Majors
 - +One problem has to do with our priorities.
 - +While many scientists like to teach, relatively few have
 - +the good fortune to be able to devote a significant
 - +portion of their time, energy, and creativity to
 - +excellence in teaching without accepting significant
 - +professional and monetary penalties.
 - +Students view entry-level courses in science as
 - +inaccessible or if accessible, unrewarding to them.
 - +Many freshmen who come to college well prepared
 - +and expecting to major in science disappear after the
 - +freshman year even though they may have done very
 - +well in AP courses. Entry level courses are
 - +“watersheds” that determine both the place of science
 - +in the lives of those who go to college and the vitality
 - +of UG programs in science.
 - +Common practice of using entry-level courses as barriers
 - +to protect more advanced courses for all except the
 - +most able students still persists, and at worst, students
 - +view these classroom environments as destructive
 - +and hostile. A positive and supportive human
 - +environment has value to all students and is
 - +particularly valuable to women and minorities. The
 - +success of many liberal arts colleges in encouraging
 - +and enabling undergraduates to pursue graduate
 - +study in science and mathematics may lie in a rich
 - +human support system made available to their
 - +students.
 - +Indeed, the general response to the quality of science
 - +education from educators has been
 - +“Don’t educate them better; raise the standards,
 - +filter harder. We’ve gotten so good at weeding
 - +out that no one’s left.”
 - +The higher levels of intellectual abstraction in modern
 - +science has led to intensifying the introductory
 - +curriculum, asking students to assimilate
 - +abstractions before they have sufficient experience
 - +with the phenomena that are the rational base of the
 - +abstractions, and in so doing, making SME inaccessible
 - +to many students.
 - +There is strong evidence that students learn best from
 - +hands on activities with peers, not from lectures or
 - +rote acquisition of facts.
 - +So too, the reliance of research universities on teaching
 - +assistants who all too frequently lack the motivation, preparation,
 - +or communication skills to teach well strikes another
 - +blow at the quality of UG instruction.
- +NSB Report:

- +Evidence mounts that UG education in science,
 - +mathematics, and engineering is not fulfilling
 - +its mission.
- + "Serious problems, especially problems of quality, have
 - +developed during the past decade in the infrastructure of
 - +college-level education in the United States in mathematics,
 - +engineering, and the sciences."
- + "The deterioration of college science, mathematics,
 - +and engineering education is a grave, long-term
 - +national threat."

+PhD Education: our Future Faculty

- +25% of engineering faculty will retire in next 6 years
 - +On the basis of BS production alone, PhD production will
 - +decline by 20% in the decade after the mid-1990s.
 - +Yet, over the next two decades, PhD replacement needs will
 - +double in all sectors (academic, industry, government)
 - +The PhD production rate simply cannot respond quickly to market signals.
 - +Salary increases, now projected at doubling during the 1990s, will
 - +increase production, but response will be quite delayed.
 - +Further, the increasing number of foreign PhD graduates will
 - +reduce salary inflation, thereby reducing the number of
 - +Americans pursuing PhD degrees.
 - +Must focus on currently enrolled college students to affect
 - +PhD shortfall in late 1990s.
 - +Of 10,000 HS sophomores, fewer than 20 receive PhD's
 - +If one looks at the ratio of BS to doctorate degrees over next
 - +decade, one sees a precipitous decline. The stabilization is only
 - +because of the rapid growth in foreign citizens receiving US degrees.
 - +While we can be proud our universities attract so many foreign
 - +students, we should not be blind to the fact that, increasingly,
 - +American students are not pursuing careers in S&E. Depending on
 - +foreign students is a dubious substitute for growing our own.
 - +Hence US PhDs will decline due to reduced BS graduates
 - +Foreign PhDs are beginning to return...
 - +Strong evidence that foreign students are beginning to return home.
 - +US universities are becoming less attractive...
 - +we've become complacent
 - +Like balance of trade problem--we are building our
 - +infrastructure (including faculty) on foreign nationals
 - +All multinational companies are going after US-trained
 - +foreign nationals to be based in their home countries
 - +We have created a situation in which we are highly dependent on a resource
 - +over which we have little control.
 - +PhD shortage in faculty...
 - +Compensation (in constant dollars) was constant from 1964 to 1984
 - +It has gone up by 21% in past 5 years and will accelerate even
 - +more rapidly as the real PhD shortages appear late in the 1990s
 - +Note that the PhD recipients of 2000 are already in college.
- #### +Scientific Literacy
- +We really haven't appreciated impact of technology.
 - +Today we are witnessing an unprecedented explosion of
 - +knowledge.
 - +Technology doubles every 5 years in some fields!
 - +Graduates are obsolete by the time they graduate!
 - +Technological change is a permanent feature of our environment
 - +Examples of just the past few months:
 - +i) hole in the ozone layer over Antarctica
 - +ii) new supernova in the heavens
 - +iii) new high temperature superconductor

- +iv) a new theory suggesting that all matter is composed
 - +of infinitesimal "superstrings" rather than point particles
- +Yet, at the same time public ignorance is extraordinary!
 - +A recent NSF survey indicated that only 18% of those
 - +asked said they knew how a telephone works -- and
 - +only half of these gave the right answer.
 - +Yet more than half of those surveyed indicated they
 - +believed we were being visited by aliens from outer
 - +space!
- +By surveys, very low levels of scientific literacy...
 - +3% of high school graduates
 - +12% of college graduates
 - +18% of PhDs
- +It is clear that most people--including many intelligent people--
 - +are not only ignorant of science, but many are actually
 - +hostile to it.
- +We are rapidly becoming a nation of illiterates ...
 - +in science and technology, no longer able to comprehend
 - +or cope with the technology that is governing our lives.
 - +Public's knowledge and understanding of science has not
 - +kept pace with technology
- +An Obsolete Labor Force**
 - +The education of the national workforce is inadequate
 - +to the demands of the next century.
 - +Our nation is undergoing dramatic change in industry...
 - +Away from low-skill, blue-collar workers
 - +The factory of the future will have NO low skill workers
 - +Unskilled labor will lose relevance in a world dominated
 - +by microelectronics, computers, and automation.
 - +An example: Expert systems
 - +The "expert system" craftsman...
 - +Key input, however, is quality of the workforce.
 - +Our principal competitors are simply producing
 - +workers better capable of absorbing modern
 - +production skills. The lack of these skills is preventing
 - +us from achieving the productivity gains that we should
 - +be getting.
 - +Serious concern:
 - +1. The present generation of blue-collar workers does not
 - +have the formal education to be retrained!!!
 - +2. Little sign that education system is adapting to this
 - +future. High school graduates "illiterate" in science
 - +and mathematics will be condemned for the remainder of
 - +their lives to low-level service employment ... IF they
 - +can find jobs at all!
 - +It is bad enough to face the prospect of a significant fraction
 - +of our labor force becoming permanently unemployable because
 - +of an inadequate education. Do we want to condemn their
 - +children...OUR children...to a similar fate? Can we afford it?
- +Undergraduate Engineering Education
 - +Since I've been taking potshots at everything else,
 - +let me aim a few at my own discipline for a moment...
- +Changes in Engineering Education:
 - +1. We all know the rapidly changing environment in which
 - +the engineer must work.
 - +The time scales of research, development, and
 - +implementation have been significantly compressed
 - +in recent years.
 - +Important problems command far more of a cross-

- +disciplinary approach.
- +In both the federal and corporate sector, there is an
 - +increasing emphasis on the macroscopic,
 - +on systems.
- +2. Indeed, even the tools used by engineers are
 - +changing rapidly.
 - +The computer serves now not only as a lever for the mind,
 - +greatly enhancing one's intellectual span,
 - +but it has also become a medium of communication
 - +and collaboration.
 - +While it is clear that one must saturate the engineering
 - +curriculum with information technology to take
 - +advantage of its enhanced productivity, there are
 - +other more profound changes triggered by this tool.
 - +In a sense, the computer is rapidly changing engineering
 - +practice because of the degree to which it has
 - +extended the intellectual span of the engineer.
 - +It is no longer necessary to pass a product along a
 - +sequence of engineers from R&D to design to
 - +analysis to production.
 - +Now modern computer-aided engineering tools allow
 - +one engineer to span all activities.
 - +Hence engineering practice is increasingly demanding
 - +the generalists rather than the specialists
 - +produced by our engineering schools.
 - +Furthermore, the computer has provided powerful analytic
 - +tools thereby freeing the engineer from the need to
 - +spend most of his or her time analyzing a particular
 - +design
 - +Instead the engineering today can explore many designs
 - +and let the computer rapidly perform the analysis.
 - +In a sense, the computer now allows us the freedom to
 - +reemphasize creativity over analysis.
- +3. The third theme of change has to do with the use of engineers
 - +themselves.
 - +Increasingly, the problem-solving orientation of engineering
 - +education is viewed as an excellent "preprofessional"
 - +education for a host of other careers, including
 - +business, law, and medicine.
 - +Indeed, at Michigan we now find that over 50% of our
 - +engineering graduates will find themselves in
 - +management positions within five years of graduation.
- +It is appropriate to ask whether the present, narrowly focused
 - +education typical of most engineering programs is really
 - +appropriate for the rapidly changing world society in which
 - +our students must function.
- +In the past, engineering education has gone through
 - +several identifiable stages of evolution.
- +Of course, centuries ago, engineering was essentially
 - +an art, a craft; and it was passed on from generation
 - +to generation by an apprenticeship process similar
 - +to that of artisans and craftsmen.
- +The early 20th century saw the formation of engineering
 - +schools, similar to those characterizing other
 - +professions such as medicine, which taught the
 - +profession in a highly self-contained way.
- +With the dramatic shift to a scientific base in the
 - +years following WW II, we began to see a shift
 - +more toward engineering science.

- +The increased complexity of engineering practice
 - +demanded increasing specialization; the four
 - +early engineering disciplines--civil, mechanical,
 - +electrical, and chemical--have subdivided into
 - +dozens of specialties.
- +Furthermore, engineering functions themselves have
 - +subdivided into research, development, design,
 - +production, management, marketing, and so forth.
- +Yet today further changes seem necessary.
- +The problem is that we really aren't preparing our graduates for
 - +a world of change.
 - +In this type of world, the most successful people will be
 - +those who can critically analyze ideas, who can look
 - +at things from many perspectives.
 - +Yet, in engineering education, we continue to move to more
 - +and more specialization.
 - +Furthermore, we are approaching the point of information
 - +overload, and it will take highly discerning individuals
 - +to figure out what is important, what they should use,
 - +and how they can understand it.
 - +Further, too many people coming out of our universities
 - +today have weak communication skills and a very
 - +limited view of the world.
 - +Young people are too quickly encouraged into job-oriented
 - +specialization.
 - +That may have worked for our past industrial and domestic
 - +economy, even if it deprived people of a truly rich
 - +and liberal education. But today it is simply fool hardy!
 - +Instead, they should use their college education to challenge
 - +the ideas of the past, discovering the wisdom of others,
 - +exploring knowledge, and stretching the intellectual
 - +breadth of their minds.
- +General Observations on the Pipeline Problem
 - +Conclusions:
 - +i) If we couple demographics with student preferences, we have
 - +got a timebomb on our hands...
 - +ii) Indirect effects, since smaller enrollments in S&E will mean
 - +less justification for investments in faculty and facilities...
 - +iii) We must act rapidly...
 - +First to plug up the leaks in the pipeline...
 - +Then, over the longer term, to reform the education system
 - +in America to respond to a changing population
 - +and a changing world.
 - +The Seamless Web
 - +Obvious
 - +K-12 feeds UG
 - +Universities provide teachers to K-12
 - +Not-so-Obvious
 - +U.S. Phd Shortage as "Air Bubble" in Pipeline
 - +Near Term vs Long Term
 - +Near Term: "Plug the leaks"
 - +Long Term: "Rebuild the entire pipeline"
- +Intervention Strategies
 - +K-12 Education
 - +What Can We Do?
 - +1. Education for All of America
 - +We must commit ourselves, and our
 - +nation, to providing a quality education for
 - +all of our citizens. We should accept the

- +premise that every child, regardless of
 - +racial, ethnic, or economic background has a
 - +right to a quality education, with the
 - +objective being at least twelve years of
 - +formal education.
- +2. Education for the 21st
- +...not the 19th century!
 - +Our public schools will only succeed if
 - +they replace the basic structure that was
 - +put in place fifty years ago to meet the
 - +needs of a smokestack economy with a new
 - +structure that meets the needs of an
 - +information society, an age of knowledge.
 - +We need creativity as well as openness to
 - +entirely new approaches to learning in the
 - +organization, management, and staffing of
 - +our schools.
 - +Of course, the first objective is to fill
 - +our schools with first-rate teachers and
 - +administrators and then set up
 - +performance-oriented systems in which the
 - +goals for students are clearly specified, and
 - +the rewards go to schools in which students
 - +make substantial progress toward those
 - +goals.
- +3. We must make teaching an
- +honored profession once again.
 - +Of course, a key objective must be to fill
 - +our schools with first-rate, dedicated
 - +teachers and administrators. This goal
 - +will require major changes in the way in
 - +which we honor and support the teaching
 - +profession.
 - +We must recognize the great importance
 - +and value of our teachers, reflecting this
 - +with better pay, including strong merit
 - +components. We must also provide our
 - +teachers with far better preparation by
 - +requiring all teachers to have education in
 - +basic core disciplines such as the liberal
 - +arts, sciences, and mathematics and then
 - +providing the necessary pedagogy at the
 - +graduate level. We must provide our
 - +teachers with more control over curriculum
 - +in the classroom. We must take teachers
 - +out of their current blue collar, assembly
 - +line, factory jobs and give them the status,
 - +the rewards, and the responsibility and
 - +authority characterizing other professions
 - +such as law, medicine, and engineering.
 - +We must provide strong incentives for
 - +our very best students to consider careers in
 - +teaching. This will require a major
 - +rethinking of the nature of teacher
 - +education. It seems clear that our best
 - +students will seek education in the liberal
 - +arts (humanities, natural sciences, social
 - +sciences, arts) and not in education majors.
 - +Hence, we need to develop concentrated

- +programs at the graduate level designed to
 - +provide the proper foundation in pedagogy
 - +and child development. Further, we must
 - +provide strong financial aid incentives for
 - +students in these programs.
- +4. School Management
- +Education can learn many lessons from
 - +business about how to improve the quality
 - +of their operation. In a nutshell, we must
 - +set up performance-oriented school--schools
 - +in which the goals for students, faculty,
 - +and administrators are clearly specified,
 - +and the rewards go to those schools in
 - +which these goals are achieved.
- +Like business, education must make a
 - +firm commitment to quality and build it in
 - +in the first place wherever possible. It is
 - +clear that we need far higher standards
 - +and expectations for our schools. This may
 - +require significant structural changes, such
 - +as lengthening the school year from 180
 - +days to 240 days (noting that this action
 - +would also enable significant increases in
 - +teachers' salaries and ease child-care
 - +needs in our society).
- +Our schools must reward success in
 - +producing quality. When a system for
 - +rewarding quality is in place, they should
 - +then allow the people on the firing line,
 - +the teachers, to determine how to get the
 - +job done. And they simply must eliminate
 - +as much of the bureaucracy and as many of
 - +the intervening rules and regulations as
 - +possible.
- +The key is to get the incentives to make
 - +sure there are appropriate rewards for
 - +success and real consequences for failure. If
 - +we want quality, we should reward it. If
 - +we want student progress, we should reward
 - +it. If we want efficiency in the use of public
 - +resources, we should reward this too.
- +5. School Financing
- +It is clear that even though public
 - +education in America is relatively well
 - +supported, additional support will be
 - +needed to affect the major overhaul that
 - +will be necessary. We will need more tax
 - +support for public education--at least
 - +through the reform decade of the 1990s.
 - +Since education is the real key to our future,
 - +it seems appropriate that we place a
 - +higher value on it.
- +In particular, in Michigan, we simply
 - +must re-shape our state's priorities to bring
 - +a better balance to school finance by seeing
 - +education as an investment in the future
 - +that deserves a higher priority in
 - +relationship to our immediate needs. We
 - +simply have to turn the state priorities

- +around and make education far more the
- +centerpiece of our efforts. We have to stop
- +treating the symptoms and summon the will
- +and courage to seek a cure.
- +It is clear that we must devise
- +alternative tax methods, shifting from an
- +overdependence on property taxes. Indeed,
- +unless our state can find a way to shift from
- +an overdependence on property taxes, we
- +will continue to find strong tax resistance
- +impeding progress in school reform. So too,
- +we must come to grips with serious equity
- +issues, leading to extremes between rich and
- +poor school districts. This inequity
- +continues to result in the least investment
- +going to the state's schools whose students
- +are most in need of quality education.
- +6. What Higher Education Can Do?
- +Higher education must awaken to its
- +responsibilities for the quality of public
- +education in America. It is clear that we
- +need to reach out more to school districts--
- +working with them and responding to their
- +needs. We need to work with our public
- +schools to experiment with new techniques,
- +new texts, new methods of instruction, new
- +ways of organizing knowledge, and
- +engaging students in the excitement of
- +experimental problem solving.
- +An important effort in this respect is
- +the new Partnership for a New American
- +Education. This consortium, consisting of
- +the state's three research universities--the
- +University of Michigan, Michigan State
- +University, and Wayne State University--
- +is working closely with state government
- +and the private sector to develop in the
- +State of Michigan a model for higher
- +education in America.
- + Universities must re-examine our
- +priorities and ask ourselves whether we
- +are not partly to blame and whether each
- +of us should not put a much higher priority
- +on preparing talented graduates for
- +primary and secondary education. In this
- +regard, we must pay particular attention to
- +our own schools of education. Traditionally,
- +these units have had the lowest status of
- +any of our academic units on our campuses.
- +During the 1970s and early 1980s our
- +education schools were regarded as a haven
- +for mediocre students and mediocre faculty.
- +It is ironic that if one looks at the reform
- +movement over the last five years, there is
- +very little mention made of our schools of
- +education. It is clear that our universities
- +need to mount much more effective programs
- +to train teachers, principals, and
- +superintendents.

+Finally, our universities really can set
 +the pace for public education in America by
 +simply insisting on far higher entrance
 +requirements and communicating these
 +clearly to parents and prospective students.
 +In this way, we may be able to generate the
 +necessary pressures for reforms of our public
 +schools.

+7. A Major Cultural Change: Demand Success

+Major changes in public perspectives
 +are clearly needed. For example, we should
 +shift public education to a "zero defect"
 +philosophy, in which we simply will not
 +tolerate failure. In essentially every other
 +developed nation drop-outs are effectively
 +eliminated by developing multiple track
 +systems in which students who do not
 +achieve the highest performance level are
 +given many other options and chances to
 +succeed. As a result, these nations have
 +succeeded in building a highly-skilled and
 +diverse workforce at all levels, thereby
 +avoiding the incredible social costs of
 +dropouts and the development of an
 +underclass.

+It is clear that our students need to gain
 +a greater sense of participation in the
 +learning process, so that they feel
 +responsible for their education and
 +connected to their school--regarding
 +themselves as a community of common
 +concern. These partnerships must reach
 +beyond the school and strongly involve the
 +parents as well.

+8. The Need for a "Sea Change" in Public Attitudes

+Part of our problem has to do with the
 +absence of a national consensus on either the
 +magnitudes or the solutions to the problem.
 +While the seriousness of the problem may
 +be beginning to dawn on us, we are still
 +looking for cop-outs by blaming others; by
 +complaining that we are already spending
 +too much on public education; or by saying
 +that the needs of the moment are more
 +urgent, and we can deal with public
 +education later when our economy is in
 +better shape. Perhaps this procrastination
 +is the greatest challenge that we must face
 +if we are to build in this nation a system of
 +public education appropriate for

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 - +and most parents--currently expect of them.
- +General strategy
 - +To develop a challenging, coherent, and concrete set of academic standards
 - +to empower local schools to meet those standards, and to hold them
 - +accountable for the achievements of their students.
- +Key Words:
 - +management by objectives
 - +site-based management
 - +accountability
- +1. Clear objectives
 - +Develop clear objectives for our schools...
 - +...an ambitious and challenging core curriculum that
 - +focuses on higher order thinking and learning.
 - +Public Act 25 requires this...
 - +...but State Board proposed core curriculum is weak
 - +conditioned by the status quo, and does not meet
 - +the needs of schools for serious and coherent
 - +guidance in raising their educational sights.
 - +...Should follow lead of California and Connecticut.
 - +NOTE: These must not be local standards...
 - +...or Michigan standards
 - +...or even U.S. standards
 - +These must be world standards...
 - +since our children must learn to compete
 - +in a global community
 - +Hence, while educators and parents will be important
 - +in defining these objectives, so too will be
 - +“consumers” such as business, industry, and
 - +higher education.
- +2. Accurate assessment
 - +Develop methods for accurately assessing student
 - +achievement...which are aligned with objectives.
 - +Here, we have a good tool:
 - +...the Michigan Educational Assessment Program
 - +...but it is strongly resisted by teachers and school
 - +districts
 - +NOTE: Here it may be necessary to create truly
 - +independent assessment bodies...perhaps
 - +nonprofit corporations governed by boards representing
 - +wide constituencies
 - +Telling schools, parents, students...colleges and employers
 - +...and the public...how our schools are doing.
- +3. Moving to site-based management
 - +Breaking the chains of laws and bureaucracy that bind schools
 - +...allowing them to determine their own strategy for
 - +achieving the objectives
 - +We must shift genuine authority and resources to the school
 - +level to given principals and teachers new flexibility to
 - +try new approaches, reallocate resources, adjust
 - +staffing, ...and make their schools work better.
 - +A shift in authority to the school takes control away from
 - +state legislators, state officials, local school boards,
 - +and central district offices. All of these groups must
 - +agree to revoke existing policies that currently constrain
 - +school activities, and to forbear from enacting new ones.

- +Providing strong support:
 - +...improved preparation of professional staff
 - +Michigan teacher education
 - +Dominance of teacher colleges...
 - +...produce 7,000 for 2,000 jobs
 - +...have 3 of to 5 factories in US
 - +Clearly need an overhaul
 - +...curriculum and materials development
 - +Who? Michigan Department of Education?
 - +Nonprofit entities?
 - +...modern management methods
 - +...exemplary practice sites
 - +Michigan Partnership for New Education
 - +Kalamazoo Area Math and Science Center
 - +...school finance reform
 - +Allowing them to implement a variety of options
 - +...parental choice
 - +...alternative certification
 - +...longer school years
 - +...merit teacher reward systems
 - +Special needs:
 - +Bring all children into the 3rd grade with solid skills
 - +in reading and mathematics
 - +...Full funding of Head Start for 4 year olds
 - +...Extended day kindergarten in poor schools
 - +Provide extra support for schools that serve concentrations
 - +of poor children
- +4. Insisting on accountability
 - +...Outcome-based accreditation
 - +...Business actions:
 - +Hiring decisions based on academic performance
 - +...Higher Education]
 - +Minimum graduate requirements (with remedial education
 - +required of those not meeting admission requirements)
 - +...New state authority to take over failing schools
 - +Those schools which are capable of moving toward objectives
 - +will be left alone.
 - +Those which cannot will be subject to a number of actions
 - +...alternative management
 - +...consolidation
 - +...financial penalties
- +UG Science Education
 - +Some General Recommendations
 - +1. In most colleges, there is not a faculty consensus on the purposes
 - +of undergraduate education, whether in general or in the
 - +sciences. Hence the first task is to bring together science
 - +faculty with their colleagues in the humanities and social sciences
 - +to determine the role of the sciences in a liberal education.
 - +2. It is clear that entry level courses and core course sequences
 - +need to be rethought (if not entirely replaced) from the
 - +perspectives of the students as well as the faculty.
 - +While scientists like to teach, relatively few have
 - +the good fortune to be allowed to devote a significant
 - +portion of their time, energy, and creativity to
 - +excellence in teaching without accepting significant
 - +professional and monetary penalties.
 - +There is far too little innovation and creativity that
 - +attempt to take advantage of how learning really
 - +occurs.

- +No wonder our students leave our disciplines.
- +Indeed, it is amazing that any perservere!
- +How can we re-design entry level courses to
 - +enlarge entry window, taking into account
 - +differing maturation rates.
- +Studies show that scientific understanding develops best when
 - +students are active partners in learning through
 - +interacting with the physical world
 - +and refine their interpretations through social
 - +interactions with their peers and mentors.
- +When courses depend exclusively on lecture and
 - +reading to transmit the canons of science,
 - +students do not come to understand that the
 - +methods of science are as important as the
 - +body of knowledge that the methods develop.
- +Because students are unaware of the broader
 - +applications of scientific knowlege and skills,
 - +they do not value science.
- +J. Bronowski in his Science and Human Values puts it this way.
 - +“It is a common and cardinal error to suppose,
 - +as the nineteenth century supposed,
 - +that the facts on which science builds
 - +are given to us absolutely and call for
 - +no judgements or interpretations from us.
 - +The great discoveries in the physical sciences
 - +in the twentieth century begin from
 - +a radical denial of this philosophy.
 - +We now understand that science is built
 - +not on facts but on observations;
 - +that observation is not a passive state
 - +of reception, but an active relation between
 - +the observer and his world; and that science
 - +therefore is not a mechanical index of facts,
 - +but an evolving activity.”
- +3. It is essential that the very best faculty be brought into the
 - +entry level coruses in an effort to convince more students
 - +to pursue majors in the sciences.
 - +We are not presenting the excitement of learning.
 - +It is ironic that at a time of such dazzling advances,
 - +in knowledge, our teaching methods have hardly
 - +changed at all.
- +4. Where possible, one should move away from the lecture format
 - +and stress instead laboratory and field experiences and team
 - +learning activities.
 - +One should move away from large lecture formats as
 - +the dominant method of instruction--
 - +Some recent research on the effect of public speakers
 - +on an audience...
 - +...the audience is able to pay attention and
 - +remember most of what a speaker says
 - +for the first 10 minutes
 - +...for the next 10 minutes, their minds begin
 - +to wander
 - +...then, after 20 minutes, the majority of
 - +people in any audience begins to have
 - +sexual fantasies
 - +“So at least I want you to know that you will
 - +enjoy a part of my speech.”
 - +These courses should be concerned with the processes

- +of investigation and hands-on experience, not simply
- +accumulating facts and passively accepting the
- +opinions of others.
- +Perhaps far more use should be made of
 - +...“peer” teaching assistants...i.e., undergraduates
 - +...as well as instructional technology (e.g., Mathematica)
 - +...Kleinsmith’s successes in biology--
- +5. The tightly sequenced majors now characterizing most science
 - +disciplines should be made more flexible, allowing students the
 - +opportunity to both interrelate and perhaps even shift among
 - +science majors as their interests shift.
 - +Must reduce tensions in science majors which are
 - +simply too intense--and do not allow enough
 - +opportunity for a liberal education.
 - +Many problems with tightly sequenced majors, since these
 - +are seen as one-way roads by students.
 - +UG curricula should be viewed as a network of roads with many
 - +points of entry and many cross overs--points of
 - +opportunity to broaden academic programs and
 - +move to other majors.
- +6. Since the curriculum of most science majors is already seriously
 - +overburdened, the exponential increase of new knowledge and
 - +skills can only be accommodated by replacing existing content,
 - +not by making majors even more intense.
- +7. Indeed, both the explosion and evolution of scientific knowledge
 - +demand a lifetime commitment to learning, and this should be
 - +factored into the design of the undergraduate curriculum.
 - +Faculty should develop courses and programs that
 - +effectively integrate the practical and liberal
 - +aspects of education in the sciences.
 - +Consequences of neglecting the liberal aspects of
 - +education in the sciences tend to make students
 - +less valuable and adaptive in the workplace.
 - +For example, if science faculty view the purpose
 - +of preparation of concentrators solely as
 - +vocational training--the development of the
 - +technical skills and knowledge required for a life
 - +in research--there is a danger that the social and
 - +ethical issues that confront practicing scientists
 - +will not be examined as part of UG experience.
- +8. The fundamental goals of undergraduate science education for
 - +all students should be the development of a knowledge base
 - +and intellectual skills that enable them to engage in lifelong
 - +science learning and to be able to apply their scientific
 - +knowledge to personal, professional, and civil endeavors.
 - +UG courses and curricula in sciences influence the
 - +scientific literacy of all Americans--either directly
 - +or indirectly through teachers.
 - +Although academic scientists have the potential to
 - +influence scientific literacy, their attention has
 - +been largely directed toward building the nation’s
 - +science research capability.
 - +Faculties have the essential task of preparing UGs for
 - +life in a society in which science is becoming more
 - +persvasive; at the same time, they must also
 - +maintain or improve the education available for
 - +students intent upon careers in science.
 - +Let me digress for a moment to suggest that as scientists
 - +we need to be concerned about educating the broader

- +public, not just our own students.
- +I think we need to try to communicate what we do and why it
 - +is important, and to be involved in the reforms of K-12
 - +education as well as undergraduate and professional
 - +education.
- +We are an arrogant lot, on the whole--and a privileged one.
 - +I think we can repay society for granting us the privilege
 - +to teach and do research by actively contributing to
 - +public understanding of the strengths of science and
 - +its limitations.
- +More Specific Recommendations
 - +1. A Science "Liberal Arts" Major
 - +Perhaps as science faculty we need to take a broader view of
 - +the science major itself and cease assuming that every
 - +student majoring in our field intends to become a
 - +professional scientists.
 - +After all, most history majors do not intend to become
 - +historians..or philosophy majors philosophers...
 - +(some may even become investment bankers!!!)
 - +Yet we assume that all physics majors will become physicists,
 - +all chemistry majors will become chemists...and so
 - +forth...and hence design highly specialized, intensive
 - +majors with this in mind.
 - +What about a physics, chemistry, or mathematics major for
 - +students intending to continue their studies in other
 - +professions such as business, law, or medicine?
 - +Indeed, it would seem that a liberal education with a
 - +strong concentration in the sciences would be an
 - +excellent preparation for the "age of knowledge"
 - +characterizing our society in the years ahead.
 - +2. Major/Minor Curriculum Options
 - +In years past, it was common to encourage (or even require)
 - +students to pursue intensive studies in both "major"
 - +and "minor" areas. For example, the physics major might
 - +have a minor in English Literature...or the English major
 - +might have a minor in astronomy.
 - +Perhaps we should once again encourage our best
 - +undergraduates to pursue two majors--or at least a
 - +major and a minor--in widely separated fields of study.
 - +Study Group concluded that in-depth quantitative
 - +understanding of a single natural science is
 - +preferable to a superficial survey of several
 - +natural sciences--but also that such in-depth
 - +knowledge of two or more natural sciences is
 - +preferable to knowledge of a single one.
 - +Our ideal can never again be the One Man who individual
 - +incorporates all human capacity and knowing,
 - +as in the ideal of Jefferson's time--
 - +but perhaps instead the person who works deeply and
 - +productively in 2 or 3 disciplines which are not
 - +contiguous--in English literature and physics, or
 - +in mathematics or art.
 - +Some examples of the Great Straddlers:
 - +da Vinci: military engineer, physician, artists
 - +Darwin: Malthesian economic theory & biological change
 - +Wiener: mathematics, thermodynamics, communication
 - +Prigogine: chemistry, literature, philosophy
 - +Of course, these are towering intellectual figures.
 - +BUt is is possible that we have set our sights too low.

- +We might be wise to aspire to greater breadth as scholars
+and teachers.
- +Why only 2 or 3 fields?
 - +Learning that many disciplines deeply and well is
+about all that is humanly possible
 - +Further, the object should not be just breadth in
+the old sense--rather it should be the unpredictable
+release of intellectual energy which occurs by
+connecting within one mind two widely separated
+fields of thought.
- +Alternative: Case-Western Reserve approach
 - +56 credit hour core in calculus, probability,
+discrete math (computers), physics and astronomy,
+natural philosophy, and computer science.
- +3. The Science Content of a Liberal Arts Curriculum
 - +It is clear that we are doing great disservice to our
+undergraduates by allowing them to leave the university
+in a state of scientific illiteracy.
 - +Further, to the degree that the natural sciences are indeed
+important components of the liberal arts, few of our
+graduates leave our institutions with a truly liberal
+education. (Indeed, few of our faculty have benefited
+from a liberal education from this perspective.)
 - +A century ago it was felt that at least 25% of the curriculum
+of a liberal education should consist of science and
+mathematics. Is it not appropriate to question whether
+in this increasingly science and technology-dominated age,
+a similar content is needed by our students today.
 - +What can be done? If MIT and Caltech demand that their
+science students take 25% in the humanities, perhaps
+we should require that humanists invest 20% to 25% of
+their effort in science...at least leading them up a gentle
+slope to a more considerable level of learning.
- +4. Transition Majors
 - +Our present approach to science education is essentially a
+filtering process--a highly vertical and hierarchical
+sequence of courses which pile, one upon another,
+thereby making it very difficult for students to change
+directions as their interests or abilities mature.
 - +However, perhaps it is possible to design an educational
+program (although perhaps using nontraditional instructional
+methods) at the upperclass or graduate level that would
+allow students with degrees in the social sciences or
+humanities to make the transition into further studies in
+science.
 - +One of the fundamental reasons for this difficulty is
+that education in science is highly vertical, where one
+subject is built upon knowledge of another, whereas
+scholarship in the humanities is much less vertical;
+it is primarily extensive rather than intensive.
 - +Unlike literature or social science, the highly vertical subjects
+of science are very difficult to learn after college. Unless
+one learns the language of science, mathematics, in
+college, one is likely to remain scientifically illiterate
+for life.
- +5. Lifelong Education
 - +Perhaps we should simply conclude that our conventional
+perspective of science education as a four-year undergraduate
+major--or even as a 8-10 year graduate program--is obsolete in a

- +world in which the growth of knowledge increases at exponential rates.
- +The exponential increase of scientific knowledge and uncertainty about what scientific knowledge will be required to comprehend future issues make it impossible for any student to acquire all knowledge required for a lifetime anyway.
- +Of all applications skills, those that contribute to the capacity for lifelong learning are of most basic value.
- +Instead we might consider science education as a lifetime commitment to formal learning--and prepare our students for this future.
- +Then if we began with the assumption that our students would continue to study throughout their professional careers, we could probably redesign our undergraduate programs to make them far less specialized and far more suited to a world of change.
- +The Weisbuch Recommendation
 - +1. "All science and mathematics faculty will teach at least one undergraduate course per year.
 - +2. "I really mean it. I'm the president. I'm the boss. And there will be no exceptions."
- +PhD Education
 - +Most critical in near term...
 - +...and yet the easiest to solve...
 - +Major expansion on federal fellowships/traineeships
 - +NSF Traineeship Program
 - +FCCSET Objective
 - +Eliminate Feudal System of Servitude
- +Engineering Education
 - +Engineering Education for 21st Century
 - +Common agreement that what is needed is:
 - +Engineers who are technically competent,
 - +socially aware, with a business perspective,
 - +effective communication skills, and
 - +a global awareness.
 - +Yet it is also clear that industry will only support a 4 year education program (even with inadequate high school preparation).
 - +("Leonardo de Vinci with a hard hat")
 - +I suspect that we have just begun to realize the major changes required in engineering education. I furthermore believe that those changes will be just as profound as the earlier transitions from a craft to a profession or from an "experienced-based" to a "science-based" discipline.
 - +Of course it is true that few today seem to realize the changes which must occur. Industry, government, even present-day engineers, seem satisfied with our present approach to engineering education. Indeed, these institutions even resist changes.
 - +It seems clear that the challenges and changes characterizing our society suggest that the principal focus of an undergraduate education--engineering or otherwise--appropriate for the 21st century will be the goal of liberally learning, that is, a liberal education as the preparation for a lifetime of learning.
 - +In the 21st Century people will finally think in terms of life-long education; college will be viewed as only one intermediate step in one's education.
 - +Only solution: must develop an effective lifelong learning

- +infrastructure.
- +Recommendation 1:
 - +Eliminate ABET...
- +Recommendation 2:
 - +Eliminate all the technical crap from the curriculum
 - +Return to a more classical "liberal arts" curriculum
 - +...with the
- +Recommendation:
 - +Ah, what the hell...
 - +Just eliminate the undergraduate engineering degree
 - +and shift it to the graduate level
 - +like law, medicine, and other "learned professions"
- +Conclusions
 - +My crystal ball suggests a future characterized
 - +by rapid, unpredictable, and frequently dramatic change...
 - +...in the nature of our people...
 - +...in our bonds to other societies...
 - +...in what we do...
 - +As the United States becomes a pluralistic world nation, intensely
 - +dependent upon knowledge--upon educated people
 - +and ideas.
 - +It will be a future of great challenge and responsibility...
 - +In my frequent interactions with the
 - +leaders of the public and private sectors
 - +throughout this country I detect an
 - +increasing sense of both urgency and
 - +pessimism about America's will and
 - +capacity to take the actions necessary for
 - +our future. Indeed, many of these leaders
 - +now believe that our nation is well down
 - +the road toward "outsourcing" its
 - +knowledge resources, just as we have been
 - +our labor, our manufacturing, and our
 - +products. American industry is losing
 - +confidence in our domestic supply of
 - +knowledge resources--that is, a well-
 - +educated labor force or an adequate supply
 - +of scientists, engineers, and other
 - +professionals.
 - +There are several principal trends
 - +which lead to this growing pessimism:
 - +First, there is increasing concern that the
 - +staggering problems facing K-12 education
 - +can simply not be overcome on a time scale
 - +necessary to preserve our economic strength.
 - +The bureaucracy and political resistance
 - +may just be too great.
 - +Second, despite the fact that most
 - +other nations regard higher education as
 - +America's greatest strength, there is little
 - +sign that this view is shared either by our
 - +elected political leaders or the public at
 - +large. Indeed, in recent years it has become
 - +fashionable to attack our universities, even
 - +as we continue to underfund them in many
 - +cases.
 - +The third trend involves the rapid
 - +growth of "transnational" companies, that
 - +is, companies which have no particular

- +allegiance to a region or nation, but rather
- +seek resources, whether they be labor,
- +processes, or knowledge, wherever they can
- +get them at the highest quality and lowest
- +cost. The changing structure of the global
- +economy suggests that outsourcing of
- +knowledge from other parts of the world
- +will become increasingly common as the
- +quality of American education deteriorates.
- +There are already many signs of this. For
- +example, Motorola has recently announced
- +it is establishing a permanent recruiting
- +office for scientists and engineers in India.
- +Furthermore, we already know that over 60
- +percent of all doctorates produced in this
- +nation in engineering and physical science
- +are awarded to foreign nationals.
- +The prospect that we will give up on
- +our efforts to produce an educated workforce
- +capable of creating and supplying new
- +knowledge is frightening. Industry has
- +already outsourced labor and
- +manufacturing. Can we afford to lose our
- +competitive capacity to produce knowledge
- +as well?
- +We must face the facts. We are not
- +going to be rich and prosperous if all we do
- +is mow one another's lawns. Or, more to the
- +point, if all we do is engage in financial
- +gymnastics such as leveraged buy-outs
- +financed by junk bonds, we will destroy our
- +capacity to make the long-term investments
- +and commitments necessary for
- +competitiveness. We simply have to bring
- +something to the table of the international
- +marketplace. We have to generate our
- +wealth through our people, their
- +knowledge, and their skills.