

Educating for a World of Change

Introduction 1: High Tech

High Tech Hype

Tremendous hype surrounding "high tech"
robotics, the chip, computers, genetic engineering
Visions of Silicon Valley dance in our head...

A major resurgence of interest in science and technology

Almost akin to Sputnik era

But now focussed on industrial competitiveness
and military security (Star Wars)

Since I have been immersed in this technology for many
years, it seemed appropriate to make several comments
about its implication for your business: education

Personal Background

To discuss this challenge, I am going to toss aside
my hat as chief academic officer of the University
of Michigan, and instead return to my roots
as a scientist and engineer.

Throughout my scientific career, I have been heavily
involved in stimulating technological change...

In areas such as nuclear energy, lasers,
thermonuclear fusion...indeed, I even worked
on the Rover Project to develop a nuclear
rocket in the 1960s intended to fly men to
the planet Mars!

I am going to put on a hat as former dean of the
College of Engineering at Michigan...as one
who has been involved for the past several
years in attempting to strengthen and
diversify Michigan's industrial base.

Instead, I would also like to put on another hat as well...
that of a member of the National Science Board...our
nation's principal source of science policy...
In fact, I am co-chair of one of the NSB's two
principal standing committees...that on
"Education and Human Resources"...
and it is from this perspective that I would like
to make some observations.

Why the sudden interest in science and technology?

Society --> love-hate relationship with technology

Early 60s: Sputnik era -- space program

1970s: environmental movement, Vietnam
distrust of technology

Today: strong signs that technology is in vogue again
but for a much different reason...

the economic strength of our nation...

Throughout our state and nation one concern has
risen to the top to dominate all others....

"international competitiveness"

And this could be no more evident than in Michigan...
in the heart of the Rust Belt...

Introduction 1: Change Themes

Personal Introduction

As many of you know, I am a scientist by
training and background...indeed, I
am perhaps the worst of all types of
scientists...a burned-out theoretical physicist.

As such, I suffer from two character flaws:

i) First, I tend to a bit too candid in my remarks...

...I generally tell it like it is...

...or at least how I think it is...

ii) Second, I tend to be one of those folks
who lives more in the future than
in the present or the past...

My life as a scientist and engineer has been
spent working on futuristic areas such as:

- i) Nuclear rocket propulsion
- ii) Laser-driven thermonuclear fusion
- iii) Supercomputers
- iv) robotics and artificial intelligence

Hence, perhaps it is natural that as we enter
the 1990s, I should find myself
looking once again to the future, facing
the challenge of helping to build a University
capable to serve our state and our nation in
the 21st Century.

A Message of Change

My message today will be suffer from both of
my character flaws as a scientist/engineer...
...it will be a vision of the future...
...and it will be unusually candid.

In a nutshell, as I look to the future, I am sensing
an ever-accelerating pace of change
in our society, in our state, in our nation, in our world.

Yet I also fear that few have realized the enormous
changes that 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
more interdependent with other nations as
the United States becomes a world nation,
a member of the global community.

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, that is,
educated people and their ideas.

The themes of change,

- i) the growing pluralism of our society
- ii) our evolution into a world nation, ever more
tightly coupled to the global community
- iii) and our rapid transition to a knowledge-based
economy

are not themes of the future...

...they are themes of today...

...and they are already dominating
every aspect of American life.

It is clear that the key strategic resource of our society
has become knowledge itself...
that is, educated people and their ideas.

Knowledge will play the same role that in the past were played
by natural resources or geographical location or
unskilled location...

In the pluralistic, knowledge-intensive, global
future that is our destiny, it is clear that the
quality of and access to

...education in general

...higher education in particular

...and great research universities

such as the U of M most
specifically of all
are rapidly becoming the key determinants
of the strength and prosperity of our state.
But here there is some good news...
America is particularly well positioned,
since our research universities are clearly
the envy of the world, as evidenced by the
extraordinary demand by graduates of
every country to see advanced education
and training in the United States.
Indeed, higher education is not only our nation's
highest quality, but also probably also its most
competitive industry as measured by the
test of the marketplace!
Further, Michigan is particularly well-positioned
from this perspective, since our state has
built over the years not only one of the
strongest systems of public higher education in
the nation, but possesses several of the world's
leading research universities.
But, now for the bad news...and the candor...
We--that is YOU AND ME--seem hell-bent, both as a nation
and as a society, on destroying the extraordinary
resources represented by our research
universities, just as we are entering an
age of knowledge in which they will become
our most valuable resources.
Indeed, a tragic combination of public
misunderstanding, short-sightedness,
and downright selfishness, is now threatening
to constrain and hamper our universities...
Leading to the frightening prospect that we will
manage to destroy our international competitiveness
of higher education just as we have many other
American industries.
Worse, this failure comes at just that moment in
our history when we are becoming more and
more dependent on these same universities
to lead our state into the future.
In my home state Missouri we have an old saying
that the best way to get a mule to move
is to first hit it over the head with a 2x4 to get its attention.
Now that I have your attention,
let me explain more clearly what is at stake here...

Some Personal Memories

This year has seem like one long sequence of silver anniversary events...

In a more personal sense, this was the year my wife and I celebrated our silver anniversary... and our 25th class reunions at our undergraduate colleges.

In fact, last week I experienced the trauma of my 25th Year College Reunion back at Yale...

When I think back, I remember a time of great optimism in America... the glow of Camelot of the Kennedy administration... still lingered with us.

There were great causes to take up such as

- ...world peace...
- ...the conquest of space
- ...the Civil Rights movement

My Class of '64 graduated with feeling of boundless confidence in ourselves and our country.

But there were already clouds gathering on the horizon even during my senior year that suggested that things would be not quite so simple, that dramatic changes were coming...

John F. Kennedy was assassinated during the fall of my senior year... The Cold War had begun to heat up with the Cuban Missile Crisis

A few people were talking about a distant war in a place called Viet Nam

The Free Speech Movement at Berkeley was revealing a new spirit of student anger and activism on the campuses.

But even with these warning signs, we were not prepared for the dramatic crises and confrontations, the great changes that Americans and their institutions would face in the years immediately following our graduation...

- the war in Vietnam that so profoundly affected all of our lives...
...both those who served and those who protested...
- the eruption of assassination and terrorism which robbed us of our heros
- the racial turmoil that tore apart our cities
- the emergence of the drug culture...
as more people turned on and tuned out...
- Watergate, and the crisis in confidence in our leaders

In a sense, during the decade following my graduation America lost its innocence...

In many ways, my class may have represented the last generation of Americans to be truly optimistic about the future... to welcome its challenges and to feel equal to them.

I can't say whether my own choice of a career would have been different if I could have foreseen the future... but it seems appropriate this morning to engage in some futuring...to speculate a bit about the world you will be entering...

Possible Futures

The French poet Paul Valery once said that "The trouble with our times is that the future is not what it used to be."

If my experience is any guide, your future will be a time of greater change and transformation than any experienced before in our nation's history.

You are graduating at a truly extraordinary time... Think about it for a moment... You were born and educated in the 20th Century, indeed, most of you are children of the 60s generation...
...**my** generation (and that's a frightening thought!) Yet you will be spending the majority of you life in the

next century...in the 21st Century.

And while it is always risky to speculate about the future,
three themes of the next century seem clear...

1. Demographic Change: The New Majority

America is changing rapidly...

When we hear references to the demographic changes occurring in our nation, our first thought probably focuses on the aging of our population.

It is indeed true that the baby boomers are now entering middle age, and their generation has been followed by a baby bust... in which the number of young adults will be declining over the remainder of this century by roughly 20%.

Indeed, today there are more people over 65 than teenagers in this country, and this situation will continue for many decades.

Further, the growth rate in both our population and workforce is declining to the lowest level in our nation's history.

America will simply not be a nation of youth again in your lifetimes.

Yet, there is a far more profound change occurring in the population of our nation.

What most don't realize is that the social and racial mix of these cohorts will be enormously different from what it was in the 1960s and 1970s.

America is rapidly becoming the most pluralistic, multicultural nation on earth.

Women, minorities, and immigrants now account for about 90% of the growth in the labor force.

By the year 2000, they'll represent 60% of all of our nation's workers!!!

The 21st Century will be the first post-European century in American history.

An absolute majority of young people born in US in the 21st Century will be born of parents of other than European background...

Asian, African, Hispanic

And this will represent a major change in the character of our society.

Those groups we refer to today as minorities will become the majority population of our nation in the century ahead...just as they are today throughout the world.

And women have already become not only the predominant gender in our nation and our institutions, but they are rapidly assuming their rightful role as leaders of our society.

In this future, the full participation of currently underrepresented minorities and women will be of increasing concern as we strive to realize our commitment to equity and social justice.

But, in addition, this objective will be the key to the future strength and prosperity of America, since our nation cannot afford to waste the human talent represented by those currently underrepresented in our society, this human potential, cultural richness, and social leadership.

If we do not create a nation that mobilizes the talents of all our citizens, we are destined for a diminished role in the global community, increased social turbulence, and most tragically, we will have failed to fulfill the promise of democracy upon which this nation was founded.

But there are other important challenges associated with such demographic change.

In particular, it is important to realize here that 21st Century America will NOT be a melting pot in which all cultures are homogenized into a uniform blend -- at least not during our lifetimes.

Rather, it will be pluralistic...composed of peoples of vastly different backgrounds, cultures, and beliefs...peoples seeking to retain their cultural roots...to maintain their differences and identities.

Our challenge will be to find the common bonds and values that unit us, even as we learn to respect and value our differences.

The growing pluralism of our society is perhaps our greatest challenge as a nation...yet it is also among our most important opportunities, since it gives us an extraordinary vitality and energy as a people.

2. The Internationalization of America

The second theme is triggered by an event that happened from almost exactly two decades ago...when Apollo 11 set down on the Sea of Tranquility to put man on the moon.

The image I have in mind is that extraordinary photo of the earth taken by Lunar Orbiter as it circled the moon...
...an image that dramatically revealed how nations and peoples are passengers together on spaceship Earth.

It was a portent of today, a time in which all aspects of American life are becoming increasingly "internationalized", in which our nation has become a member of a truly global community.

Whether through travel and communication, the arts and culture, the internationalization of commerce, capital, and labor, we are becoming increasingly dependent on other nations and other peoples.

The world and our place in it have changed.

The fact is that a truly domestic US economy has ceased to exist. ...It is no longer relevant to speak of the California economy or the American economy...or the competitiveness of California industry or American industry.

Our economy...our companies...are truly international, spanning the globe...and intensely interdependent on other nations and other peoples.

In slightly more than 5 years, US trade deficit has taken us from the world's largest creditor to its largest debtor nation.

We are no longer self-sufficient or self-sustaining. We are not immune to the shocks of the world society.

As the recent events in China and the Soviet Union make all too clear.

But beyond commerce and national security, there is an even more important reason to pay attention to the trends of internationalization...

The US has become the destination of about half the world's immigrants. Probably 10 million this decade alone...

With falling fertility rates, immigration will soon become the main determinant of the variability in our population.

As we have been throughout our history, we continue to be nourished and revitalized by wave after wave of immigrants, coming to our shores with unbounded energy, hope, and faith in the American dream.

Yet today, in a very real sense, America is evolving into the first true "world nation",

with not simply economic and political but also ethnic ties to all parts of the globe...

From this perspective, it becomes clear that understanding cultures other than our own has become necessary not only for personal enrichment and good citizenship, but indeed, necessary for our very survival as a nation.

3. The Age of Knowledge

Looking back over history, one can identify certain abrupt changes, discontinuities, in the nature, the very fabric of our civilization...

The Renaissance, the Age of Discovery, the Industrial Revolution

There are many who contend that our society is once again undergoing such a dramatic shift in fundamental perspective and structure.

Today we are evolving rapidly to a new post-industrial, knowledge-based society, just as a century ago our agrarian society evolved through the Industrial Revolution.

In a sense, we are entering a new age, an age of knowledge, in which the key strategic resource necessary for our prosperity, security, and social well-being has become knowledge--educated people and their ideas.

Themes of Change...

The America of the 20th Century that I have known... was a nation characterized by a rather homogeneous, domestic, industrialized society...

But that is an America of the past.

You will inherit a far different nation...

a highly pluralistic, knowledge-intensive, world nation that will be the America of the 21st century

These themes of your future,

the changing nature of the American population...

our increasing interdependence with other nations and other peoples...

and the shift to a knowledge-intensive, post-industrial society.

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, the brave new world I have been describing as America of the 21st Century is California of the 1990s!!!)

But, whether these are themes of the present or of the future, it is clear that they are also themes of change...

...themes that will both reflect and stimulate even more fundamental structural changes in the nature of our society and our civilization.

The Challenge of Change

Indeed, change itself might be regarded as the fourth theme characterizing your future that I can predict with some certainty.

It is clear that the future will never again be what it used to be!!!

New ideas and concepts are exploding forth at ever increasing rates...

Indeed, in many fields, the knowledge base is doubling every few years... the knowledge you have mastered as undergraduates is becoming obsolete even as you are graduating!

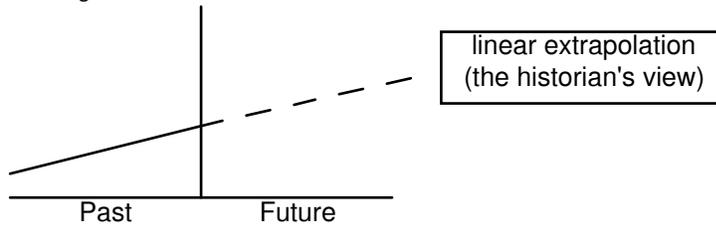
As the pace of the creation of new knowledge accelerates, it seems apparent that we are entering a period in which permanence and stability become less valued than flexibility and creativity...

in which the only certainty will be the presence of continual change...

and the capacity to relish, stimulate, and manage

change will be one of the most critical abilities of all.

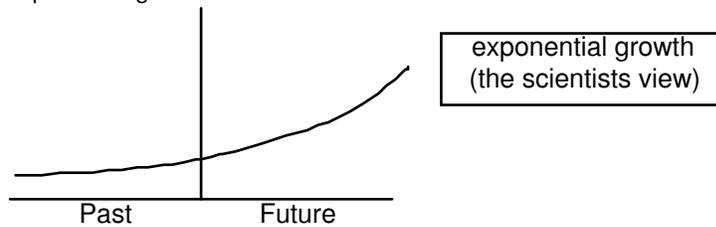
Models of Change Linear growth



Here we face a particular challenge, since most of us have been trained to think in terms of change from a historical perspective...
...as a linear, causal, and rational process.

We have been taught that by looking back to the past, we can simply linearly extrapolate to predict the future.

Exponential growth

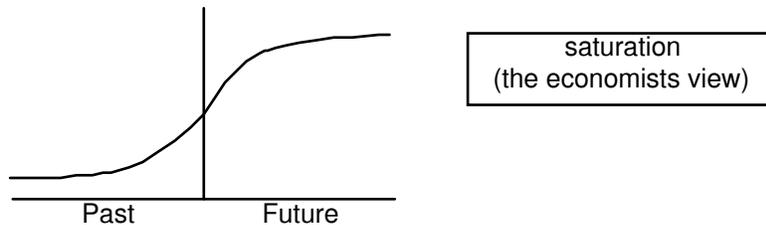


Of course, the scientist has a much different view of change...
...a view that is much more disturbing.

The scientist notes that most change in our natural world does not occur linearly with time, but rather exponentially, at every increasing rates.

From this view, the challenges that face us, challenges such as the growth in the world's population or the consumption of our natural resources or the pollution of our planet are growing ever more serious at exponential rates.

Saturation



Enter the economist, who says "not to worry"...

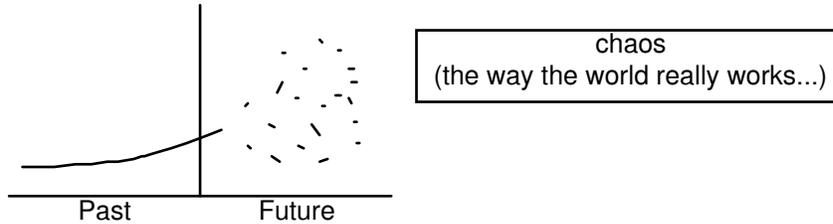
Sooner or later every exponential phenomenon eventually reaches a limit, a saturation, as a Parkinson's law of diminishing returns sets in.

Sooner or later, we run out of the necessary resources to sustain exponential growth, and the process of change slows to a halt.

The bacterial colony on the petri dish runs out of nutrient.

World population will run out of land surface... perhaps when, in the year 2500, there are 40 trillion people on Earth with only one square yard per person!

Chaos



Ah, but we have learned in recent years that the world really doesn't work like this either!

Instead, we have learned that even the simplest systems in nature tend to behave in a far more complex and unpredictable fashion...

They follow a change process known in today's popular lexicon as "chaos".

While the early stages of change are linear, exponential, and perhaps even saturating, at later stages, change frequently occurs in far more dramatic and unpredictable ways.

In this view of the world, systems become unstable and undergo dramatic and often chaotic change to create new levels of order and complexity.

Ex: Witness the complex evolution of clouds in the sky, or the complexity of flowing water, or the extraordinary complexity and diversity of living creatures.

There are several particular features of this modern view of change... that have major implications for the world in which we live:

- i) First, from this modern view, change is not simple and gradual and linear. Rather it is characterized by nonlinearities that lead to complex behavior frequently to dramatic rather than gradual change... to revolution rather than evolution.
- ii) But that's not all. Change is also not predictable and deterministic but rather random and stochastic in nature. The real world works in sharp contrast to the deterministic views of classical science of Newton or such modern determinists as Freud or Marx or Skinner.

That's the bad news. Now for the good news!

- iii) Chaotic change depends far more sensitively on small disturbances than we had ever thought possible. To mathematicians, chaotic systems are "ill-posed"... But the popular press has a more picturesque term... known as the "butterfly effect"...which arises from the suggestion that the even the disturbance in the air caused by a butterfly's wings could cause major changes in weather halfway around the globe because of the chaotic nature of weather patterns.

Translated into more human terms, dramatic change is frequently triggered by a few extraordinary people with extraordinary ideas--or by the young or newly initiated--people who haven't had the time yet to become trapped in the same ruts as the more experienced of us...

More specifically, change is frequently triggered by people exactly like you here before me today!

To put it more bluntly, if this modern view of change is right, each of you will have a truly remarkable chance to change the world!!! But you will also be faced with some unusual challenges.

General

Transition from linear to nonlinear world
...from a world of gradual change to
a world of revolutionary change

Deterministic to stochastic
"Ill-posed"--unstable dependence on initial

conditions or perturbations
("butterfly effect")
Unusual importance of young or newly-initiated
in triggering change.

Implications

For Our Institutions...

Responding to Intellectual Change

If our future is indeed one in which the capacity to stimulate and manage intellectual change becomes important...

And in which change is also viewed as a highly nonlinear, occasionally dramatic, and usually unpredictable process triggered by extraordinary people and their ideas...

Then, this suggests that academic institutions may well wish to think carefully about how they go about their business of teaching and research...

In this future, renewal and change will become essential for both the achievement and sustaining of excellence.

It seems critical that academic institutions not just respond grudgingly to change;
A university must relish and stimulate and manage a process of continual change and renewal if it is to achieve excellence and leadership.

Here we must seek programs that accomplish the following:

1. To act as a "change agent" to stimulate intellectual change...to encourage paradigm shifts...bifurcations of the knowledge curve... knowledge revolutions...
2. And to provide the kind of fault-tolerant environment in which people are encouraged to take chances, to pursue bold and daring scholarship...without fear of failure.
3. In a sense, we must encourage the fluctuations in our scholarship...in a sense, encouraging "chaos"...and through this, evolving new forms of knowledge...

The Changing Role of the University

Further, as our society becomes ever more knowledge-intensive, and hence ever more dependent upon educated people and their ideas...

It is clear that will become ever more dependent upon our research universities as primary sources of new knowledge and those capable of applying it.

Hence our institutions will face a period of unusual responsibility, challenge, and opportunity in the years ahead.

But I believe we will also face a period of major change.

But in a very real sense, the university as we know it today was invented to serve an America of the past...
...a nation characterized by a rather homogeneous, domestic, industrialized society.

"The organization characteristics of the university were invented after the Civil War: the academic department, the undergraduate college, the graduate school, the professional school training format, the semester credit hour. All of these developments coincided with the expansion of industrial America. (Indeed, the synchronous, serial approach to undergraduate education of universities is similar to early production lines, we find that these are the last institutions to retain the factory system. We are, in effect, one of the last artifacts of the industrial

age.

It is becoming increasingly apparent that it is time to develop a new model of higher education--- to re-invent the university, if you will--so that it is capable of responding to the needs of the highly pluralistic, knowledge-intensive, world nation that will be the America of the 21st Century.

Of course, there have been many in recent years who have suggested that the traditional paradigm of the public university must evolve to respond to the challenges that will confront our society in the years ahead...

But will a gradual evolution of our traditional paradigm be sufficient...or, will the challenges ahead force a more dramatic, indeed, revolutionary, shift in the paradigm of the contemporary research university...

For Students...

In many fields, the knowledge base is doubling every few years...indeed, in some fields the knowledge taught undergraduates becomes obsolete even before they graduate!

The typical college graduate of today will likely change careers several times during a lifetime...

Hence a college education will only serve as the stepping stone to a process of lifelong education... and the ability to adapt to...indeed, to manage change...will become the most valuable skill of all.

If indeed, your future will be one characterized by rapid, unpredictable, and dramatic change, then it becomes apparent that your capacity for continual renewal and personal development will become increasingly important.

Educational Change

The problem is that we really aren't prepare people for a world in which they'll change careers four or five times in a lifetime. In this type of world, the most successful people will be those who can deal with ideas, who can look at things from many perspectives.

Yet, in education, we continue to move to more and more specialization. Further, we are approaching the point of information overload, and it will take discerning individuals to figure out what is important, what they should use, and how they can understand it. Yet the majority of people coming out of universities today have weak communication skills and a limited view of the world.

Young people are too quickly encouraged into job-related specialization when they really should be challenging the ideas of the past, discovering the wisdom of others, exploring knowledge, and stretching the intellectual breadth of their minds.

In the 21st century, people will finally think in terms of lifelong education; college will be only one intermediate step in one's education.

Has your education helped you to value, welcome and control change?

I hope so.

While most of you have probably looked at your college education as preparation for a career...

as scientists or engineers...
or doctors, lawyers, or teachers...
or even investment bankers...

I suspect that was not the real purpose of your education at Caltech.

The eminent philosopher Alfred North Whitehead once stated that the purpose of a college education was "to learn the art of life".

Well, in a very real sense, that is what you should have been learning at Caltech.

You should have sought...and must continue to seek... a spirit of liberal learning...a spirit that will enrich your lives and through you, the lives of your families, friends, and colleagues.

But I suspect that it may be dawning on many of you this morning that perhaps you did not learn as much of "the art of life" at college as you might have wished... (I certainly didn't when I was an undergraduate!!!)

Not to worry...

Your college education was intended only as a the stepping stone to a process of lifelong education...

Indeed, most college graduates of your generation will find themselves changing careers several times during their lives.

Hence you will find yourselves continuing to learn--and relearn-- and relearn yet again through self study and returning to school on occasion, as you attempt to adapt to a world of change.

Just look at my example! Who could have predicted that a Caltech graduate would end up a president of a university that won both the Rose Bowl and the NCAA national basketball championship in the same year!!!

The importance of human capital...

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 similar changes in our state.

Indeed, I am personally convinced that our nation faces a very unusual period of challenge in the decade ahead...a watershed, in a sense, from which we can either emerge as a world leader...or as an also run...an economic backwater

My central theme is that education, broadly defined, will be the pivotal issue in determining which of these two alternative futures will be America's.

Indeed, I am absolutely convinced that the dominant issue of the 1990s will be the development of our human resources.

People must be the major focus...

People -- not equipment or buildings -- are the source of creativity.

They generate the knowledge that makes the technological innovation possible. They are the workforce that makes society run.

They are our researchers and teachers, our leaders, managers, and decisions makers in modern technological society.

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.

But here we face very serious challenges...

Clouds on the Horizon

Maintaining America's competitive edge requires attention

to our traditional strength -- people and research -- and a strong offensive strategy based on these resources.

Taxes, trade, and fiscal policies influence economic competitiveness. But in the long run, a strong base of science and engineering research and education is more important.

Central theme is that education, broadly defined, will play a pivotal role in the coming economic transition and its impact on individuals.

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.

Signs in Michigan

Look at the prosperous areas in Michigan

Grand Rapids
Oakland County
Grand Rapids

and contrast these with impoverished areas

Detroit
Battle Creek
Benton Harbor
Saginaw
Muskegon

Real difference stands out: education!!!

"Most economically successful areas are those with educated and highly skilled labor force.

In Ann Arbor, 90% of people 25 or older have completed at least 12 years of school:

Saginaw: 57%
Flint: 60%
Jackson: 63%
Lansing: 72%
Kalamazoo: 73%
Grand Rapids: 67%

WARNING SIGN 1: America is slipping

No question that we have lost lead in many areas
Industrial productivity and heavy manufacturing
Steel, durable goods, ...

Moreover, key activities such as product design, engineering, and software development increasingly are likely to be done overseas.

Whether automobiles or refrigerators, computers or microchips, nuclear power or energy transmission systems, the likelihood is increasing that the systems are assembled from components designed, engineered, manufactured, and shipped from all parts of the world.

US trade deficit is only a symptom of America's lagging competitiveness. It means that the US economy has been living beyond its means.

The most serious long term problem is low productivity growth, however. With productivity growing at less than 1% per year, the American standard of living is falling relative to those in most industrialized nations. Our wages are already below those in Europe and Japan.

Over the long haul productivity growth is the main determinant of trends in living standards, and no amount of fiscal ledgerdom can obscure a basic weakness.

The necessity for lower wage growth in US is result of lagging US productivity--that is, a lower rate of growth in physical

output per worker and a declining advantage in technology and quality.

To do this, all the major inputs into our economy--quality of workforce, amount of capital investment, level of technology, and skills of managers--must be as good as the equivalent inputs going into the economics of our major competitors.

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.

WARNING SIGN 2: We are seriously underinvesting in R&D and Education

For over two decades, US investment in civilian R&D has dropped while that of our competitor nations has risen rapidly. US investment in civilian R&D as a percent of GNP is now less than that of any other developed nation (and only 60% that of Japan and West Germany...)

Almost all growth has gone into military research (70% of federal R&D budget)

Support of basic research has dropped significantly (as has support of research in C&S)

We need a major commitment by the federal government and industry to research on understanding how people learn and to the development of new educational technologies.

"If the fraction of gross expenditures invested in research were the same for education as for the average privately owned business in the United States, about \$9 billion a year would be spend on educational research--60 to 90 times more than the present allocation"

Note: While midwestern states such as Michigan and Ohio have undertaken many important new initiatives, we still lag considerably behind areas such as California and New England in our investment in knowledge-based resources such as education. We've come a long ways in the past few years, but we still have one hell of a long ways to go.

WARNING SIGN 3: The "Pipeline Problem"

But there is an even more ominous cloud on the horizon and it involves the knowledge and skills of our people

Introduction

Today, an unprecedented explosion of knowledge marks the onset of a new era. Since people are the source of new knowledge, we will rely increasingly on a well-educated and trained work forced to maintain our competitive position in the world and our standard of living at home.

Yet here we are in real difficulty, because we are not educating enough new people to keep our economy competitive.

Further, there are serious signs that the education of the present American workforce is simply inadequate to meet the demands of the next century.

Key input to a competitive economy is quality of the workforce. Our principal competitors are simply producing workers better capable of absorbing modern production skills.

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

By any measure, K-12 is in serious trouble.

We are "A Nation At Risk"...

Our education system simply has not responded to the challenges of the age of knowledge...

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

Yet, in the face of this knowledge explosion, it is clear that both the knowledge and skills of the graduates of our primary and secondary education systems continue to deteriorate.

Note: it is bad enough that...

10% of Americans are illiterate

25% now fail to complete high school

Our students bring up the rear in most international comparisons

Compared to students in 15 other nations, US high school seniors scored among the bottom fourth on calculus and algebra achievement tests.

International Association for Evaluation of Educational Achievement (IEA)
Grades 4, 8, and 12

US was 8th of 17 for 4th graders

US was 14th of 17 for 8th graders

US was 11-13 of 17 for 12th graders

Bottom 25% of US students were scoring at chance level, indicating that they were scientifically illiterate

(Top scores were Japan, Korea, Hungary

"For a technologically advanced country, it would appear that a reexamination of how science is presented and studied is required...in the United States."

Science and mathematics education

But the coins of the realm in the age of knowledge will be science, mathematics, and technology...

Knowledge is cumulative, especially in math, science, and engineering. Without basic skills, a student cannot advance his studies.

But most American high school students are not developing these skills. Only 7% of the 17 year-olds tested are prepared for college-level science courses.

Nearly 30% of nation's high schools offer no courses in physics, 17% offer none in chemistry, and 70% offer none in earth or space science.

Scientific Literacy of K-12 Teaching Force

Only 30% have had college chemistry

Only 20% have had college physics

Less than 50% have had calculus or computers

More than half of all our high school graduates have not had even one year of science.

Face it, gang:

The tragedy is not simply our poor showing relative to other nations.

Science, mathematics, and computer literacy will increasingly become a requirement for almost all employment.

We are condemning an entire generation to a lifelong estrangement from the very technology that will

inevitably govern their lives.

A particular challenge to Michigan:

Michigan 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...

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!

The education of the Michigan workforce is inadequate to the demands of the next century.

Yet, we continue to be paralyzed in our efforts to come to grips with school finance reform or major structural changes necessary to achieve quality in public education.

In the past few decades we have neglected education's collective economic function. Whatever its individual payoff, it determines the human quality of the team on which every American plays.

If, in the final analysis progress depends on having the generations who follow us be smarter and better educated than we are, it is evident that we are sliding backwards rapidly!

College Education

Yet the US faces a S&E manpower crisis of unprecedented proportions

0. Indeed, today the United States awards the smallest proportion of university degrees in science and engineering of any industrialized nation!

1. Proportion of graduating seniors who major in science and engineering is smaller today than it was in 1970s (5%). Particularly severe drops in physical sciences and mathematics. (Fallen by 40% over past decade)

2. Per capita production of US engineers lowest among industrialized nations:

US: 72,000 (3%) (7 in 1,000 graduates)

Japan: 85,000 (21%) (40 in 1,000 graduates)

USSR: 300,000 (35%)

Japan has doubled its technical workforce in past decade...

7 of 1,000 American students receive engineering degrees

40 of 1,000 Japanese -- indeed, Japan with less than half the population is producing far more scientists and engineers!

President of Sony:

"In US you produce 4 lawyers for every engineer.

In Japan, we graduate 4 engineers for every lawyer!"

As Americans take degrees in law and business, foreigners are replacing them in graduate science and engineering programs.

3. More than 60% of engineering PhDs are now foreign

Indeed, foreign students account for nearly 85% of growth.

It is bad policy to be dependent on an unpredictable resource and not to be able to meet more of our needs with American talent.

But things are going to get MUCH rougher: NSF Study

Dominant factor controlling BS degree supply is the size of

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

1. Demand for S&E likely to go up
 - Population is growing
 - S&E share of workforce is growing
 - Industry is becoming more scientific
 - Most experts predict growth in S&E jobs
2. Supply will probably fall off dramatically simply due to demographics...
 - Number of 22 year olds is a major driving force in determining BS S&E degrees
 - 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.
3. Trends in Intended Majors:
 - Long term data suggest that percent of college age population receiving BS degrees is unlikely to be over 5%
 - This is compounded by the declining preference of college students for NS&E majors
 - Annual Freshman Survey: K. C. Green (UCLA)
 - Overall interest in science majors has dropped by half between 1966 and 1988, from 11.5% to 5.8%
 - Interest in biological sciences is sustained only by large number of pre-med students who major in biology
 - Largest decline has occurred in mathematics:
 - Dramatic decline in freshman interest in math majors.
 - From 1966 to 1988, dropped from 4.6% to 0.6%, almost a factor of 10!!!
 - Trends for men and women are similar
 - Note the implications, not only for technical careers, but also for pool of future graduate students and secondary school teachers!
 - Decline in physical sciences from 3.8% to 1.6%!!!
 - While women enrollment increased during 70s and 80s, it now appears to be dropping:
 - Interest in engineering is also declining
 - After recording big increases during late 70s and early 80s (increasing to 12%), now has dropped by almost one-third since 1982 (now down to 8.6%).
 - Again, decline is occurring among both men and women.
 - Puzzling, since no precipitating event in labor market demand helps to explain this drop.
 - The shift in student interests must be driven by other factors.
 - Clearly these declines point to potential problems in future supply of newly trained engineers.
 - Freshman plans to pursue computing careers is down more than two-thirds since 1982, from 8.8% down to 2.2%.
 - Where are they going?
 - Business is not the most popular major and career among college freshman, having doubled since the late 1960s.
 - One-fourth (24.8%) of the 1988 class plan to major in business, up from 16.4% in 1966.
 - The proportion of freshman women has increased by

a factor of 6, from 3.3% to 21.2%.

More women plan to pursue accounting careers (6.4%) than men (5.6%). NOTE: Total interested in math is only 0.6%, almost ten times less!!! (My daughter says she can believe this, since accountants can make money and mathematicians cannot.)

After a 14 year decline, freshman interest in teaching has almost double over past 6 years, from 4.7% in 1982 to 8.8% in 1988.

Even with these recent increases, far fewer freshmen plan to pursue teaching careers than 20 years ago (23.3% in 1968).

Furthermore, recent gains have not off-set the dramatic decline in freshman interest in secondary school teaching.

Far fewer freshmen entering teaching plan to study liberal arts fields than two decades ago.

Virtually all aspiring teachers are education majors!!!

All S/E fields have experienced a decline in the proportion of aspiring freshman major four-year institutions:

Biology: -21%

Engineering: -9%

Physical Sciences: -39%

Pre-Med: -20%

In contrast, business is up 22% since 1978.

Humanities majors have increased 10% over past decade...

...social science is up 20%

Survey data provide some evidence that minority participation has increased in past several years.

Corporate, governmental, and institutional investment in fostering minority interest in science is beginning to show a return.

Gains in front of pipeline do not automatically translate into more minority graduates, however.

Some good news, however:

Over past decade, fraction of freshman planning to earn graduate degrees rose by 20%, from 49% to 58.7%.

Proportion of women planning to earn PhDs increased from 6.5% to 11.7%.

NOTE: These data suggest that students no longer view the BS as adequate preparation for the demands of the labor market in the 21st Century.

More bad news:

Increased in college teaching has dropped by more than 3/4 over past two decades, from 1.8% to 0.4%.

Preference for research careers has fallen from 3.5% to 1.6%.

Why get a college education:

Get a better job: 70% to 85%

Get a general education: 70% to 60%

Earn more money: 50% to 75%

Note shift in life goals:

"Developing a meaningful philosophy of life": 85% to 35%

"Being very well off financially": 35% to 80%

Other tidbits:

Larger proportion of S/E majors spent significant time on homework and studying than peers in other majors.

S/E freshmen rake higher on academic skills.

Some observations:

The 1960s were a period of social upheaval;

the 1980s are an era marked by economic upheaval

Today's students:

Have less confidence in their academic skills....
Came of age during a period of continuing economic upheaval...
inflation, recession, restructuring
See the middle-class "goodies" as being difficult to attain,
now requiring real wealth.

But this situation may become even worse:

Over period from 1966 to 1987, proportion of students who intended to major in physical sciences has dropped from 3% to 1.3%; in mathematics, the decline was from 4% to less than 1%.

Recent trends in engineering also show softening.

Applications to most engineering schools are down by 10-20% this year. (USC 30%)

Interest in computer science is always waning. Drop from 4% in 1983 to below 2% in 1987.

Note: dramatic increase in proportion of freshmen interested in business majors--now up to 25% and rising rapidly

Furthermore, the dropout rate is extraordinary...

From 8th grade through PhD, the half-life of students in the mathematics curriculum is one year!

That is, if we begin with 32 million students in junior high school, we lose 50% each year until only a few hundred attain the PhD.

Number of freshman planning to major in computer science has dropped by two-thirds since 1982. Interest in engineering, which increased during late 1970s, has dropped by a quarter in 1980s.

4. Later effects

Further, there is an alarming loss of students in the early college years due to difficult courses, bad teaching, and declining interest. Only 40% of NS&E freshman survive to BS.

And of those getting BS, fewer than half are in NS&E jobs within 5 years because of reward structure biased toward management

5. 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 to mention the least likelihood to study science and math.

Furthermore, virtually none of the Black college freshmen who score highest on the SAT intend to major in mathematics or the physical sciences

Among engineering students, 70% complete school... but completion rate among Blacks is 30%; Hispanics 40%.

Indeed, while Blacks and Hispanics account for 20% of total population, they account for less than 2% of scientists and engineers!

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.

At sophomore level, 20% of all students are interested in science, but only 10% of minorities.

1988 Engineering enrollments:

Women: 15% BS, 12% MS, 7% PhD, 2% faculty

Blacks: 3% BS, 0.3% PhD (14 total, nationwide)

Last year only 10 Blacks received PhDs in math and only 12 received PhDs in Engineering. Hispanics were not much better: 9 and 24, respectively. Of 4,614 doctoral degrees awarded in physical sciences, 41 were awarded to Blacks.

This number is declining, down from 60 a decade ago.

Among women, despite significant increase in the number enrolled in graduate programs, they earn fewer than 15% of all technical degrees.

We must reverse this now, because women and minorities are the key human resource of the future and they need extra encouragement to pursue technical careers.

NOTE: We must make special efforts to expand participation by these groups...not just because that is good social policy, but because we cannot afford to waste their talents!

Demographics

We are halfway down the curve in the dip of 18 year olds.

The curve will reverse in early 1990s.

What most don't realize is that the social and racial mix of these cohorts will be enormously different from what it was in the 1960s and 1970s.

The 21st Century will be the first post-European century in American history.

An absolute majority of young people born in US in the 21st Century will be born of parents of other than European background...

Asian, African, Hispanic

And this will represent a major change in the character of our society.

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 adapt the education system in American to a changing population

Graduate Education

Over the next two decades, PhD replacement needs will double in all sectors (academic, industry, government)

For example, 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.

Already symptoms: 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

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.

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.

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.

Time to Degree

Average length of time from BS to PhD (past 20 years)

All Fields: 7.9 to 10.4 y

NS&E: 6.7 to 7.9 y

Market forces will probably lower NS&E

However, a successful effort to accelerate PhD achievement could increase degree production up to 25% for several years

Key factors to shorten:

Minimize field and institution switching

Long-term financial support commitments

WARNING SIGN 4: Scientific Illiteracy

Importance of Science

US remains leading nation in science. Americans still dominate world scientific literature. Large numbers of foreign students still flock to our universities.

Science pays: it is essential for attacking the major diseases of mankind, to competing for global markets in advanced technologies, to better understanding the ills of our society such as environmental change.

An exercise: Think over a typical day, from the moment when your digital alarm clock wakes you up until your VCR shuts itself off as you doze off in the evening... and try to imagine what your life would be like without science and technology.

The social rate of return on academic research--how much society receives in benefits from an investment--was recently estimated at 28% (Edwin Mansfield-1988)

Technological innovation accounts for 44% to 77% of increased productivity

We really haven't appreciated impact of technology.

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
- v) global warming...greenhouse effect...biodiversity

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!

Claim: 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

Public attacks on science are now routine...

Environmental impact
(Yet, what pray tell, will save the environment...)

Fraud and scientific misconduct...
Congressional hearings are taking on the spectre of witchhunts (almost a McCarthist tone)

Attacks on the research university: Profscam
Few seem to realize that during the decades following WWII the US built the strongest research base in the world in science and technology by asking its universities to play the key role in basic research.

Yet, perhaps in part because we have been so successful, we are now subject not simply to attack but suggestions that we should cease research and focus exclusively on teaching.

Q: If we do so, then whom, pray tell, will sustain the scientific and technological strength of our nation?

WARNING SIGN 5: Michigan's Work Force is Becoming Obsolete

The education of the Michigan workforce is inadequate to the demands of the next century.

Each year, 700,000 drop out of HS and 700,000 graduate without functional literacy;
1,000,000 immigrants must be added to this.
Hence each year we have 2.5 million persons entering our complex economy annually with limited language and work skills

Yet our adult functional illiteracy rate is 13%--our high school graduate rate is down to 72%--and our high school graduates perform poorly relative to students in the rest of the world.

Michigan is undergoing dramatic change in industry...
Away from low-skill, blue-collar workers
The factory of the future will have NO low skill workers
Statistical quality control and just-in-time inventory systems require production workers with mathematical abilities that are far beyond the present level.
Unskilled labor will lose relevance in a world dominated by microelectronics, computers, and automation.
An example: Expert systems
The "expert system" craftsman...

About 45% of the job growth between 1980 and 1986 was in professional and managerial occupations, and almost 50% of the new jobs created between 1983 and 1986 went to people with at least 3 years of college.

Of the net increase of 25 M jobs to be created by 2000, 40% will be professional or technical positions; 58% will be marketing and sales, administrative or supervisory.

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.

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.

In the past few decades we have neglected education's collective economic function. Whatever its individual payoff, it determines the human quality of the team on which every American plays.

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?

The economic challenge, in simplest terms, requires upgrading the skills of 25 million American workers by 40% by the end of the century. A strong back and willing hands will no longer suffice.

Some observations:

Claim: 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

In the past few decades we have neglected education's collective economic function. Whatever its individual payoff, it determines the human quality of the team on which every American plays.

If, in the final analysis progress depends on having the generations who follow us be smarter and better educated than we are, it is evident that we are sliding backwards rapidly!

WARNING SIGN 6: The Dangers of Underinvestment

Perhaps the most ominous dark cloud on the horizon of all is the increasing evidence that we as a people we have not yet recognized either the nature or the magnitude of the investments we must make to achieve prosperity in an age of knowledge.

While we all give the "age of knowledge" lip service, the evidence suggests that in reality, we long for a return to the agricultural and manufacturing economies that once made us reach...

1. For over two decades, US investment in civilian R&D has dropped while that of our competitor nations has risen rapidly. US investment in civilian R&D as a percent of GNP is now less than that of any other developed nation (and only 60% that of Japan and West Germany...)
(US: 1.8%, Japan, 2.7%, Germany, 2.5%)
As a percent of GNP, US R&D spending has been flat at 2.8% for a long time. Meanwhile, Japan's spending has increased two fold, while West Germany's has increased three-fold over the last 25 years.
Almost all growth has gone into military research (70% of federal R&D budget)
2. Over the past several years, numerous studies have suggested that Michigan is seriously underinvesting in its "knowledge infrastructure"...by as much as 30% to 40% relative to other states.
Interestingly enough, studies performed by both the Democratic administration and the Republican Senate agree with this prognosis...and yet nothing has happened...and we slip even further behind!
3. Particular concern has been focused on the "education pipeline" in Michigan...from pre-school through K-12 education through higher education to lifelong education.
Two-thirds of new jobs are in professional, managerial, and sales area...just 5% go to unskilled workers...as

Michigan economy shifts from manufacturing to knowledge-based and service jobs.

3.5. Preschool

The plight of the poor in this state continues to worsen, as inadequate state tax revenues (due to voter resistance) and an out-of-control corrections program threaten those programs designed to protect the young.

"Studies show that high-quality preschool programs for at-risk children resulted in higher literacy, employment and educational attainment, and lower levels of school dropouts, public assistance dependence, and arrests."

4. The challenges faced by K-12 education were well-summarized in a recent editorial in a Detroit paper:

"If Michigan is to prepare tomorrow's workers for tomorrow's jobs, major structural changes are needed in public education, both in classroom quality and in the adequacy and fairness with which the system is financed."

"What is required is a strengthened commitment in Lansing to school finance reform and improving the quality of basic and higher education, and a greater political willingness to stand up to special interests who would thwart those long-term goals to pursue short-term objectives. The opportunity to eliminate chronic unemployment in Michigan may be never more within our grasp than between now and the end of the century. The alternative is a growing mismatch of job opportunities and job training that threatens not only the state's recent prosperity, but its very solvency."

(Free Press editorial, 1/5/89)

Earlier this year we learned that Michigan ranks 48th in the nation in the rate of retention to H.S. graduation.

I cannot believe that we as a people can accept that kind of performance.

Yet, we continue to be paralyzed in our efforts to come to grips with school finance reform or major structural changes necessary to achieve quality in public education.

5. The situation is somewhat different yet no less acute for higher education in our state.

While the quality of Michigan higher education today is very high, the long term prognosis remains guarded...

The Investment in Higher Education

Michigan Rankings:

Total state appropriation per student (CC + U): 46th

Total state appropriation per student (4 Y): 32nd

State appropriation per capita: 24th

Increase over past 10 years: 45th

Increase over past 2 years: 42nd

Our state has dropped from 6th in the nation in its support of higher education to 35th over the past two decades... into the bottom third!!!

Indeed, we have dropped to 32nd in tax revenue for higher ed--7.8% compared to 11.4% for California!

We are being outspent by 30 - 40% in state support per student... Not simply by prosperous states like California...but by neighbors such as Indiana and Ohio!

Over the past 10 years, high tech states such as California, New Jersey, Massachusetts, and New York have seen real dollar increases in higher education appropriations of roughly

20 to 30%. In sharp contrast, over this period Michigan has declined by 4.5%...

Certainly these states are prosperous...but they are also investing substantially more of their resources in higher education...in preparation for a knowledge-based future...than are we. Indeed, one measure of the importance of higher education in the state budget is the ratio of tax dollars per enrollment ratio... a measure by which Michigan ranks 47th in the nation! It seems clear that higher education faces a serious challenge in Michigan. Our present level of public support is clearly inadequate to maintain a system that is competitive on a national basis.

We are attempting to compete in this knowledge-intensive future with an underfunded public system of higher education... and no private capacity (such as a Stanford, MIT, or Caltech). Only the autonomy granted to our public universities have allowed them to "overachieve" their public support through higher tuition and other sources of financial support.

This has given public higher education in Michigan some capacity to face the devastating impact of the past decade...but it is rapidly losing this capacity...and there seems little doubt that the quality of our system will probably be gone in the next 10 to 20 years if the present trends of inadequate state support coupled with tuition constraints continue.

Whether measured in terms of state appropriation per student or fraction of our tax dollars directed toward higher ed, it is clear that in comparison with other states, our present level of public support is simply inadequate to maintain over the long run a system of higher education that is competitive on a national basis.

Despite herculean efforts by the Governor and the State Legislature in recent years to restore adequate support for higher education in Michigan after the devastating cuts of the early 1980s, we continue to fall further behind the national average in state support.

And what will then happen to Michigan. We will become a "have not" state, competing in low wage industries in dying industries. We will have rejected the age of knowledge!

Eroding state support...

Over the past two decades, the State of Michigan has dropped from the position of a national leader (ranked 6th in 1965) in its public support of higher education to among the lowest in the nation (ranked 37th in 1989)

- i) Appro per student 43rd
- ii) Appro as % of tax 37th
- iii) Two year % inc 42nd
- iv) Ten year % inc 45th

As a highly industrialized state undergoing a dramatic change to a knowledge-intensive economy, Michigan is critically dependent upon quality higher education. Yet Michigan has now fallen into the bottom ranks of industrialized states in its support of these critical resources.

Tuition wars...

This situation has been compounded by political efforts to force tuition levels to artificially low levels, even as our universities have become ever more dependent on tuition revenues in the face of eroding state appropriations.

This latter effort is ironic, since in reality, tuition levels in Michigan's public institutions (\$2,000 to \$3,000 per year) are quite comparable to those at most other public institutions and quite low compared to private institutions (\$10,000 to \$15,000 per year). Further, these tuitions cover only a small fraction (typically 20% to 30%) of the cost of an education at a public institution.

Further, Michigan public universities have significantly increased their financial aid programs to protect access. Indeed, at the U of M, we have a policy that all Michigan resident undergraduates are provided with adequate financial aid to meet their needs until graduation.

Since federal funding for financial aid has declined 50% in recent years, tuition revenue has become a primary source of funds for financial aid programs. Hence, political efforts to drive tuitions down also drive down financial aid pools as well. The result is that those least able to afford a quality education are in danger of becoming deprived of this opportunity.

6. Threats to autonomy...

It seems clear that higher education faces a serious challenge in Michigan. Our present level of public support is clearly inadequate to maintain a system that is competitive on a national basis.

We are attempting to compete in this knowledge-intensive future with an underfunded public system of higher education... and no private capacity (such as a Stanford, MIT, or Caltech).

Only the autonomy granted to our public universities have allowed them to "overachieve" their public support through higher tuition and other sources of financial support.

This has given public higher education in Michigan some capacity to face the devastating impact of the past decade...but it is rapidly losing this capacity...and there seems little doubt that the quality of our system will probably be gone in the next 10 to 20 years if the present trends of inadequate state support coupled with tuition constraints continue.

But political efforts to set tuition levels in Lansing rather than on our campuses raise another even more serious threat.

The traditional autonomy of governance of Michigan's public universities has been the critical factor in sustaining program quality while continuing to serve the state in spite of sharp erosion in public support.

This autonomy allowed Michigan's universities to take strong internal actions, reallocating resources, redefining priorities, and increasing tuition levels to partly compensate for reduce public support.

In recent years, however, even as state appropriations have been declining, the political pressure to restrict tuition levels to artificially low levels has increasingly threatened this autonomy.

While such political efforts have been portrayed as an effort to protect access (affordability) to public education in Michigan, they have had just the opposite effect by slashing financial aid programs.

It is clear that these forces from Lansing are being

driven by not by concerns about access, but rather by fears that the Michigan Education Trust program, a prepaid college tuition program developed and financial on the assumption of low tuition levels, will become financial insolvent.

7. Prisons

In fact, the only area where we now lead the nation is in our prison system...

We are now investing more in prisons than in higher ed...that is, we spend more money putting people into jail than we do in keeping them out of jail!

Over the past 5 years, the Corrections budget has increased by 141%, compared to a 25% increase for higher education.

Michigan has now embarked on yet another program to build 26 new prisons by 1991. Portion of state GF budget allocated to corrections has risen from 2.8% to 6.9% over past decade (now approaching \$800 M per year). At the same time, human services fell from 53.2% to 49.6% while K-12 education fell from 36.6% to 20.0%.

Corrections will be \$633 in FY88-89 (compared to \$1,137 M for higher ed and \$2,144 M for social services), but projected to grow to \$2 B in 1990s.

Each of 25,000 inmates require \$22,000 per year...

Furthermore, we have spent over \$1.3 B to build new prisons...every penny of new construction funds... and now appear prepared to launch a second wave of prison construction, even though demographics suggest that many of these prisons will remain empty.

Further, while state revenues are projected to increase 5% in the year ahead, the exploding corrections budget (\$140 M additional just to operate the new prisons) will eat up this growth, thereby crippling other state priorities such as education and social services.

Recent study by Joan Abbey and Ira Schwarz:

"Spending on prison construction and operation will have serious consequences on efforts to reduce infant mortality, treat drug dependence, monitor child care facilities, and care for the mentally ill...not to mention education."

Michigan's corrections policies are threatening the state's future by inadequately financing the educational, medical, social, and other efforts needed to raise the living conditions of poor people in Michigan.

While prison construction has been politically popular, these investments will lock Michigan into a vicious cycle wherein limited state resources will be consumed for the operations and maintenance costs of these buildings."

"Strategic investments in programs for children, including schools, child care, and health care, will pay valuable dividends in the future."

"Studies show that high-quality preschool programs for at-risk children resulted in higher literacy, employment and educational attainment, and lower levels of school dropouts, public assistance dependence, and arrests."

8. Gimmicks

One of the curses of the American people has been their gullibility...in our rush to find quick fixes, simple solutions to complex problems, we are frequently sold placebos which actually aggravate the problem.

Example 1: The Michigan Lottery

Instead, we continue to rely on gimmicks...such as the State Lottery, which in effect robs from those most in need of state assistance...

Furthermore, since these Lottery funds flow into the General Fund, and since state support of education has clearly not tracked the increase in lottery revenues, it is clear that lottery revenues are, in effect, going to build and operate more prisons (the only part of the state budget which has growth at this pace).

Some irony here, since the Lottery, in effect, is transferring funds from the deprived components of our population..

Example 2: The Michigan Education Trust

Good Intent...but in serious need of modification

i) Seriously underfunded...

- Impact of tax rulings
- Requires long term real return of over 15%!
- First round of contracts will cause \$100 million shortfall
...who will pay? The taxpayer or the institutions?
- Indiana model: Redeemable SCH

ii) Highly regressive social income transfer program:

- Takes both tax dollars and financial aid dollars from those who can least afford higher ed and transfers them, in effect, to high income families (Note Zip Code information)

iii) Convey false perception of real costs of education

- Not tuition (\$12,000 per year less than car...)
- Rather room, board, books, supplies
- E.G. At UM, budget is \$8,500
Tuition is \$3,000 (or 35%)

What has happened to our priorities?

What is wrong here???

Who is to blame???

Our schools and colleges???

Certainly they must take stronger actions to improve quality...and strive harder to operate in a more cost-effective manner...

But their present situation reflects as much as anything else our own personal priorities...

...as parents

...as volunteers...

...as citizens and voters...

What about our elected public officials???

It is certainly not their fault!!

It is clear that our elected leaders, whether in Washington or Lansing or our local communities...

Would like nothing better than to make education their highest priority.

To become

...the Education Governor

...or the Education Party

...or the Education President

They understand clearly the importance of investing in our human resources, and they are searching valiantly for creative ways to improve the quality of our schools and provide adequate and equitable financial support.

But they also face formidable constraints, since in the end they must be responsive to the wishes of the electorate...and face it, gang...the electorate today

says:

i) no more taxes...

ii) no more crime...

iii) no more cuts in social services or national defense...

and our public officials have no choice but to respond.

No, the real finger of blame for the crisis we face in education should be pointed, as Michael Jackson would say, at "The Man in the Mirror"...

...at you and at me...

We are the ones who fail to demand the highest quality in our educational institutions in Michigan...

We are the ones who steadfastly resist a tax base adequate to support both our needs and desires...and provide an adequate level of support for quality education in this state.

We are the ones who block any effective efforts to achieve equitable financing of education in Michigan.

We are the ones who generally are too busy to help our own children in their studies or participate in their activities.

And we are the ones who insist on building more and more prisons, even when we know that this investment comes out of the hide of education and social services-- which are, of course, the only true long term solutions to crime!

We have become consumers of education, not investors in the future.

What's Going On Here?

Something has changed in America...

You know, I was brought up in a long tradition in which one's first responsibility was to one's children

My parents scrimped and saved for my college education...

...and my wife and I have done the same for our daughters (who, since they attended eastern private universities, have taken essentially all of the savings we have been able to muster over the past 20 years)

Saving for a college education came first...

...before a house, before a fancy car, before an exotic vacation

But today's generation is different...

...the "me generation" of the 1960s has grown up into comfortable Yuppies...

...it is bad enough that they have not saved for their children's college education

...and not supported adequate tax programs to support higher education

...but they have actively encouraged government at both the state and federal level to intervene in an effort to hold tuition levels to unrealistic low levels...

(either not realizing or perhaps not caring that they were undermining the quality of the education their children would receive at these bargain-basement prices--and depriving many others from less fortunate backgrounds of the opportunity for a college education because of the erosion of financial aid programs in the face of inadequate tuition revenue).j

Our approach to education...like to so much else in life

these days...can be summarized by that T-shirt slogan:

"Eat dessert first, life is uncertain"

We see ourselves caring about the future, but we are not preparing for it.

"American's look ahead 10 minutes while

Japanese look ahead 10 years..." (Morita, Sony)

“The last ten years have witnessed the substantial abdication by our governments of their responsibility in critical society areas, including education”. When matched against the Japanese commentary, it is virtually cause and effect.

Without the opportunity for all Americans of limited or virtually no real income to obtain the benefits of an outstanding education, the class gap will continue to grow. And we will develop an educational elite in the 19th Century European tradition, to be sure, with all of its unfortunate results.

Japanese trade negotiations:

US should upgrade schools, invest in scientific research, close the Federal deficit, and take other drastic steps to improve American industrial competitiveness.

“If the US wants Japan to change its system, the US must be more ready to correct its own shortcoming. We can't solve our trade imbalances looking at Japan alone.”

American high schools and colleges must upgrade the teaching of mathematics, science, and foreign languages.

Yet the writing on the wall could not be clearer:

As we prepare to enter the Age of Knowledge, our ability to sustain the strength of our state and our nation...to achieve the quality of life for our citizens...will be determined, more than any other factor, by how we develop, nurture, and educate that most precious of resources, our people.

Intense international competition, turbulent markets, rapid technological change present new challenges to our future.

To stand still...to fail to make the investments in our research universities so necessary for tomorrow...is to lose the race for future prosperity and well-being of our citizens.

We really have no choice but to forge ahead, to pick up the pace, and to increase these investments in order to secure once again the position of leadership to which our state has long been accustomed.

Hence, let me conclude my brief remarks by tossing at you--and at me--several challenges:

Possible Solutions:

General Observations

Maintaining America's competitive edge requires attention to our traditional strength -- people and research -- and a strong offensive strategy based on these resources.

Taxes, trade, and fiscal policies influence economic competitiveness. But in the long run, a strong base of science and engineering research and education is more important.

Central theme is that education, broadly defined, will play a pivotal role in the coming economic transition and its impact on individuals.

As we enter the Age of Knowledge, our ability to sustain the strength of our nation...to achieve the quality of life for our citizens...will be determined by, more than any other factor, how we develop, nurture, and educate that most precious of resources, our people.

In the long run it will be our investments in the most important resources of all, in people and ideas, that will determine the future prosperity and well-being of our state.

Pipeline Problem

Solutions:

1) Investment

Long term trends tell us two things about our human resource base:

One is that we have not been investing in our human capital

sufficiently to prepare ourselves for the future.

Knowledge, in the modern competitive world, is the new critical commodity just as natural resources and access to low skilled labor were until just a few decades ago.

The second thing that long term trends tells us is that important demographic changes are taking place in this country and that these changes sharply increase the importance of attracting women and minorities into knowledge-based careers.

We must avoid a dangerous myopia on two fronts:

We must avoid replicating the British experience where a failure by industry to support and take advantage of a first class research/education system has contributed to economic decline

We must guard against the illusion that basic research and advanced education is a luxury on which we can economize.

2) Cooperation

Although Americans tend to equate competition with all that is good--progress, efficiency, high quality goods and services at affordable prices--this competitive attitude has serious drawbacks when carried to an extreme.

Zealous competition can lead to a myopic defense of prerogatives and turf at the expense of indentifying and achieving common goals.

3) Education

K-12 Level

Better prepared teachers

A better reward system for teaching--salaries and other recognition

Better curriculum and delivery system

Instructional equipment and access to well-equipped laboratories

Lengthen school year from 180 days to 240 days

(note this would also achieve higher teacher salaries)

(It also eases child care needs)

All world-class industrial nations have some post-secondary skill training system for noncollege bound.

Only US has nothing.

State governments now subsidize every student that gets a college degree. How about a federal subsidy for noncollege bound?

Also

More demanding requirements

Higher standards

Better communication between science and mathematics teachers and University faculty

Intensive teacher involvement

Parental support and commitment

A conviction in our communications that education is the key to personal success.

Needs

More programs at grade school level to excite children about science

Better programs at high school level to raise students to standards of our international competitors

Innovative programs to encourage, mentor, and support women and minority students in science

Relevant, well-equipped science programs at UG level to give graduates the skills they will need in workplace

Well-financed programs at graduate level to attract and support American students in study and research.

Challenge

Our education system is complex and decentralized and the primary responsibility is located at the state and local level.

There is no simple solution...we must push on all fronts.

We must weave a strategy of many strands--a strategy that places existing programs in a larger context that established a clear

sense of direction, develops the leadership for the task, and insures continuity of effort.

Above all, we must be consistent and persevere.

Coordinated campaign to improve the image of science as a career for young people. Must attack the simplistic and often antagonistic stereotypes of scientists in media

Massive federal fellowship program (3,000 new starts), since otherwise shortfalls in PhDs will have devastating consequences for colleges and universities and for business and industry

Better support for GSAs, since while they are doctoral candidates, they are also doing research and teaching

Fight cultural and social barriers that can make research careers an extraordinary hurdle for women and minorities

Knowledge Infrastructure

Level of Funding

How much money is enough? Better to point out the loss to the nation that will occur if we can only support at a certain level.

In FY89, \$64 B in R&D. But \$37 B of this is DOD.

Only \$10 B into basic science. Should double this!

Annual growth rate of 14% for each of next 5 years

Note that doubling basic science research over 5 years is a mere drop in the bucket.

(In fact, during Reagan presidency, defense budget doubled from \$150 B to \$300 B...there would hardly be a ripple if science budget doubled to \$20 B)

What about federal deficit: "This requires not only spending austerity, but also a long term strategy to generate new wealth."

A National Response

NOTE: Taxes, trade, and fiscal policies influence economic competitiveness in the short term. But in the long run, a strong base of science and engineering research and education is more important.

Maintaining America's competitive edge requires attention to our traditional strength -- people and research -- and a strong offensive strategy based on those resources.

People must be the major focus...

People -- not equipment or buildings -- are the source of creativity.

They generate the knowledge that makes the technological innovation possible. They are the workforce that makes society run.

They are our researchers and teachers, our leaders, managers, and decisions makers in modern technological society.

Two-fold challenge

1. Achieve basic scientific literacy among all our citizens
2. Provide enough scientists and engineers for industry and academe

For this reason, the administration has chosen as its highest priority in the year ahead major new initiatives aimed at strengthening the source of intellectual capital in this nation.

Hopefully, Congress will join in with strong support of this national imperative!

A State Response

Joe Stroud's 4 points:

1. Need more tax support for education...
Education is so much the key to our future that we had better place a higher value on it.

Must reshaping state's priorities, gradually putting more into schools than into other state obligations.

Lottery experience is cause for cynism.

Fact that the state offset the lottery revenue by cutting back on what would have otherwise been invested from the general fund has created a deep distrust on part of voters.

We have to wrench the state's priorities around and make education far more the centerpiece of its efforts.

2. Reshape the schools and make them more effective.

Try to bring about curriculum improvements, to raise standards, to better focus efforts.

3. Devising an alternative tax method

Shifting from overdependence on property taxes. Unless Michigan finds a way to get away from its overdependence on property taxes, we will continue to have tax revolts.

4. Equity issues: extremes between rich and poor districts

This inequity continues to assure that many of the state's most needy kids will get the least investment in their education.

Need a difference school aid formula.

A Local Response

The real power to influence the education at the level

But here, we as parents and citizens have abdicated our political responsibilities.

We have not demand that our publically elected officials respond to the seriousness of our ever-weakening system of education.

While it is true that our school districts have suffered serious damage from an erosion in public support, the responsibility for education does not rest with the schools alone.

How many parents commit themselves to working with their children?

How many support the millages necessary to build strong schools?

How many are willing to make sacrifices to pay for college?

Perhaps it is the lack of commitment of the American

public, in general, and American family in particular which so contrasts us with other nations such as Japan.

Few parents take an active interest in their children's education.

Few save toward a college education...

...whether due to an unrealistic expectation of public support...

...or a preference for expensive cars, vacations, snowmobiles...

Time after time, when given a choice, we vote against good schools.

We complain about taxes necessary to support education...

Even try to roll back taxes, even as education continues to starve

Why?

Is it simply an aging electorate?

Is it the "Me Generation" of the 1960s now growing up into mature Yuppiedom?

No...root causes lie much deeper.

We have ceased investing in our future!

We have chosen instead to mortgage this future to pay for mistakes made in our past.

Six-month planning horizon...desire for immediate results...inability to identify the investments which have to be made today to yield the objectives for tomorrow.

Education always falls at the bottom of the list of social needs.

Even though surveys indicate public supports education, our elected public officials do not seem to listen. They prefer

to fund roads or prisons or football stadiums rather than the education of our youth!

Indeed, Michigan, a state with one of the highest per capita incomes in the nation, continues to slip further and further behind in its investment in education -- just as our nation continues to fall further and further behind those very nations now challenging our economic strength and prosperity.

The attitude we have taken toward our most precious resource, our youth, is both callous and alarming.

I simply cannot accept the excuse that "we can no longer afford this investment in the educational opportunities we offer our youth.

To be sure, the immense social needs for welfare assistance, medical care, prisons, and all of the other programs that drain our tax dollars are compelling.

However, by choosing to meet these needs with resources taken away from our system of public education rather than through reforms in our tax structure or political system, we have in reality mortgaged our future by withdrawing the educational opportunities from our youth.

We seem to have forgotten the commitments that past generations of citizens have made to build educational institutions of exceptional quality -- institutions that have provided many of us for years with unsurpassed educational opportunities.

We simply must re-establish the importance of both our personal and public investments in education, in the future of our children, in our own future, at the local level if Michigan -- indeed, if our nation -- is to face the challenge of the age of knowledge.

The University of Michigan Response

What can an institution such as my University do?

A Narrow Mission

Do we confine our attention to simply educating the scientists and engineers, the doctors and lawyers, the leaders of our increasingly technological society?
the leaders

Is this enough?...Of course not.

I believe our responsibility must go far beyond this...
indeed, I believe that as the flagship of higher education in this state, the University of Michigan has a particular responsibility to provide leadership in education at all levels...from cradle to grave, if you will....

To work with you -- to strengthen your capacity to provide your students with opportunity to develop their abilities to the fullest...

But there is another important responsibility...

Recall the challenge of demographics -- the shortfall of 700,000 scientists and engineers that will occur due to the decline in the number of college age students...

But there is another important aspect of that challenge...

Note: Composition of college age population is also changing...

By 2020 30% will be composed of Blacks and hispanics...
students who have not traditionally chosen S&E careers.

The fastest growing pool of youths has the lowest participation rate in college and the highest dropout rate in high schools -- not to mention the least likelihood to study science and math.

NOTE: We must make special efforts to expand participation by these groups...not just because that is good social policy, but because we cannot afford to waste

their talents!

A Future of Hope

The modern view of change suggests that the future is indeed not what it used to be...
...or at least as it has traditionally been portrayed, as a time of gradual, predictable change, rigidly moored to the past.
Rather, 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...

It will be a future of great challenge and responsibility...
Indeed, as you stand today on the threshold of a new century, it seems clear that your generation will face problems and challenges of a magnitude that would have been incomprehensible in earlier times...

Further, your years following graduation will be a time of less security, less stability, and more unpredictability than mine.

But you will also face a future of extraordinary opportunity and excitement.

For, as the philosopher Whitehead has noted,
"The great ages have been unstable ages!"

Concluding Remarks

Emerson once noted that the wisest council of all to the young was to
"always do what you are afraid to do."

The truth is that adapting to change and challenge is what keeps our species evolving.

We should relish change. Welcome it. Seek it out.

Not for its own sake but for the challenge it brings and the possibility for progress.

We should approach life as a true adventure of opportunity and risk.

We are made for risk. We thrive on it.

I guess I tend to be an incurable optimist.

I believe that we can be masters of our fate.

That we can seize control of forces around us--most of all ourselves--and bring progress to the world.

In fact, I even think that each individual has the possibility to change the world--

just remember the "butterfly effect"--you can change the world with the beat of your own wings...

As Caltech graduates, you are uniquely qualified to work in the exponential region of the knowledge curve!

There is an old saying that...

"The best way to predict the future is to invent it!"..

That is the real challenge before you!

To go out into that exciting world full of challenge and opportunity...

...and to invent the future!

Indeed, it is your challenge to make certain that

the future will not be what it used to be!

Conclusion:

As President at the University of Michigan, I have become convinced that key to our mission in serving this State and its people is a renewed commitment to our aspiration of as one of our first presidents put it, providing "an uncommon education for the common man"...

This will require major new commitments of human and financial resources. It will also require the active involvement and cooperation of our faculty, students, staff, alumni, friends, and supporters in the effort to move toward this important goal.

The new agenda we have embarked upon aligns naturally both with the mission of the University and with our determination to be a leader in efforts to achieve new levels of understanding tolerance, and mutual fulfillment for peoples of diverse

backgrounds.

As a Presidential appointed member of the National Science Board,
let me convey my personal belief as well that the most
important natural resource of our nation are our youth...

As we enter the Age of Knowledge, our ability to sustain the
strength of our nation...to achieve the quality of life for
our citizens...will be determined by, more than any other
factor, how we develop, nurture, and educate that most
precious of resources, our children.

We simply must provide them with the most outstanding
education possible to prepare them for the age in which
knowledge will hold the key to prosperity and quality of
life...

And we must make a special effort to ensure that all students...
regardless of race, creed, or national origin...have the
opportunity to develop their talents to the fullest...

For, after all, that is what America is all about, isn't it!