

## **Science Education for the 21st Century**

**(Tuesday, January 16th, Science Research Club and Sigma Xi)**

**It is a special and a very personal pleasure  
to be here tonight.**

**More like a homecoming**

**Or perhaps more like the return of the prodigal son!**

**This may surprise you but,**

**the subject you have asked me to talk about**

**Science Education for the 21st Century**

is one I have been thinking a great deal about recently.

### **Personal Perspective**

**While it is true that my new responsibilities**

**have taken me away**

**from the daily practice or teaching of science,**

The fact is that I am finding myself spending

more time thinking about learning and education--

particularly science education --

than I have ever done before.

Even more than I did as an active teacher who

supervised the preparation of xxx dissertations

or who taught as many as xxx undergraduate students

for twenty years or more

in our College of Engineering.

Why should this be so?

For many reasons.

As a scientist, albeit a fallen-away one, I am increasingly dismayed by the damaging ignorance of science and technology

among the leaders and citizens of our country

as well as among the great majority of our own students

and dare I say it, the majority of our faculty and administrators

At the same time, as a citizen, I am also concerned about

how we are educating our scientists and engineers.

Based on my own experience in science,

I have come to appreciate how important it is to provide

science and engineering students

with a broadly based education in liberal arts

that equips them to

think critically, learn to learn, and to see their work in the

broad social context of human needs and values and.

incidentally ,if my life is any example,

to prepare them for the many careers students of the future can expect to have in your lifetime.

As a member of the National Science Board, for the past three years,

I have learned that we face a true national crisis in the projected shortfall between the numbers of scientists and engineers we will need over the next few decades to run our country and the numbers we are actually producing.

XXXNational numbers here

Finally, as Dean of Engineering Provost of our University

and now as President,

I see every day the problems we face as an insitution,

a state, and a nation and as part of an emergent  
global society

And many of these problems center on how to prepare the  
people

and produce the ideas that will form the basis for  
our social well being and prosperity for the coming  
new century.

And here, one of the most pressing issues is :

How to give every citizen an understanding of  
science and technology sufficient to inform their  
decisions

as workers and citizens of an “age of  
knowledge”

And,at the same time, how to educate our  
scientists, engineers and other professionals  
about the values and context of human  
civilization so that their work is informed by  
humane values and commitment to community  
and society-- with a recognition of the limitations  
as well as strengths of science.

As a result of my various experiences and perspectives, I  
have become convinced that the fundamental problem

we face as a university and as a nation is to improve  
education, especially science education, at all levels .  
for every person .

By the way, not all of our educational system

is a basket case.

I recently attended a high level international  
conference sponsored by the national Academy of  
Engineering

At which it was unanimously concluded by the  
XXX participants who were all eminent scientists  
and leaders,that our nation's greatest

strength as a nation is our system of higher education

At the same time, it was also unanimously concluded that our greatest weakness was our system of k-12 education.

Quite a paradox, isn't it?

Quite a challenge!

### **Dismal Failure of k-12**

Obviously higher education cannot long sustain its excellence and its emerging key role in national life in isolation.

Our very roots lie in the quality of the schools that provide us with our students.

Just as our national social and economic well being are rooted in the quality of the education we provide to our workers and citizens..

If our schools are failing, for how long can we continue to achieve our own goals and sustain high standards of quality in our research, teaching or service?

And it is equally obvious and more ominous that our society cannot long aspire to or achieve greatness, perhaps even survival, without a vastly improved system of education at all levels.

In particular, when we look at the horrendous waste of human talent represented by the failure of urban schools to educate minority children even to literacy let alone skills needed for participation in a knowledge based society,

I think we have to recognize that no nation can long endure with literally millions of its people consigned to permanent unemployment, destitution and despair.

Thus a major issue we must address is to improve k-12 education dramatically.

In this connection, I am convinced universities, indeed every institution and citizen of our society must become actively involved in cooperation --and sacrifice if necessary--to bring reform.

In fact, let me repeat that I think the issue of education presents the greatest challenge to us all in the decade ahead.

Our children are our future!

Either we get serious as a people, make sacrifices, and resolve to settle for nothing less than the best education

for our children

or we bequeath to them instead a legacy of mediocrity and inevitable decline in the quality

of their own and our national life.

Indeed, I along with many others, predict that unless we come to grips with the quality of education, will make ours an also ran

in the international marketplace of ideas and values as well as economic productivity.

But I also believe that the challenge before us is not just to reform k-12 education.

### **Challenge to higher education**

Despite what I think is the international consensus about the preeminent quality of American higher education,

we in universities cannot by any means be complaisant.

There are clouds on the horizon.

In addition to the looming consequences of our failure in the schools,

We must also re-evaluate

the education we are providing to our students

if we are going to serve our society well in preparing for our nation's future.

We must also confront the challenge of renewal of our own mission and goals in the years ahead.

Hannah Gray "A curriculum represents an expression of aims that have no life if that (animating) spirit dies or fades. It needs continuing re-energization. Excellence in education requires continuing reflection and debate in the light of the questions and opportunities created by new knowledge and new conditions, new generations of students, and of teachers alike."

Since I have become President, I have been talking about the need to re-invent the University to serve 21st century America.

Whitehead (memories p91 wrote in an essay more than fifty years ago:

"Unless we are careful, we shall conventionalize knowledge. Our literary criticism will suppress initiative. Our historical criticism will conventionalize our ideas of the springs of human conduct. Our scientific system will suppress all understanding of the ways of the universe which fall outside their abstractions. Our modes of testing will exclude all the youth whose ways of thought lie outside our conventions of learning. In such ways the universities, with their scheme of orthodoxies, will stifle the progress of the race, unless by some fortunate stirring of humanity they are in time remodeled or swept away."

Well, I am no advocate of sweeping universities away, but I think the need for continuing renewal is clear for universities as for other institutions of society.

I don't come here tonight with answers about what this means.

Quite the opposite!

What I have to offer are some questions, observations and speculations about the issues of renewal--re-energization--

in our teaching, research and service missions.

In this way I hope to begin a dialog that will engage us all in thinking about the future and our place in it.

On some occasions later this year, I hope to say more about renewing our mission in relations to the schools and other relations with our community, as well as about our fundamental missions of research, graduate and professional education and service.

However, this evening, I would like to focus my remarks on some questions about intellectual renewal of undergraduate education

I want to talk about science education in the context of undergraduate education and liberal arts

**As Hannah Gray, one of our great educational leaders, recently observed to students at the University of Chicago,**

“...to think about education is to think about the future, to assess the present, and to judge the past...”

**She adds,**

“...To think about the aims of education is to ask what kind of person, what kind of human competence, what kind of goals might be most desirable for the social order and the quality of civilized existence.”

**and, in addition, she says,**

**“...to wrestle [with these questions] is also to confront complex issues**

**of individual and public choice.”**

**I would add that these are not just the most complex**

**but also the most critical issues and choices before us.**

### **Some thoughts about Undergraduate Education Today**

#### 1) Who we Teach

Numbers/pipeline

Insert here numbers of students and measures of knowledge

#### 2) Goals-

-Many of our practices are embedded in our role as producer of manpower for a homogeneous workforce in a national , industrialland, hierarchically organized economic structure. Such as system depended on having a few people at the top of organizations capable of analysing and leading but with the mass of management and workers carrying out routines dictated from above. Furthermore, the workforce was largely homogeneous with occupationally defined gender and, racial and ethnic roles.

(SAC to get Drucker and Reich quotes/notes here)

#### 3) What we teach

Requirements/

An article by Harvard Chemist, F.H. Westheimer asks “Are our Universities Rotten to the Core” ? He refers to the continuing erosion of science requirements in major universities

“Many of the most prestigious American colleges and universities require the equivalent of only about two and a half courses in science for graduation, and some of these courses are special watered down courses at that.”

....”This contrasts to Harvard’s curriculum in 1849-1850 included a course in science or mathematics, or both, in every semester of every year.”



Division of [two cultures"] is lopsided; in the better colleges, at least, students in science find out something about the modern technological world and in addition, learn a modest amount about the humanities and social sciences. The humanist cannot make a reciprocal claim, nor can many of the social scientists."

But the deeper question that is troubling me is not just to increase the number of courses/distribution requirements

because that does not address the more fundamental problem

of how we move beyond conveying facts alone and

find a way to place them in intellectual and human context.

how to teach about the fundamental "connectedness" of reality

#### Hardening of the Disciplinary Arteries

- Excessive abstraction divorced from context/reality
- Specialization--too narrow in scope and method
- disciplinary inertia

A.N. Whitehead warned in his Essay on the Aims of Education "We must beware of what I will call inert ideas, that is to say, ideas that are merely received into the mind without being utilized or tested or thrown into fresh combinations. ...."Every intellectual revolution which has stirred humanity into greatness has been a passionate protest against inert ideas. Then, alas, it has proceeded to bind humanity afresh with inert ideas of its own fashion."

#### parochialism/xenophobia

despite growing pluralism and internationalization, our education is not giving students a useful knowledge of other people and culture or the skills they need to work effectively in all parts of the world and with people from many different backgrounds,

experiences and beliefs. This calls for direct experience in working together with others to achieve tasks.

### 3) How we Teach

Lectures as opposed to active participation in learning/experimentation/real world applications

Students work alone and get little experience in teamwork in own fields let alone in working with people from many fields and levels.

Accumulation of facts

J. Bronowski in his Science and Human Values puts it this way.

“It is a common and cardinal error to suppose, as the nineteenth century supposed, that the facts on which science builds are given to us absolutely and call for no judgements or interpretations from us. The great discoveries in the physical sciences in the twentieth century begin from a radical denial of this philosophy. We now understand that science is built not on facts but on observations; that observation is not a passive state of reception, but an active relation between the observer and his world; and that science therefore is not a mechanical index of facts, but an evolving activity.

- emphasis on individual selection as opposed to group success

### 4) Values of Community and Responsibility

Students choosing get rich quick majors as we conclude the “Greed Decade” of the 80’s.

Idea of developing character as part of education has been abandoned.

But education is a privilege and we aren’t doing much to provide experience or example of the obligations of citizenship in a democratic and decent society.

There is some evidence that we take too many freshman who come to us full of creativity, enthusiasm and idealism and three years later

graduate them as narrow, doctrinaire technocrats whose main aim is looking out for number one in work and in life.

### **Educational Renewal for the Future**

#### **Exactly what kind of world is that we are preparing for?**

##### **What kind of society will we be?**

**By now most of you have heard me talk about some of the changes I see ahead for our society in the 21st century.**

I won't repeat much of this here except to draw your attention to three significant trends already apparent that will shape the world you will soon enter.

Changing population

international

age of knowledge

#### **Even more important, that what are we likely to be is the question**

what kind of society do we want to be?

#### **For I think that we humans must always strive for the ideal--we**

must hold to some utopian vision of the future.

#### **Ahe late and towering scientist and humanist**

Andrei Sakharov put it

"..there is a need to create ideals even when you can't see any route by which to achieve them because if there are no ideals then there can' be

no hope and then one would be completely in the dark."

Surely, the events of the past few months offer eloquent testimony to Sakharov's faith in the powere of ideals to shape the world.

So in thinking about the future of education in our field, let's not be too practical or limited in our vision.

**On the contrary I think we should aim high. We should try to visualize a world of the future that is peaceful, productive, democratic and creative. A world without poverty or racism either in our own country or in the world. An adventurous world in which we literally aim for the stars --exploring our universe and beyond, and in which science and technology alleviate human suffering, enhance human creativity, and alleviate human suffering.**

**If we set these lofty goals then the question is,**

what kind of education do we need to provide for our children to prepare them to create our ideal future?

**What do we know now about our future that will tell us how to prepare?**

**Key Role of Science and Technology**

**Obviously, we cannot predict the exact details of our future with any certainty, at all.**

**But one thing is obvious.**

**We are in the midst of radical transformations**

as a people

as a nation

and in economic, political and cultural life.

We are experiencing one of the great historical discontinuities.

Whitehead pointed out that “new epochs can emerge with comparative suddenness” and I think it is reasonable to propose that this is truly such a time.

We are a society in transition--not just in the United States--but a world society in transition.

**The transformation we are experiencing can be traced to the habits of mind, discoveries and applications of science and technology--**

**We live in a truly dazzling time!**

**Rarely in human history has there been such a burst of creativity, such an explosion of knowledge.**

**As scientists you live with this reality every day.**

**And so perhaps you have come to take our**

intellectual and technical progress for granted.

**But just stop for a moment and reflect**

on the extraordinary richness and excitement of discovery and advance of the last fifty years.

**•In my own field of nuclear physics, for example**

fission, late 30's

**• Or take biotechnology, where arguably the most advances have occurred.**

**•aeronautical engineering**

moon and beyond

**XXXXXXX Add additional examples and dates**

**•Computers and information technology.**

**There is no aspect of modern life untouched by these**

intellectual advances.

**To demonstrate the revolutionary cultural impact of technology on society, just consider a few examples**

**•Political revolution in Eastern Europe, China,**

**•globalization of trade, capital, labor,**

**Impacts are by no means confined to politics and economy**

Consider the impact on culture and the arts

From music, to choreaography, to the restoration and creation of art, architecture to archeology

scholarly analysis of history, literature, linguistics

Computers are the tools and, arguably even the creators of scholarship and creative expression

(Note--SC get new Hardison book for quotes and examples here)

When we look at where we are and what is possible in the future, there should be every reason for optimism about the liberating role of technology--knowledge in our lives--

**But of course, we cannot ignore the negative side of science and technology in our lives**

atomic weapons

pollution of the environment

witless mass media

Both positive and negative aspects rooted at least partly in our educational failures and especially gap between science and humanistic understanding.

Saxon:"How many of us in the disciplines are satisfied, really satisfied, to see our former students and colleagues in positions of power and leadership as they apply their expert knowledge to practical ends--in the Department of Defense, or elsewhere in government or industry?"

Between our knowledge and its application in life.

**Two Cultures**

If science and technology are now central and driving forces in our society today and

are destined to play an increasingly dramatic role in our future,

Then I think our efforts to reflect on what education is appropriate for the future must center on

(1) how to educate about science and technology in broadest sense

both educate scientists

and educate other intellectual leaders

as well as the general public.

(2) How to renew liberal learning to make it a dynamic force for good

by illuminating the eternal questions and issues of human

and planetary life

Saxon: "a liberal education should give all students a sense of the richness and complexity of creativity in the humanities (and in life--sac) and an understanding of how that kind of creativity concerns itself not so much with the measurable and quantifiable aspects of the world as with the universals of human experience. A liberal education should help all students understand how the humanities seek to explore not only the rational but the other dimensions in our experience that are no less real and no less significant than those revealed by science."

"specifically, the study of the humanities should help science students understand the limits of rationalism as well as its powers, even as they learn the enormous difficulty of making judgements when it comes to questions of values, although the very process of living inevitably forces us to do so."

**It is no longer possible to consider any person literate who does not have some knowledge of science.**

**Conversely, we cannot consider a scientist or engineer, professional or citizen educated unless they have learned something about human civilization and values**

**In other words, we come back to the problem**

**identified by C.P. Snow in the early 1950's.**

**He pointed with alarm to a widening gap separating**

scientific and literary culture.

**I think he was right to be concerned about this problem**

which I believe has grown more acute in the intervening years.

**Until, today, we can see not just ignorance but actual hostility to science on the part of many influential segments of our intelligentsia.**

David Saxon notes a colleague who received a letter from an otherwise intelligent student that began "Science sours the spirit". (Saxon Georgia Review, 597)

**And among the populace at large, we can see this ignorance and hostility demonstrated in fundamentalist and mystical movements**

**and other irrational behaviors around the world and in our own country.**

**The potential cost of ignorance is great.**

**It could include the end of life on earth.**

**Nearly every critical issue before us as a nation today involves complex judgments about difficult scientific and technological issues.**

peace and security, environment, population, economic transformation, AIDS and Cancer, etc.

**But from our top leadership down to each individual voter, we have few people equipped to make judgments in a fully informed and rational way**

**And too often our professionals from different sides of the two- culture gap cannot communicate in ways that can be mutually understood about values, means and ends.**

**Can we bridge the gap dividing the “two cultures”?**

**Perhaps the first step is to remind ourselves**

that both art and science are products of human culture .

Separation that has occurred has occurred as an outgrowth of philosophical methods and propositions and does not reflect any underlying reality which, of course, is a seamless whole.

J. Bronowski “There exists a single creative activity, which is displayed alike in the arts and in the sciences. It is wrong to think of sciences as a mechanical record of the facts, and it is wrong to think of the arts as remote and private fancies. What makes each human, what makes them universal, is the stamp of the creative mind.” (p27)..

Whitehead “But the ideal of the good life, which is civilization-- the ideal of a university--is the discovery, the understanding, and the exposition of the possible harmony of diverse things, involving and exciting every mode of human experience. Thus it is the peculiar function of a university to be an agent of unification.



.....Even methods are limitations. The difficulty is to find a method for the transcendence of methods. The living spirit of a university should exhibit some approach to this transcendence of limits.”

Saxon

First, we should teach our students that science is neither a mystery for the few nor a haphazard collection of facts; that on the contrary, it is a highly unified and consistent view of the world. Second, we should describe and explain just what that view is and in so doing we should seek to give our students the understanding that science is built on a foundation of large general laws that link together various (to be continued)

**Reconceptualized liberal arts to re integrate scientific and humanistic culture.**

**90's years of transition to new century**

**Now is time to think about renewal of liberal arts.**

**We have already pointed to some of the things we aren't doing well or are actually doing badly in light of what we know of our future.**

**1) What are our goals/what should an educated person know and be able to do**

Critical skills and knowledge needed by educated person for tomorrow's world

More specifically how do we educate leaders for this society,.

for that is what Michigan is about!

Knowledge

field of specialization/need to know one subject well

general and humane knowledge

CivicValues

/Foreign languages, knowledge of other cultures and nations and foreign experiences

## Characteristics

- Adapt to and Manage Change/flexibility
- Ability to continue learning/intellectual self-renewal
- Ability to work with diversity of people, including teamwork with professionals from many specialized fields as well as people of diverse backgrounds and nationalities

## 2)How do we educate to provide such knowledge and skills?

Clear that one approach of the past to which we still cling too tenaciously is the idea that education consists of stuffing students full of useful and too often unconnected facts. And in science we have tended to stuff facts in a certain prescribed sequence.

While it is true that, in most scientific and engineering fields, learning advances on stepping stones so that for example, theoretical physics cannot be understood without first learning calculus, XXX ADD EXAMPLES

But the larger question is whether education can ever concentrate on accumulation of facts at all.

The truth is that much of what you learn today in the way of facts and or methods may well be obsolete by the time you graduate.

Specialization--no one subject well and two more pretty well

The means of teaching how to think critically,

focus on the methods, history, principles and approaches of fields of knowledge

Focus on connectedness of reality/perhaps through applied experiments but also real world engagement and service

how to keep on learning,

how to generate intellectual self renewal are many.

They vary with the talents of individual teachers and students

and in different fields but I think fundamentally

we come down to the need to ground knowledge in practice

and experiential engagement.

In direct participation in the process of learning.

Not just to keep abreast of the rapid changes in knowledge because the knowledge base is sure to continue growing and changing at an accelerating pace

But also to be able to adapt to new fields and professions as most of people will do many times in their lives in a future that is continually in flux.

### **Who should we teach?**

more women, minorities

non-traditional students

### **What should we teach**

### **How should we teach**

Engagement in learning and service--Opportunities for service to community/society

New technologies-

Student engagement in learning itself

Focus more on success of group and on teamwork

### **The ultimate objective of all teaching and learning**

**Wisdom /Knowledge**

But most critical of all for the future is to aim beyond knowledge to achieve wisdom.

Of course, this is not something we can teach.

But we can in classrooms and by example teach students to aspire to wisdom and point the way to its attainment.

Whitehead defined the aims of education

“Though knowledge is one chief aim of education, there is another ingredient, vaguer but greater and more dominating in its importance. The ancients called it wisdom. You cannot be wise without some basis of knowledge, but you may easily acquire knowledge and remain bare of wisdom.”

