Science Policy for the Next 50 Years

From Guns to Pills to Brains …

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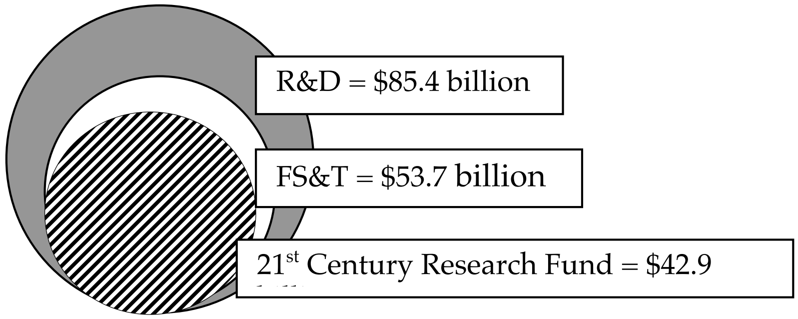
Our session chair, Eamon Kelly, has asked me to address the topic of information technology and the 21st Century workforce with a particular focus on its implications of for science policy in the 21st Century. This topic relates well to two studies I currently chair for the National Academy of Sciences: 1) a steering group of the NAS Committee on Science, Engineering, and Public Policy (COSEPUP) that each year analyzes and identifies trends in the federal science and technology (budget, and 2) a NAS committee concerned with the impact of rapidly evolving information technology on the future of the research university.

This is also a very timely topic, since last week our FS&T steering group met in Washington to lay out our approach to the analysis of the FY02 R&D budget, which will be announced by the new administration within the next month. Furthermore, in January our committee concerned with IT and research universities hosted a workshop at the National Academy of Sciences drawing together over 100 leaders from the IT industry, higher education, and the federal government to discuss these issues.

In my brief remarks this morning, I will begin by summarizing several of the early conclusions from each of these studies, then relate these to several broader issues concerning national priorities, and finally speculate a bit about the future evolution of American science policy.

The COSEPUP Subcommittee on the FS&T Budget

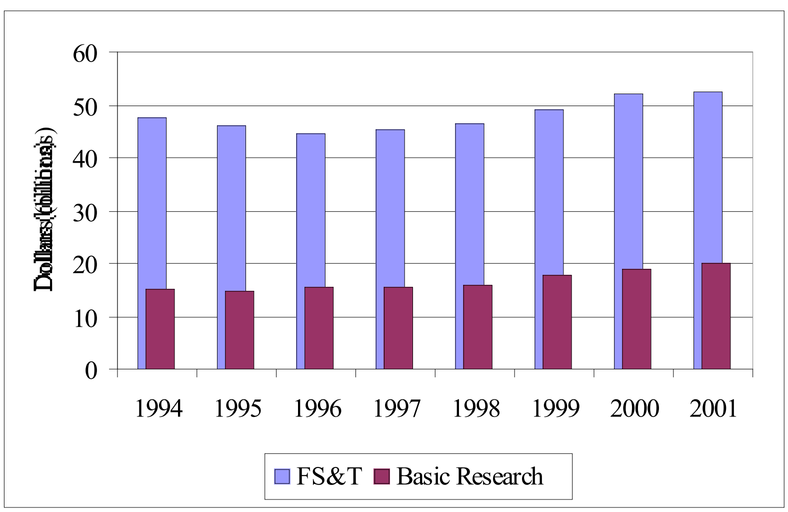
In 1995, the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council issued a report entitled, *Allocating Federal Funds for Science and Technology*,[1] that recommended tracking federal investments in the creation of new knowledge and technologies from the perspective of what the report referred to as the *federal science and technology (FS&T) budget* that reflects the real federal investment in the creation of new knowledge and technologies, excluding activities such as the testing and evaluation of new weapons systems. For example, in FY01, although the federal R&D budget recommended by the administration was $85.4 B, only $53.7 B was identified as the FS&T component. In recent years the Clinton administration moved toward a similar budget concept known as the 21st Century Research Fund that stressed its own research priorities.



FY 2001 R&D, FS&T, and 21st Century Research Fund (in billions)

The task for analyzing the federal R&D budget from this perspective and identifying key issues and trends was assigned to the National Academies Committee on Science, Education, and Public Policy (COSEPUP). In each of the past three years, a COSEPUP subcommittee, which I chair, has worked closely with the AAAS to track the administration's R&D budget recommendations from the FS&T perspective. Our analysis is presented each spring as a chapter in the AAAS publication on the federal R&D budget.[2] During the past three years of this effort, our studies have identified the following themes:

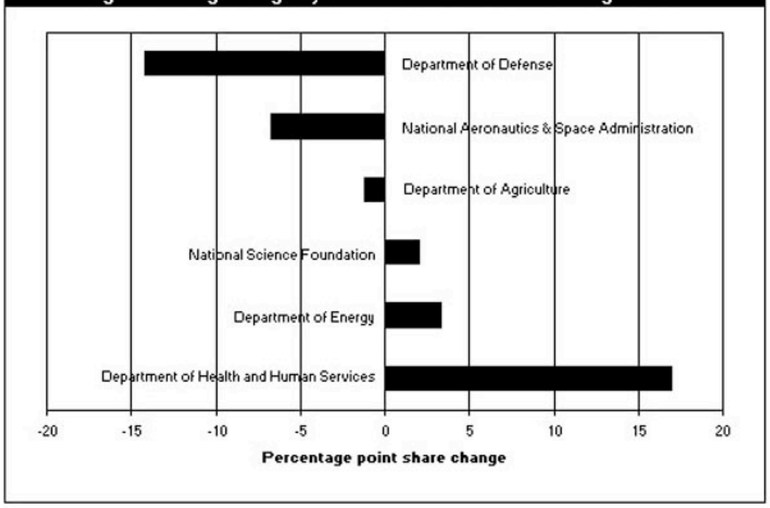
1. The FS&T budget dropped significantly in early 1990s and has only recovered in past two years.



FS&T Budget and Basic Research, FY 1994–FY 2001 (budget authority in billions of constant FY 2000 dollars)

2. During the 1990s, the big winner in federal research appropriations has been NIH (the biomedical sciences); NSF has held its own with modest gains; most mission agencies have lost ground.

Figure 2. Changes in agency shares of Federal research funding: 1970-97

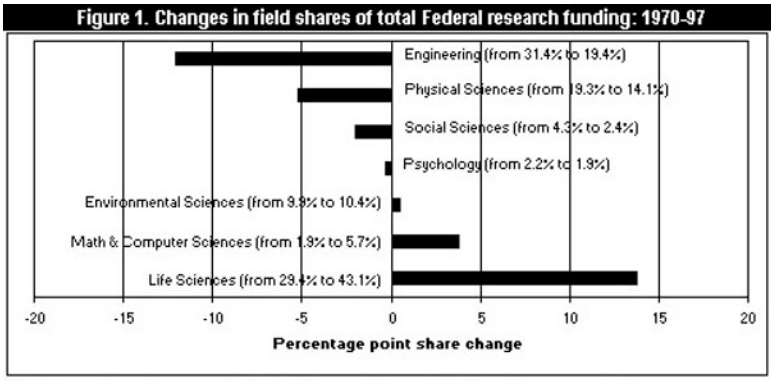


SOURCE: National Science Foundation, Division of Science Resouces Studies, Survey of Federal Funds for Research and Development.

More specifically, during the past eight years, the R&D increases experienced by the federal agencies amount to +111% for NIH, +68% for NSF, + 21% for NASA, + 11% for DOD, and –1% for DOE. As a result, today over 55 cents of every federal research dollar spent on university campuses is for biomedical research.

3. Since scientific disciplines are supported by different federal agencies, a serious imbalance has developed in federal funding among the physical sciences, engineering, social sciences, and life sciences.

Figure 1. Changes in field shares of total Federal research funding: 1970-97

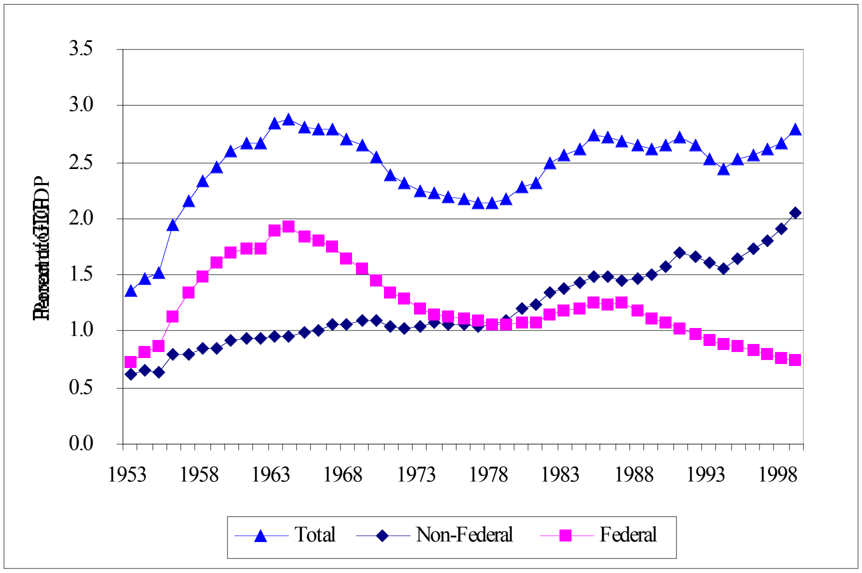


NOTE: Other sciences not classified within one of the broad fields listed above are excluded.

SOURCE: National Science Foundation, Division of Science Resouces Studies, Survey of Federal Funds for Research and Development.

As an example, DOD supports 60% of computer science, 69% of electrical and mechanical engineering, 27% of mathematics, and 38% of materials research, so when DOD R&D budgets are cut, these disciplines suffer.

4. The federal government's share of R&D has fallen far below that of industry, dropping from 65% to 26% in 1999.[3]



Federal, Non-Federal, and Total Support for R&D as a Percent of GDP,

There is a wide consensus that U.S. scientific preeminence and economic growth depend on maintaining and possibly increasing the share of GDP devoted to R&D, with a target goal of 3% proposed by the Clinton administration. And, indeed, total R&D spending has been increasing over the past decade, rising to 2.8% in 1999. Yet since 1987, industry R&D has increased by 196% while the federal share of total R&D has dropped from 46% to 27%. In part this remarkable growth in private sector R&D has been stimulated by the importance of applied research and development in a technology-driven economy. But it also depends on the flow of basic research findings and the associated training of scientists and engineers, principally the concern of the federal government. Hence the growth of industry spending on R&D should not lull observers into thinking that the federal FS&T budget can be reduced. In fact, one might well question whether the current federal investment is adequate to sustain the necessary private sector investment in these activities, so critical to our economic prosperity. Furthermore, a continuing need exists to address possible imbalances among the fields of science and engineering – at a time when many fields are increasingly interdependent for achieving optimal results in the productivity of the economy and the pursuit of knowledge.

These statistics raise the obvious question: How are federal research priorities really determined? One might attribute the pronounced shift in federal science policy from the support of the physical science and engineering to the support of the biomedical sciences as a reflection of changing national priorities over the past 50 years, as the urgency of military security declined with the end of the Cold War, and the concerns about health care grew with the aging of the baby boomer generation. More cynically, one might also consider this shift due in part to the sausage-making process used to construct the federal budget, a process that relies on a Congressional committee structuring strongly favoring biomedical research and particularly susceptible to lobbying influence, while penalizing many other science and engineering disciplines by embedding their support in mission agencies subject to appropriations cuts (e.g., DOD and DOE).

Whatever the reason, it is clear that the past 50 years of federal science policy can be captured with the simple phrase: *From guns to pills…*

So much for the past. What might we expect for the next several decades? This brings me naturally to my next topic.

The NAS Committee on the Impact of Information Technology on the Future of the Research University

Last year (2000) the presidents of the National Academies (Science, Engineering, and Medicine) launched a major new study to explore the impact of information technology on the future of the research university, which I was asked to chair. The premise is a simple one. The rapid evolution of digital technology will present many challenges and opportunities to higher education in general and the research university in particular. Yet there is an increasing sense that many of the most significant issues are neither well recognized nor understood either by leaders of our universities or those who support and depend upon their activities..

The first phase of the project, funded from internal Academy funds and organized under the Government-University-Industry Research Roundtable (GUIRR), was aimed at addressing three sets of issues:

1. To identify those technologies likely to evolve in the near term (a decade or less) which could have major impact on the research university.

2. To examine the possible implications of these technology scenarios for the research university: its activities (teaching, research, service, outreach); the organization, structure, management, financing of the university; and the impact on the broader higher education enterprise and the environment in which it functions.

3. To determine what role, if any, there is for the federal government and other stakeholders in the development of policies, programs, and investments to protect the valuable role and contributions of the university during this period of change.

To this end, a Steering Committee to guide the project was formed last year consisting of leaders drawn from industry, higher education, and government with expertise in the areas of information technology, research universities, and public policy. Since first convening in February 2000, the Steering Committee has held several meetings (including site visits to major technology development centers such as Lucent (Bell) Laboratories and IBM Research Laboratories) and held numerous conference calls to identify and discuss trends, issues, and possible recommendations. The key themes addressed by these discussions were:

1. The pace of evolution of information technology (e.g., Moore's Law).
2. The ubiquitous/pervasive character of the Internet (e.g., wireless, photonics).
3. The relaxation (or obliteration) of the conventional constraints of space, time, and monopoly.
4. The democratizing character of IT (access to information, education, research).
5. The changing ways we handle digital data, information, and knowledge.
6. The growing importance of intellectual capital relative to physical or financial capital

In January 2001 a two-day workshop was held at the National Academies with invited participation of roughly 100 leaders from technology, higher education, and government. The purpose of the workshop was to stimulate a conversation, to launch a dialog, aimed at identifying key themes and issues, to suggest possible recommendations and strategies for research universities and their various stakeholders, and to provide guidance on the next phase of the project. The key presentations and discussion of the workshop were videotaped and will be broadcast on the Research Channel and video-streamed from its website during the spring (2001) to serve as an archive for further discussion.

Although the project is still in an early phase, there are already some important preliminary conclusions:

1. The extraordinary evolutionary pace of information technology will not only continue for the next several decades, but it could well accelerate on a superexponential slope. Photonic technology is evolving at twice the rate of silicon chip technology (e.g., Moore's Law), with miniaturization and wireless technology moving even faster, implying that the rate of growth of network appliances will be incredible. For planning purposes, we can assume that within the decade we will have infinite bandwidth and infinite processing power (at least compared to current capabilities).

2. The event horizons are moving ever closer. Getting people to think about the implications of accelerating technology learning curves as well as technology cost-performance curves is very important. There are likely to be major technology surprises, comparable in significance to the PC in 1980 and the Internet browser in 1994, but at more frequent intervals. The future is becoming less certain.

3. The impact of information technology on the university will likely be profound, rapid, and discontinous–just as it has been and will continue to be for the economy, our society, and our social institutions (e.g., corporations, governments, and learning institutions). It will affect our activities (teaching, research, outreach), our organizations (academic structure, faculty culture, financing and management), and the broader higher education enterprise as it evolves into a global knowledge and learning industry.

4. For at least the near term, meaning a decade or less, the research university will continue to exist in much its present form, although meeting the challenge of emerging competitors in the marketplace will demand significant changes in how we teach, how we conduct scholarship, and how our institutions are financed. Universities must anticipate these forces, develop appropriate strategies, and make adequate investments if they are to prosper during this period.

5. Over the longer term, the basic character and structure of the research university may be challenged by the IT-driven forces of aggregation (e.g., new alliances, restructuring of the academic marketplace into a global learning and knowledge industry) and disaggregation (e.g., restructuring of the academic disciplines, detachment of faculty and students from particular universities, decoupling of research and education).

6. Procrastination and inaction are the most dangerous courses for colleges and universities during a time of rapid technological change. To be sure, there are certain ancient values and traditions of the university that should be maintained and protected, such as academic freedom, a rational spirit of inquiry, and liberal learning. But, just as in earlier times, the university will have to transform itself to serve a radically changing world if it is to sustain these important values and roles.

7. Although we feel confident that information technology will continue its rapid evolution for the foreseeable future, it is far more difficult to predict the impact of this technology on human behavior and upon social institutions such as the university. It is important that higher education develop mechanisms to sense the changes that are being driven by information technology and to understand where these forces may drive the university.

8. Because of the profound yet unpredictable impact of this technology, it is important that institutional strategies include : 1) the opportunity for experimentation, 2) the formation of alliances both with other academic institutions as well as with for-profit and government organizations, and 3) the development of sufficient in-house expertise among the faculty and staff to track technological trends and assess various courses of action.

9. In summary, for the near term (meaning a decade or less), we anticipate that information technology will drive comprehensible if rapid, profound, and discontinuous change in the university. For the longer term (two decades and beyond), all bets are off. The implications of a million-fold increase in the power of information technology are difficult to even imagine, much less predict.

This second phase of the National Academy project will include a number of further activites: 1) the formation of an ongoing roundtable group consisting of leaders from higher education, industry, and government to monitor and assess the implications of evolving technology; 2) the conduct of campus-based discussions among faculty and administrators on a number of university campuses (similar to the "Stresses on the Academy" study jointly conducted by the National Academies and the National Science Foundation during the 1990s); 3) leadership development conferences drawing together key constituencies both from the campuses (e.g., university administrators, faculty leadership, trustees) and from the stakeholders of the research university (e.g., government agencies, foundations, scholarly societies); and 4) the launch of a series of more focused research projects and technology demonstration efforts designed to raise awareness and assist institutions in developing appropriate strategies. These activities will be supported through the development of web-based resources such as web portals and knowledge environments that are intended to be maintained and serve for the next several years as resources for the higher education community and its stakeholders.

The ultimate goal of the National Academies project is to assist research universities and their various stakeholders in responding to the challenges and opportunities presented by digital technology in such a way that strengthen and enhance those roles so important to the future of our nation and our world.

Several Other Data Points

Ask any governor about state priorities these days, and you are likely to hear concerns about education and workforce training. The skills race of the 21st Century knowledge economy has become comparable to the space race of the 1960s in capturing the attention of the nation. Seventy percent of Fortune 1000 CEOs cite the ability to attract and retain adequately skilled employees as the major issue for revenue growth and competitiveness. Corporate leaders now estimate that the high performance workplace will require a culture of continuous learning in which as much as 20% of a worker's time will be spent in formal education to upgrade knowledge and skills. Tom Peters suggests that the 21st Century will be known as the Age of the Great War for Talent, since in the knowledge economy, talent equals wealth.[4]

The signs of the knowledge economy are numerous. The pay gap between high school and college graduates continues to widen, doubling from a 50% premium in 1980 to 111% today. Not so well know is an even larger earnings gap for those with graduate degrees . The market recognizes this, as evidenced by a comparison of the market-capitalization per employee of three companies:

General Motors	$141,682
Walt Disney Company	$743,530
Yahoo	$33 million

In fact, the market-cap-per-employee of the top 10 Internet companies averages $38 million! Why? In the knowledge economy, the key asset driving corporate value is no longer physical capital or unskilled labor. Instead it is intellectual and human capital.

Today we are evolving rapidly—decade by decade, even year by year—into a post-industrial, knowledge-based society, a shift in culture and technology as profound as the transformation that took place a century ago as an agrarian America evolved into an industrial nation.[5] Industrial production is steadily shifting from material- and labor-intensive products and processes to knowledge-intensive products. A radically new system for creating wealth has evolved that depends upon the creation and application of new knowledge.

In a very real sense, we are entering a new age, an *age of knowledge*, in which the key strategic resource necessary for prosperity has become knowledge itself, that is, educated people and their ideas.[6] Unlike natural resources such iron and oil that have driven earlier economic transformations, knowledge is inexhaustible. The more it is used, the more it multiplies and expands. But knowledge is not available to all. It can be absorbed and applied only by the educated mind. Hence as our society becomes ever more knowledge-intensive, it becomes ever more dependent upon those social institutions such as the university that create knowledge, that educate people, and that provide them with knowledge and learning resources throughout their lives.

But here we face a major challenge, since it is increasingly clear that we are simply not providing our citizens with the learning opportunities needed for a 21st Century knowledge economy. Recent TIMMS[7] scores suggest that despite school reform efforts of the past two decades, the United States continues to lag other nations in the mathematics and science skills of our students. Despite the growing correlation between the level of one's education and earning capacity, only 25% of those in our population over the age of 25 have graduated from college. Furthermore, enrollments in graduate programs have held constant or declined (particularly in technical fields such as engineering) over the past two decades.[8]

The space race galvanized public concern and concentrated national attention on educating "the best and brightest", the elite of our society. The skills race of the 21st Century will value instead the skills and knowledge of our entire workforce as a key to economic prosperity, national security, and social well-being. We can well make the case that it has become the responsibility of democratic societies to provide their citizens with the education and training they need throughout their lives, whenever, wherever, and however they desire it, at high quality and at a cost they can afford. Yet there is growing concern about whether our existing institutions have the capacity to serve these changing and growing social needs—indeed, even whether they will be able to survive in the face of the extraordinary changes occurring in our world.

Both young, digital-media savvy students and adult learners will likely demand a major shift in educational methods, away from passive classroom courses packaged into well-defined degree programs, and toward interactive, collaborative learning experiences, provided when and where the student needs the knowledge and skills. The increased blurring of the various stages of learning throughout one's lifetime–K-12, undergraduate, graduate, professional, job training, career shifting, lifelong enrichment–will require a far greater coordination and perhaps even a merger of various elements of our national educational infrastructure.

The growing and changing nature of higher education needs will trigger strong economic forces. Already, traditional sources of public support for higher education such as state appropriations or federal support for student financial aid have simply not kept pace with the growing demand. This imbalance between demand and available resources is aggravated by the increasing costs of higher education, driven as they are by the knowledge- and people-intensive nature of the enterprise as well as by the difficulty educational institutions have in containing costs and increasing productivity.

The Federal Role in Meeting the Nation's Need for Intellectual Capital

As the United States enters a new century, we face social and economic challenges triggered by globalization, technological change, and demographic change that have established the development of our nation's human and intellectual capital as our highest domestic priority. At similar critical periods in our nation's history, the federal government took strong action to our citizens' needs for education. The Northwest Ordinances of 1785 and 1787 established the principle of government support of schools by setting aside public lands to support public schools in each new state. The Morrill Act of 1862 and the other Land-Grant Acts democratized higher education, transforming it from a privilege of the elite to an opportunity for the working class, while stimulating the development of academic programs in applied areas such as agriculture and engineering to serve an industrial economy. The 1944 GI Bill provided millions of returning veterans with the opportunity for a college education. The Truman

Commission of 1948 stated its belief that every high school graduate should have the opportunity for a college education and laid the foundation for the sequence of federal student loan programs which has made this dream possible for a significant fraction of our population. The concern for national security stimulated a research partnership between the federal government and our universities that led to strong support of graduate education and research on our campuses.

Hence there are strong precedents for federal policies, programs, and investments that work through our colleges and universities to address national priorities. What might we expect in the decades ahead?

Federal R&D in "The Science of Education"

We have argued that the development of human capital is becoming a dominant national priority in the age of knowledge, comparable in importance to military security and health care. Yet our federal investment in the knowledge base necessary to address this need in miniscule. In FY01, the nation will invest over $247 B in R&D. Of the federal government's share of $90 B, $20.4 B will be invested in NIH, $8 B in space, $4.4 B in NSF, and $2 B in high energy physics. How much will the federal government invest in research directed toward learning, education, and schools? Less than $300 million–less than 0.2% of our investment in the biosciences or 1% of that in high energy physics.

To view this paltry investment from a somewhat different perspective, most industries spend between 3% to 10% per year of revenues for R&D activities. By this measure, the education sector of our economy (including K-12, higher education, and workforce training), which amounts to $665 B, should be investing 20 B or greater each year in R&D, roughly the same order of magnitude as the health care sector.

Of course, one might raise the question of how we define R&D in education. It is not my intent to wade into the swamp of discussing whether the bulk of the activity supported by the Department of Education, such as the office of Educational Research and Improvement, is actually "research", at least in the sense that most other scientists would understand it.[9] Nor will I address the growing investments of for-profit competitors such as Unext.com and the University of Phoenix in the development of educational products or assessment tools.

Rather I would like to focus my discussion on what many term the "science of education", meaning research that would be classified by scientists as guided by the scientific method and subject to rigorous review by the scientific community. Included in this would be research in areas such as neuroscience, cognitive psychology, organizational theory, and the quantitative social sciences. Of course, there are currently very real constraints imposed by those in the Administration and Congress who have difficulty accepting a more revolutionary educational role for the federal government. Although education is clearly felt to be a priority in our society, it is generally viewed and supported within the constraints of existing perspectives, policies, and programs. It may well be true that the current problems plaguing education in America may be political, organizational, and economic, but without a firm scientific understanding of how learning actually occurs and how learning environments should be developed, progress will be limited. The radical rethinking of the learning ecology necessitated by a knowledge-driven society is very threatening to most public leaders.

For example, how would one explore different architectures of learning environments, institutions, and enterprises for an age of knowledge? Here the goal would be to set aside the constraints of existing educational structures (e.g., schools, colleges, workplace training) and practices and begin with a clean slate to consider how one might meet the live long educational needs of citizens in a global knowledge-driven society. How would one design learning experiences, resources, and institutions that exhibit the various characteristics suggested for learning institutions in the 21st Century: learner-centered, interactive and collaborative, asynchronous and ubiquitous, intelligent and adaptive, lifelong and evolutionary, diverse, and affordable.

Of particular interest here is the redesign of the national learning infrastructure that provides technical knowledge and skills (science, math, technology) and the learning skills necessary for a knowledge-driven society. There also needs to be consideration given to how to design a learning architecture that narrows the digital divide, with a particular concern given to providing educational opportunities to those who have been traditional disadvantaged by our current educational systems.

Although the U.S. Department of Education has traditionally been assigned the responsibility for federal leadership and policy development in education, particularly at the K-12 level, it could be that the most appropriate federal agency for providing national leadership in creating a new learning infrastructure might well be the National Science Foundation. This is suggested by several considerations: 1) Much of the knowledge most critical to our future will be based upon science, mathematics, and technology. 2) The NSF is unique among federal agencies in having both a charter and experience in the conduct of fundamental research concerning education at all levels. 3) The NSF is also unique in its ability to engage the entire research community in high-quality, merit-driven research directed at national priorities such as education. In fact, much of the innovation in life-long learning will be based upon research and development sponsored by NSF in fields such as information technology, cognitive science, and the social and behavioral sciences.

The current Interagency Education Research Initiative provides one interesting approach to rapidly scaling up federal investment in educational research. All federal agencies have human capital needs and therefore some responsibility for investment in education and skills development (much as they have been assigned roles in economic development through the Small Business Initiative Research program). Each could be a player in a broader interagency program, similar to the strategic Information Technology Research or Nanotechnology Research programs of the past several years.

An even more interesting model for the conduct of research on education and learning is provided by the DOD's Defense Advanced Research Programs Agency (DARPA). Through a process using visionary program managers to channel significant, flexible, and long-term funding to the very best researchers for both basic and applied research undergirding key defense technologies, DARPA has been able to capture contributions of the very best of the nation's scientists and engineers in highly innovative projects. Many of today's technologies such as microelectronics, computer science, materials science, and nanotechnology can be traced to earlier DARPA programs. Perhaps we need an Education Advanced Research Programs Agency to focus the capabilities of the American research enterprise on what many believe to be our nation's most compelling priority, the quality of education for a knowledge-driven societySince the Department of Education has so little experience in merit-driven basic research activities and limited credibility with the broader scientific community, other federal agencies such as the NSF and NIH might serve as partners to provide guidance and oversight during the startup phase of an "EARPA". This might also might provide a source of intellectual energy and vitality in the Department of Education, similar to that provided by basic research activities in other mission agencies (DOD, DOE, NASA, etc.). To convince the research community that this is a serious effort and not simply channeling more money into the education establishment, it might even be useful to get the National Academies both to support it and perhaps even provide some leadership.

Beyond new mechanisms to stimulate and support research in the science of education, we also need to develop more effective mechanisms to transfer what we have learned into schools, colleges, and universities. For example, the progress made in cognitive pyschology and neuroscience during the past decade in the understanding of learning is considerable.[10] Yet almost none of this research has impacted our schools. As one of my colleagues one said, "If doctors used research like teachers do, they would still be treating patients with leeches."

A Learn-Grant Act for the 21st Century

Perhaps it is time to think more broadly and reconsider the social contract between the educational enterprise and American society. After all, this is just what was done in creating the research partnership between the federal government and our universities to address priorities in national security and health care. But rather than create an entirely new model, perhaps it is more appropriate to first consider the relationship that characterized higher education a century ago: *the land-grant university model*.

Recall that a century and a half ago, America was facing a period of similar change, evolving from an agrarian, frontier society into an industrial nation. At that time, a social contract was developed between the federal government, the states, and public colleges and universities designed to assist our young nation in making this transition. The land-grant acts were based upon several commitments: First, the federal government provided federal lands for the support of higher education. Next, the states agreed to create public universities designed to serve both regional and national interests. As the final element, these public or land-grant universities accepted new responsibilities to broaden educational opportunities for the working class while launching new programs in applied areas such as agriculture, engineering, and medicine aimed at serving an industrial society, while committing themselves to public service, engagement, and extension.

As we noted earlier, today our society is undergoing a similarly profound transition, this time from an industrial to a knowledge-based society. Hence it may be time for a new social contract aimed at providing the knowledge and the educated citizens necessary for prosperity, security, and social well-being in this new age. Perhaps it is time for a new federal act, similar to the land grant acts of the nineteenth century, that will help the higher education enterprise address the needs of the 21st Century. Of course, a 21st Century land-grant act is not a new concept.[11] Some have recommended an industrial analog to the agricultural experiment stations of the land-grant universities. Others have suggested that in our information-driven economy, perhaps telecommunications bandwidth is the asset that could be assigned to universities much as federal lands were a century ago. Unfortunately, an industrial extension service may be of marginal utility in a knowledge-driven society. Furthermore, Congress has already given away much of the available bandwidth to traditional broadcasting and telecommunications companies.

But there is a more important difference. The land-grant paradigm of the 19th and 20th Century was focused on developing the vast natural resources of our nation.[12] Today, however, we have come to realize that our most important national resource for the future will be our people. At the dawn of the age of knowledge, one could well make the argument that education itself will replace natural resources or national defense as the priority for the twenty-first century. We might even conjecture that a social contract based on developing and maintaining the abilities and talents of our people to their fullest extent could well transform our schools, colleges, and universities into new forms that would rival the research university in importance. In a sense, the 21st Century analog to the land-grant university might be termed *a learn-grant university*.

A learn-grant university for the 21st Century might be designed to develop our most important asset, our human resources, as its top priority, along with the infrastructure necessary to sustain a knowledge-driven society. The field stations and cooperative extension programs–perhaps now as much in cyberspace as in a physical location–could be directed to the needs and the development of the people in the region. Furthermore, perhaps we should discard the current obsession of research universities to control and profit from intellectual property developed on the campus through research and instruction by wrapping discoveries in layer after layer of bureaucratic regulations defended by armies of lawyers, and instead move to something more akin to the "open source" philosophy used in some areas of software development. That is, in return for strong public support, perhaps public universities could be persuaded to regard all intellectual property developed on the campus through research and intellectual property as in the public domain and encourage their faculty to work closely with commercial interests to enable these knowledge resources to serve society, without direct control or financial benefit to the university.

In an era of relative prosperity in which education plays such a pivotal role, it may be possible to build the case for new federal commitments based on just such a vision of a society of learning. But certain features seem increasingly apparent. New investments are unlikely to be made within the old paradigms. For example, while the federal government-research university partnership based on merit-based, peer-reviewed grants has been remarkably successful, this remains a system in which only a small number of elite institutions participate and benefit. The theme of a 21st Century *learn-grant act* would be to broaden the base, to build and distribute widely the capacity to contribute both new knowledge and educated knowledge workers to our society, not simply to channel more resources into established institutions.

An interesting variation on this theme is the *Millennium Education Trust Fund* proposed by Newton Minnow and Larry Grossman.[13] This fund would be established by investing the revenues from the sale or lease of the digital spectrum and would serve the diverse educational, informational, and cultural needs of American society by enhancing learning opportunities, broadening our knowledge base, supporting the arts and culture the skills that are necessary for the Information Age. Newton and Grossman estimate that the auctions of unused spectrum over the next several years could yield at least $18 B. These revenues, placed in a Millennium Education Trust Fund, would work just as the Northwest Ordinance and Morrill Act did in past centuries, investing proceeds from the sale of public property in our nation's most valuable asset, our people,

Whatever the mechanism, the point seems clear. It may be time to consider a new social contract, linking together federal and state investment with higher education and business to serve national and regional needs, much in the spirit of the land-grant acts of the 19th Century.

Concluding Remarks

My remarks today have been based on three essential premises:

1. We have entered an age of knowledge in which educated people and their ideas have become the keys to economic prosperity, national security, and social well-being. Furthermore in such an age, education has become the key determinant of one's personal prosperity and quality of life.

2. It has become the responsibility of democratic societies to provide all of their citizens with the education and training they need, throughout their lives, whenever, wherever, and however they desire it, at high quality, and at an affordable cost; that is, to create a "society of learning" in which life-long educational opportunities become not only available but pervasive in the lives of all of our citizens.

3. Although the major investments in the learning infrastructure necessary to create and sustain a society of learning will come from the private sector and local government at the state and community level, leadership, research, and the development of a policy framework are the responsibility of the federal government.

These are challenging issues, to be sure. But just as the space race of the 1960s stimulated major investments in research and education, there are early signs that the skills race of the 21st Century may soon be recognized as the dominant domestic policy issue facing our nation, thereby providing an opportunity not simply for new investments but as well to break free of existing constraints and evolve toward a society of learning.

If the past 50 years of science policy can be characterized as a transition in national priorities "from guns to pills", let me suggest that the next 50 years will see the transition "from pills to brains". It is time that we realized that our nation's intellectual capital, the education of our people, the support of their ideas, their creativity, and their innovation, will become the dominant priority of a knowledge-driven nation.

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[1] *Allocating Federal Funds for Science and Technology,* Committee on Criteria for Federal Support of Research and Development, (National Academy Press, Washington, 1995).

[2] *Observations on the President's Fiscal Year 2001 Federal Science and Technology Budget*, Committee on Science, Engineering, and Public Policy (National Academy Press, Washington, 1998, 1999, 2000).

[3] Federal R&D as a percentage of total R&D in the US reached a high point in 1964 at 66.8 percent, equaled 46.4% in 1987, and in 1999 was 26.7 percent. See NSF, *National Patterns of Research and Development Resources 1999 Data Update* (NSF 00-306).

[4] Michael Moe, *The Knowledge Web: People Power– Fuel for the New Economy* (Merrill-Lynch, New York, 2000)

[5] Peter F. Drucker, "The Age of Social Transformation," *Atlantic Monthly,* November 1994, 53–80; Peter F. Drucker, *Post-capitalist Society* (New York: Harper Collins, 1993).

[6] Erich Bloch, National Science Foundation, testimony to Congress, 1988.

[7] *The Third International Mathematics and Science Study-Repeat*, National Science Foundation and Department of Education, 2001.

[8] Douglas S. Massey, "Higher Education and Social Mobility in the United States 1940-1998 (Association of American Universities, Washington, 2000)

[9] Maris Vinovskis, "The Federal Role in Educational Research and Development", Brookings Papers on Education Policy 2000 (The Brookings Institution, Washington, 2000) pp. 359-380.

[10] *How People Learn: Brain, Mind, Experience, and School*, The Committee on Developments in the Science of Learning, National Research Council (National Academy Press, Washington, 2000)

[11] *Renewing the Covenant: Learning, Discovery and Engagement in a New Age and Different World*, Kellogg Commission on the Future of the State and Land-Grant Universities (2000); Walter E. Massey, "The Public University for the Twenty-First Century: Beyond the Land Grant," 16th David Dodds Henry Lecture, University of Illinois at Chicago, (1994); J. W. Peltason, "Reactionary Thoughts of a Revolutionary," 17th David Dodds Henry lecture, University of Illinois at Urbana-Champaign (October 18, 1995).

[12] Frank Rhodes, "The New American University," *Looking to the Twenty-First Century: Higher Education in Transition* (Champaign-Urbana: University of Illinois Press, 1995).

[13] Lawrence K. Grossman and Newton N. Minow, *A Digital Gift to the Nation: Fulfilling the Promise of the Digital and Internet Age* (Carnegie Corporation of New York, New York, 2000).