Some Notes on NSF "Tutorial" on Technology and Learning
(J. J. Duderstadt)

Time: 8:30 to 12:00 noon, Wednesday, October 29, 2003

Place: National Science Foundation

Participants:

Guests:	Dan Atkins (UM) Eliot Soloway (UM) Michael Cohen (UM) John Seely Brown (Xerox, USC) J. C. Herz (Joystick Nation) Roberta Johnson (NCAR) Christine Borgman (UCLA) Diana Oblinger (Microsoft) Alfred Moye (HP) Jim Duderstadt (UM)
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Original Objective

To conduct a "conversation" concerning the impact of technology on learning in an effort to help EHR (and, more broadly, NSF):

1) Shape its agenda in these areas;
2) Review ongoing activities (and investments);
3) Move from a focus on technology to broader cyberinfrastructure issues.

A Possible Parsing of the Conversation (JJD's Opening Remarks)

1. The Evolution of Digital Technology

The first phase of the National Academies project on IT and higher education has concluded that the extraordinary evolutionary pace of information technology is likely to not only continue for the foreseeable future but could well accelerate on a superexponential slope, with the character of the technology driven by those most rapidly evolving features (e.g., processing speed, bandwidth, storage, wireless connectivity–"riding the exponential"). Our society is evolving from "e-commerce", "e-government" and "e-learning" to "e-everything", since digital devices are increasingly becoming our primary interfaces not only with our environment but with other people, groups, and social institutions.

It is essential to recognize that this is a disruptive technology. It will drive profound, rapid, and unpredictable change in learning institutions (schools, universities, workforce training) just as it has in other sectors of our economy, society, and world. It will affect all aspects of education: how we teach, conduct scholarship, serve society;

how we are organized, financed, and managed; and the broader environment with which our schools and colleges interact.

However there is an important caveat here: Although the National Academies taskforce felt confident that digital technology will continue its rapid exponential evolution, it acknowledged that it was far more difficult to predict the impact of this technology on human behavior and upon social institutions such as schools and universities.

2. The Impact of IT on Learning

Here we must broaden the conversation to include not simply K-12 and higher education, but workforce training, cultural enrichment, and lifelong learning (cradle to grave). Much of the impact of IT will be on informal learning (cultural institutions, entertainment, gaming) and the increasing rich and powerful linkages between informal and formal learning (and between intrinsic and extrinsic knowledge and skills). Not only does IT shift the epistemological paradigm (e.g., from learning "about" to learning "to be") but it reshapes the learning process (e.g., from teaching and pupils to peer-to-peer interactive learning).

3. The Impact of IT on Learning Institutions

IT will have as much impact on learning institutions (schools, colleges, universities, libraries, museums, corporate and national laboratories) as upon the learning process. In fact, increasingly robust cyberinfrastructure will likely lead to new types of learning "life-forms" such as knowledge nets and informal learning experiences (e.g., gaming) that could well threaten and perhaps even replace existing institutions as learning ecologies adapt, mutate, and evolve.

Cyberinfrastructure enables new kinds of integration among components of learning institutions, such as the relationships among teaching, learning, laboratories, and libraries. Digital libraries can support the use and creation of content, as well as discovery and retrieval, for example. Digital library services can facilitate formal and informal learning by allowing students to explore primary and secondary sources of knowledge, to use the same resources as scholars, to assemble their own personal digital libraries, and to share their resources with others.

Information technology will be adopted and adapted in ways that are often difficult to predict. This process itself deserves much closer study.

4. The Impact on STEM Workforce Needs

There is great urgency to addressing the future STEM workforce needs of the nation, driven by factors such as the increasing degree of outsourcing of high-tech services by American corporations; the disruption of the STEM pipeline of talented international students into our universities (and industry) by 9-11, Iraq, and homeland security concerns; and the massive turnover of the STEM teaching workforce anticipated for the remainder of this decade.

5. The Implications for EHR (stated in an intentionally provocative manner…)

From the perspective of resources, NSF-EHR represents a very substantial fraction of the federal investment in research and practice concerning education and learning (and most of the activity in science, mathematics, engineering, and technology education). Yet EHR programs tend to be overly constrained—by tradition, by practice, and by Congress. As a consequence, EHR is NOT viewed by the scientific community as

a place where innovative projects with high impact potential are conducted (or even tolerated). As a result, EHR has lost much of its opportunity for intellectual leadership to other programs within NSF (such as the new Science of Learning Centers, which will be primarily located in the research directorates) or other federal agencies (such as NIH). EHR faces a wide and broadening reality gap between what it is supposed to do and what it is able to accomplish, particularly in the eyes of the scientific community.

Perhaps we should begin with the simple question of what EHR sees as its mission and whether it believes its current portfolio of activities adequately addresses this mission? Does EHR have the will (and capacity) to transform itself to address the needs of a changing world in the face of almost certain resistance from the scientific community, the education community, and Congress?

This is a particular challenge in critical areas such as the impact of rapidly evolving technology for learning and its implication for the STEM workforce. Hence the most important role of this conversation may be to put key questions before both EHR and NSF more generally that will break thinking out of the box and encourage a far more innovative approach to program development.

6. A Challenge to NSF to View Itself as a Change Agent

Throughout its half-century-long history, NSF has stepped up from time to time as an important change agent to address major national priorities. The partnership between the federal government and higher education articulated in Vannevar Bush's Science, the Endless Frontier, created the American research university as we know it today. Much of the digital revolution in scientific research, education, and our broader society was stimulated by NSFnet and the resulting Internet. Today the human resource needs of the nation, an increasingly competitive global, knowledge-driven economy, and the challenge and promise presented by exponentially evolving digital technology presents a new and compelling challenge to NSF to provide leadership and stimulate change in our nation's learning enterprise.

<u>Bits and Pieces of the Conversation (from notes)</u>

There is no shortage of really interesting ideas. The real challenge is how to get them into education environments where they can impact learning. The system will resist the technology. Organizational factors and social practices inevitably swamp the technology-specific factors in determining whether a technology gets adopted. At the K-16 level, factors such as teacher time constraints, teaching to standardized tests, state education standards, classroom configurations, and incentives generally dominate technological capability.

Intellectual property policies have also become a huge constraint and dis-incentive to adopt IT for learning (i.e., the effort and expense to acquire digital content is prohibitive, while the same content in other forms is freely used in classrooms under fair use provisions). Policy issues such as these should be studied and means to address them need to be found.

Yet we have a real opportunity. There is quite a bit happening right now at all education levels. There will be a huge change in the teaching cohort over the next several years. If we miss out on influencing the next wave entering the teaching profession in the next five years, we'll be stuck for a generation. It is important to do things now, stimulate bold actions rather than simply narrow studies.

How does one shift from just doing cool stuff to making something actually happen? How do we operationalize these possibilities? Perhaps we need to look for leverage or tipping points.

- For example, there is a clear conflict between the philosophy of accountability and testing ("teaching to the test") and innovative learning since teachers are held accountable for performance on tests rather than actual learning. Perhaps NSF could actually take advantage of the accountability-testing environment, at least for STEM, and reshape the tests to stress the right kind of learning. The core issue here seems to be defining 'right." Instead, we must recognize that many types of learning are valuable, and the extremely standardized model of curriculum and testing (where even textbooks are chosen at the state level, through a process that is more political than pedagogical) is wrong headed. How can we blast open the "one size fits all" model of instruction?

- Perhaps we could use the increasing degree to which schools (and universities) are networked to help currently isolated K-12 teachers build communities of practice through the Internet. Here we can learn from work in knowledge management. People have plenty of incentives to seek information from others, but relatively few incentives to contribute. Knowledge management systems to facilitate communities of practice have not been a big success for this reason. Why do science projects, where scientists contribute to teaching, often work? Is it the difference in status? In incentives? We should look at how research in related fields (e.g., management, organizational communication, sociology, social networks) can be applied to education.

- Or perhaps we need an extension service model, funded at the federal level much as the Agricultural Extension Service was funded through the Land-Grant Acts?

Yet there is a concern here, because the changing learning needs of our society, and the disruptive nature of digital technology, may extend beyond the capacity of our existing learning infrastructure of schools, universities, training programs, and cultural institutions. Approaching the challenge by reforming existing institutions may not be sufficient. After all, "a butterfly is not simply a better caterpillar"! Instead perhaps it is time to explore entirely types of learning organizations and ecologies.

- Here it is important to realize that digital technology drives a shift in epistemology from "learning about" to "learning to be". While traditional approaches to education focus on content, IT-based learning focuses on process, on being and doing.

- This is important, since it is likely that IT will have more impact on informal learning than schools and curricula. Gaming provides an excellent example: the popular computer game, *The Age of Empires* is really a graduate course on the Middle Ages. Can digitial technologies be used to link informal and formal learning? This could be a very rich and powerful linkage, particularly important for the motivated student. But what about other students who may not be motivated or cyber-literate? Rather than "linking" perhaps the more appropriate focus should be "integrating". After all, formal and informal learning or communication are more of a continuum than a dichotomy.

- Technology has created a huge experience gap, more determined by the exponentiating pace of technology development than age. The current generation of educators (and NSF program directors and proposal reviewers?) is probably the wrong one to deal with these issues, since we really don't understand the digital generation very well. Do we really know how young people learn in

technology-intensive environments. Is NSF funding enough "observational" efforts simply to look, listen, and learn.

Furthermore, it is important to look more broadly at cyberinfrastructure–not just technology, but people, organizations, and policies. Here we are not recommending a "EDUnet" but rather a more holistic approach, a knowledge environment, a learning ecology that adapts, mutates, and evolves. Yet most educational institutions (schools, colleges, universities) are not true learning organizations. Neither is NSF, for that matter. Where are the experiments today that are as bold as those in the 1950s (UCSC, UCSD). Probably in the for-profit sector (e.g., the University of Phoenix).

How does EHR break away from a risk-intolerant culture based upon highly traditional STUDIES (e.g., hypothesis, theory, measurement, conclusion) or dictated by superficial performance objectives (a la GPRA) and instead stimulate highly innovative ACTIONS aimed at addressing key national priorities in STEM human resources.

- For example, how can one not only fund numerous experiments in technology-based learning at all levels, but build in sufficient assessment tools to understand what is happening? (We hear frequent complaints that there is not adequate funding provided in most grants for true assessment.) Furthermore, most investigators are not really very experienced in effective assessment methods. Perhaps EHR should invest more in stimulating real innovation in measurement and assessment.

- Can technology be used to link the natural interest in science and engineering on the part of young people to the massive American scientific research enterprise? More specifically, could EHR use technology to link its programs more effective to the activities of the research directorates?

- Could one build a rich connectedness among the Science and Learning Centers, the cyberinfrastructure initiatives, and SMET workforce challenges (declining immigration, underserved minority communities, etc.)? Neither EHR and NSF are sufficiently "vascular". Perhaps we need to use cyberinfrastructure to reinvent both as true learning organizations, using WiKi's and Blogs as devices to link various components of NSF together.

- It is also important to note that research on IT and learning falls into Pasteur's Quadrant as a blending of basic and applied research or "use-driven research", since it departs considerably from the traditional linear models of basic-applied-development-implementation grants most typically funded by NSF. For example, we need fundamental research on behavior and cognition, which will inform pedagogy, which will inform infrastructure design and organization models, which will inform education policy, and so on, in a highly nonlinear and interactive fashion. NSF needs to develop the flexibility to fund such efforts.

Do we need to put even bolder questions on the agenda? For example, why doesn't NSF (EHR) launch major projects that attempt to explore the design of entirely new learning ecologies that begin with a "green-field" approach to determining the needs of citizens (and workforces) in a global, knowledge-driven economy, then build resource maps and conduct a gap analysis to see what is missing in our existing educational infrastructure, and finally develop technology roadmaps aimed at developing new educational resources? (This approach worked fairly well in post-cold war Eastern Europe to help people break out of old organizational structures and apply their skills and talents in new ways.)

Another example: Information technology is driving quite extraordinary change in higher education on both a national and global scale comparable to the restructuring of other economic sectors such as health care, financial services, transportation, and energy. What is NSF doing to understand and influence these changes in a way that protects the scientific capacity of the nation?

Some Specific Recommendations to EHR (and NSF)

There is an urgent need to broaden the EHR portfolio far beyond its traditional programs, practices, and policies, all of which tend to constrain the directorate to funding the past rather than shaping the future. We would recommend as alternatives efforts that involve:

Observation: Try to observe and understand what is actually going on (the behavior of the digital generation, what is really happening in schools, colleges, what strategies learning institutions are taking, what is happening in informal learning).

Assessment: Encourage the development of rigorous assessment capability and provide both the necessary funding and assistance in grants to assess impact.

Action: EHR (and NSF) need to be far more activist, identifying critical tipping points for stimulating change and exploiting opportunities (e.g., the current testing-accountability environment or cyberinfrastructure initiatives)

Linkages: How does EHR link with the research directorates? How can NSF become more vascular.

Research Grants: EHR needs to encourage or facilitate more effective collaborations between domain experts (scientists and engineers) and researchers in education and the social sciences. The latter group knows the research methods and infrastructure – and how to deal with critical factors such as human subjects committees – that the domain experts usually lack. Collaborations would also improve the study of education. Also key is to involve social science researchers who study social networks, communication processes, social aspects of infrastructure, the adoption of information technology, use and evaluation of IT, and so on. They can serve as essential partners in innovation.

As first step, EHR needs to do a somewhat different analysis of its portfolio:

1) How many grants are going to real scientists and engineers (as opposed to those involved primarily in educational research)?

2) How many grants include adequate resources (both funding and additional assistance, if necessary) for assessment?

3) Are you funding highly innovative projects (even if they fall outside the accepted ratings of your review panels)?

4) How many grants are shared between EHR and R&RD directorates? (How "vascular" is EHR … and NSF?)

5) Perhaps the urgency of the STEM crisis requires that at least a portion of the EHR portfolio be allocated through different mechanisms than unsolicited proposals, e.g., a DARPA-like process that approaches the most thoughtful and creative members of the scientific community and enlists their participation in projects that address key priorities.

A Sense of Urgency

It is important to stress the urgency of the human resource crisis facing the nation and the role that NSF-EHR could (should, indeed MUST) play in addressing this national priority.

- The turnover in the nation's K-12 teaching cadre will occur over the next 5 to 10 years. If substantial reform in teaching education and training is not accomplished soon, it will be a generation lost (of both teachers AND students).

- There is an urgent crisis in the availability of STEM human resources precipitated by the discontinuity in the flow of talented international students to the United States as a consequence of the concerns about homeland security and global attitudes toward America in the aftermath of 9/11 and Iraq. This is a crisis of monumental importance to high-tech industries (not to mention research universities) in this country, and it should be high on the list of NSF priorities. Is it? Does the current portfolio of EHR or NSF activities address such issues? If not, why?

- New federal and state policies in testing and school accountability are driving a revolution at the K-12 level. This provides both a challenge and an opportunity to NSF: a challenge if teaching to the test dominates the student learning environment, and an opportunity if NSF were able to influence the testing and accountability process in STEM areas to enhance learning.

- Finally, the human resource implications of a global, knowledge-driven economy is driving massive change in the workforce education and training needs that must be addressed at all levels of the educational enterprise: K-12, higher education, postgraduate, workplace, and lifelong learning. Again this poses both a challenge and an opportunity for NSF.

Clearly time is not on our side in addressing these multiple human resource challenges. The NSF needs to determine what it can accomplish in the near term with existing resources. But to do so, it needs to approach its current inventory of activities in a much more strategic and rigorous fashion and then make the necessary changes. It also must launch far bolder initiatives that anticipate a radically different future for learning and learning institutions.

In other words, NSF first needs to know what it knows. It then must transform itself into a learning institution capable of providing leadership, stimulating change, and responding to the needs of the nation.