Information Technology:

Its Impact on Undergraduate Education in Science, Mathematics, Engineering, and Technology

Report on an NSF Workshop

National Science Foundation
Directorate for Education and Human Resources
Division of Undergraduate Education

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Foreword

The National Science Foundation (NSF)'s Directorate for Education and Human Resources (EHR) is responsible for providing national leadership and support for improving the quality and accessibility of science, mathematics, engineering, and technology (SME&T) education, kindergarten through graduate school. In a nation ¾ indeed a global economy ¾ increasingly based on information as its common currency, the provision of appropriate information technology in addition to well prepared teachers, instructors and facilitators of such powerful tools, must become a vital part of the entire educational continuum as we step into the next century.

In order to be effective, the use of technology in education must involve not only the provision of equipment such as computer hardware and software, but also the human aspects of essential content, engaging presentation, effective pedagogy, appropriate evaluation, and widespread dissemination. Communication and computing provide dynamic tools, placing nearly continuous demands on financial reserves and human resources as equipment and professional training are revised and upgraded. The NSF-hosted workshop presented in these proceedings addressed these and other issues in order to define unique perspectives, concerns, and desirable benefits of educational technology to a broad spectrum of constituents.

The notion of widespread, uniform access to information technology is not a trivial problem. As more adults, paraprofessionals, and part-time students utilize the classroom or laboratory to seek skills in the use of generic or specialized technology, we see that the traditional purviews of academe now extend deep into the entire community. Regardless of the rapidity or direction of change offered by exciting and revolutionary new technologies, the true challenge for developing guiding principles for their appropriate implementation lies in the inclusion of all students at all types of academic institutions, with secure and tangible links to the public and private sectors. Again, while access for all, coherence in underlying infrastructure, and compliance between the skills taught in school and those necessary in the workplace are fundamental to this discussion, it is the collective effort of our human capital that will ensure these powerful tools do not instead widen the gulf between the haves and the have-nots. As this vast endeavor is begun, the cross-divisional and multidisciplinary activities will encourage projects that create effective learning environments with the broadest possible access to them.

Luther S. Williams
Assistant Director
Directorate for Education and Human Resources

Contents

Executive Summary

In April, 1996, the National Science Foundation convened a workshop for faculty, students, academic administrators, publishers, and industry professionals to discuss the use of information technology in higher education. The purpose of the meeting was: 1) to identify prevailing themes and issues in the use of information technology and begin to establish a common vocabulary for discussion; 2) to derive a general consensus on effective and ineffective attributes and examples of information technology; and 3) to initiate discussion on the role each stakeholder might play in a national effort to use such technologies to enrich the educational experience of all undergraduates.

During the pre-meeting ***listserv*** discussion, participants called for a concise definition of "information technology," as applied to teaching and learning. Access for all and examples of effective and ineffective attributes of information technology applications were also proposed as issues in need of further discussion, as was the true costs of using information technology on a large-scale.

In breakout group discussion during the three-day meeting, ***information technology*** (IT) was used as an umbrella term to represent communication and computing tools, while ***educational technology*** was used to denote the application of IT tools to teaching and learning. Accordingly, educational technology could further be differentiated into ***instructional technology*** (tools based in the delivery of educational material), and ***learning technology***, which is centered in the experience of the student. Collectively, these technologies have the ability to provide access to world-wide resources; facilitate the accumulation and presentation of data; and enable communication, interaction, and collaboration among students and instructors to improve the practice of teaching and the experience of learning.

Workshop participants identified effective information technology applications as those that engage students with the material, illustrate complex systems or relationships, and encourage interaction with other individuals or teams. Ultimately, the technology tools should become transparent as they engage the user with the material, enabling immersion in the learning process on an individual basis or as part of a community. Ineffective applications of information technology include those: that assume advanced levels of technical expertise in the user, in which technology is intrusive or displaces content, that are unreliable or difficult to maintain, or that merely provide high-tech alternatives to traditional materials such as textbooks or blackboards.

Effective modes of learning include those in which the expectations and goals of the instructor are clearly articulated, and the learning experience is centered in the experience of the student. Inquiry should be non-linear, guided by the interests of the user, and offer flexibility in the path of inquiry and the depth of investigation.

Throughout the workshop, common areas of concern were: appropriate faculty development, determining both qualitative and quantitative measures of the effectiveness of learning and teaching in environments rich in educational technology tools, wide dissemination of effective practices, recognition of successful innovation using information technology in education, identifying the cost(s) of the information technology infrastructure, and defining the outcome(s) and challenge(s) of implementing small-scale applications of educational technology on a larger scale.

In addition to making "technology products" widely available to faculty, appropriate technical support and training on the use of the product should also be available, such as through teaching/learning resource centers. Most faculty will not be inspired to use information technology if it requires tutelage from first principles or duplicates the process of product development. Student participants in the workshop were also frustrated by the assumption of technical expertise when using information technology. Clearly, an appropriate balance must be found between "the human element" and the technological enhancement of effective pedagogy. Effective practices will also develop intellect and work skills that will serve graduates well beyond their academic studies (e.g., teamwork skills, effective communication, critical thinking, motivation). However, most workshop participants conceded that before these benefits can be fully realized, much more research is required on the learning process itself, including long-term longitudinal studies on the effects of technology-enhanced programs.

While many mechanisms for disseminating "best practices" in the use of information technology currently exist (e.g., journals, conferences, professional societies), there was a renewed call to change an academic culture that views research on education and the use of education technology as incidental or secondary to more traditional avenues of research. Innovative use of information technology and successful research on educational practices should be equally included within the professional recognition of faculty, not as a peripheral and unglamorous task for the most enthusiastic and inspired. Peer review and other means should be used to provide a measure of quality control and recognition. The best exemplars must be promoted widely, and beyond traditional disciplinary or institutional boundaries.

Colleges and universities must recognize that, increasingly, the influence and demands of their respective information technology ventures extend beyond the campus to include remote or distance learners, part-time students, collaborations with industry and consortia of other institutions. If the construction of a unified information technology infrastructure is to be cost-effective and responsive to the needs of all its users, the technology developed and implemented must demonstrate definable benefits to higher education. Specific education technology tools must also, as appropriate, be applicable across many disciplines or course levels, must operate reliably across many platforms, and be maintainable as the underlying technology changes.

Second-stage implementation funding of quality efforts, standardization of access, and a careful consideration of the benefits and pitfalls of prior attempts at similar outcomes will all help to ensure that the direction taken represents a unified effort with a minimum of backtracking or reinvention. Whatever the form or content of the national information technology infrastructure, the recognition and support of the National Science Foundation was seen as critical in identifying, coordinating, and representing impartially the various stakeholders involved.

Introduction

The past decade has witnessed spectacular improvements in the computational capabilities of calculators and computers, and more recently, stunning advances in their communication capabilities. The marriage of these two functional modes has produced powerful information technology tools that have important implications for undergraduate education in science, mathematics, engineering, and technology (SME&T).

- First, these tools can enable students to simulate, visualize, model, and experiment with complex, real-world scientific problems, thus promoting exploratory and inquiry-based modes of learning.

- Second, information technology¾ and within this broader designation, educational, instructional, or learning technologies, as applicable¾ can enable collaboration, interactive learning, and new pedagogical approaches that can lead to changes in the way students and faculty interact.

- Third, the rapid pace of change in information technology is increasingly impacting the creation, publication, and dissemination of educational materials.

- Fourth, there is a need to establish the true costs and implications of the widespread use of educational technology, as a distinct-yet-related component of the larger, national infrastructure of information technology.[1]

- Fifth, the use of information technology can, if it is made a high priority, increase access to high quality SME&T education.

- Sixth, information technology can facilitate connections across disciplinary, institutional, geographical, and cultural boundaries.

Taken together, the computational and communication capabilities of information technology offer great promise for supporting continual improvements in all aspects of undergraduate education. They also underscore the need for credible research into the practical benefits and limitations of teaching and learning in settings enhanced by information technology.

[1] A recent and comprehensive discussion of the national information infrastructure (NII) is provided in ***The Unpredictable Certainty: Information Infrastructure Through 2000*** (National Academy Press, Washington DC, 1996). The current workshop was convened to discuss implications specific to the application of information technology to education, and the ramifications for the education community. A distinction is therefore made to differentiate educational, instructional, or learning technology as components of information technology.

The existence of these powerful tools and their associated infrastructure has also led to questions that challenge the spatial and temporal boundaries¾ indeed the very form and purpose¾that have traditionally defined undergraduate teaching and learning. Information technology now offers the possibility for learning and teaching to take place in new settings and to inspire and facilitate lifelong education.

Against this backdrop it is also recognized that the backgrounds of faculty vary more widely than in the past, particularly in terms of exposure to and competency with information technology. The ways in which faculty conduct their classes and prepare material for classrooms and laboratories are changing. Students are increasingly expected and encouraged to bring new experiences and skills to the undergraduate classroom, especially as a result of changes in the practices of the K-12 community. Higher education must play an integral part in extending and enhancing the opportunities offered by the use of information technology in this complex and dynamic educational landscape.

To help provide guidance to the National Science Foundation (NSF) on issues of concern to the undergraduate community regarding the use of information technology and the possibilities it holds for enabling improvements in the undergraduate enterprise, a meeting was convened by NSF's Division of Undergraduate Education (DUE) on April 18-20, 1996, entitled ***Information Technology: A Workshop on its Impact on Teaching and Learning in Undergraduate Science, Mathematics, Engineering, and Technology Education***. This meeting brought together approximately thirty-five participants representing a cross-section of the broader undergraduate educational community, including faculty, students, academic administrators, publishers, and representatives from the information technology industry. The primary purposes of the workshop were:

- to identify examples of effective uses of information technology and education technology;
- to consider the impact of using information technology on various parts of the undergraduate enterprise;
- to investigate issues of dissemination and of evaluation that arise with the use of information technology; and
- to speculate on and help NSF anticipate the impact of future developments.

Workshop Organization

Prior to the meeting, participants communicated with each other in an open forum via electronic mail. This ***listserv*** enabled attendees to calibrate their vocabulary and experience the use of information technology, and to identify overarching themes and common issues in advance of the meeting. This exchange is summarized in Section I of these proceedings. The workshop itself was organized around a series of concurrent small group discussions. The format of the workshop and the questions used to facilitate

discussion are summarized in Section II.[2] Finally, the outcomes of these discussions and recommendations for a follow-up to this process are summarized in Sections III and IV.

The overall workshop structure is diagrammed in Figure 1 on page 13. In the first of four breakout sessions, participants gathered in groups representing their current or principal affiliation (e.g., a student group, three faculty groups, a publisher group and an academic administrator/IT professional group) to engage in discussion guided by two questions:

1. ***What comprises information technology and what are some general categories for organizing its components?***
2. ***In each of these categories, what is an example of "an effective use" of information technology?***

This session was followed by discussions on evaluation and dissemination criteria for information technology. Questions considered during this segment were:

1. ***What assumptions about the modes of learning or teaching underlie what is thought of as an effective use of information technology?***
2. ***What criteria are, or should be, used when evaluating the impact on learning or teaching of a proposed information technology tool?***
3. ***What criteria are, or should be, available to assess the degree to which information technology enables students to determine what and how they learn?***
4. ***What research questions[3] or issues are implied by the above questions?***
5. ***What criteria should be emphasized when evaluating a dissemination mechanism that proposes to exploit information technology in some way? Do these criteria change as new technology and tools are developed? If so, in what way?***
6. ***Are there new publication and/or dissemination paradigms afforded by the use of information technology, and if so, what criteria should be used to evaluate their effectiveness?***

Based on reports from this second session, themes for further discussion were identified by the participants, who organized themselves into a third set of concurrent breakout groups that focused on the following topics:

- Faculty development for the use of information technology;
- The consequences of using information technology¾ measurement, assessment, and standards;
- Sustaining communities of information technology developers and users;
- Non-traditional paradigms in teaching and learning fostered by information technology; and

[2] The discussion questions provided at the workshop have been nominally edited for presentation in these proceedings, to reflect the clarification and revision of verbiage and issues resulting from the group discussion.

[3] For example, research into the effectiveness of learning facilitated by information or educational technology, evaluation questions, etc.

- Dissemination of teaching and learning models enhanced by information technology.

During the last breakout session, participants focused their attention on future directions and recommendations, with a goal of developing a set of "needs for the undergraduate community" pertaining to the use of information technology. The following tasks and questions were posed to help facilitate the discussion:

- ***Identify four or five important needs and/or issues to be addressed by or impacting on the various constituencies in the undergraduate enterprise, given the*** current ***state of information technology.***
- ***Identify four or five important needs and/or issues to be addressed by or impacting on the various constituencies in the undergraduate enterprise, given possible*** future ***directions of information technology.***
- ***What research needs to be done to give validity to appropriate uses of information technology?***
- ***What are the implications of widespread use of*** current ***information technology on an institution's infrastructure, both human and financial?***
- ***What will be the implications of the possible*** future ***directions of information technology?***

This discussion continued via the ***listserv*** for several months following the workshop and we have tried as far as possible to synthesize and include these follow-up considerations in these proceedings. On behalf of the National Science Foundation, we wish to thank the workshop participants and the administrative staff for supporting this effort, and for helping to craft these recommendations for further courses of action.

The rapid and seemingly ubiquitous increase in “the role of technology” in the halls of higher education has raised many justifiable concerns – will technology displace essential person-to-person and face-to-face interaction? – will technology intrude on content? – is the rush to embrace tomorrow’s technology preventing us from analyzing and refining our use of today’s technology? – will time and dollars be spent on technology at the expense of less glamorous but more fundamental components of the educational enterprise? This workshop was convened to discuss the coherent, thoughtful, and responsible use of information technology tools together with other tools in the classroom. Our ultimate purpose is to assure and enhance the educational experience of students.

Lee L. Zia
Michael C. Mulder

Information Technology Workshop Organizing Committee
NSF Division of Undergraduate Education

April, 1997
Arlington, VA

I: The Discussion Begins

Two weeks prior to the meeting, a ***listserv*** was established to gain an understanding of the concerns of the invited constituents and their respective interests in the content of the upcoming workshop. It also served to reveal differences in vocabulary and thus facilitate discussion among the diverse assemblage of stakeholders.

Participants were asked to provide 2-3 major issues they would like to see discussed at the workshop. This section summarizes the more notable developments of the pre-workshop discussion in order to 1) place in context the agenda of the resulting workshop; and 2) present the issues of principal concern or "preconceptions" on the use of information technology in undergraduate education from the perspective of the various and distinct stakeholders prior to meeting to discuss a national perspective. The discussion was subsequently organized into several common themes, which serve as headings for the following subsections.

Definition of Terms

A concise definition of ***information technology*** was sought by many participants. Recognizing the breadth of materials and concepts suggested by such an "umbrella" term, ***information technology*** was taken to represent the confluence of telecommunication, video, and computing technology¾ or rather ***technologies***¾ which support a diversity of applications (e.g., microcomputer-based specialty software applications, video, multimedia, the Internet, World Wide Web, etc.). Alternately, the term ***educational technology*** was proposed, and offered to mean "the systematic application of human and technological resources in teaching and learning." Within educational technology, tools might further be subdivided into ***instructional technology*** and ***learning technology***, depending upon whether their use is centered in the delivery of material or its comprehension. For many workshop participants, learning technology was a preferred term, connoting as it does education centered in the students' experience. For the ensuing discussion, it was typically "educational technology" to which the correspondents referred, although the term was often used interchangeably with the more generic "information technology."

Access for All

There was a call for discussion about whether information technology can clearly improve the access of students to a quality education experience, or whether less-than-universal access will heighten the current disparity in facilities and connectivity. A "fair use" policy should be articulated to enable the maximum use of information technology for teaching and learning (i.e., educational technology, from the above definitions).

Benefits to Teaching and Learning

The benefits to teaching and learning related to the use of information technology at the undergraduate level should be identified. Once identified, strategies for implementing their maximum effect should be addressed. Are any ***new*** modes of teaching/learning particularly facilitated by information technology? At least one ***listserv*** participant called for more research into the demonstrable effects of using information technology to

facilitate learning. Further, what effect is the World Wide Web and the assorted campus intranets having on today's institutional culture?[4]

Experience and Expertise

How can faculty be engaged and encouraged to use information technology, and once so inspired, to use it properly and to the fullest potential? Who should be responsible for educating students and faculty in the use of educational technology, and in what context? For their part, students should be inspired to become ***producers*** of information, not simply consumers or interpreters of the efforts of others. As with any teaching/learning device, information technology tools can be used in different ways by different people in different contexts. They can be misused or used improperly, propagating the same ineffective practices in new ways. How can we ascertain true ***interaction*** in the student's learning experience, and whether the application of information technology is serving to educate and inspire, not simply entrance. Conversely, the effective use of information technology not only enhances the quality of the educational experience, but may also aspire to "level the playing field" between institutions as well as between professors and students. Beyond academe, there is an increased need for partnerships between colleges and universities and the business community. Industrial growth can be limited by an insufficient supply of "technically savvy, professionally agile" graduates; conversely, institutions often lack the funds and facilities to provide their faculty and students with hands-on experience with leading-edge technology in the latest industry applications.

Infrastructure for Information Technology

At the nexus of the infrastructure issue was the question of how to establish and maintain a system that efficiently meets the current requirements of an institution or institutions, can be broadly implemented, and will be flexible and accommodating to the technologies of the future. Who shall be responsible for developing information technology tools (e.g., authoring systems) so as to optimize the cost/benefit of using information technology in teaching? Are academic institutions assumed to be the nucleus of this "new education"? What preparation, training, facilities will be needed to assist departments and faculty to make the best use of information technology? In many cases, entire curricula may need to be redesigned, from those that rely on passive (e.g., lecture style) formats to those employing active, hands-on methods. Installation and upgrading (of facilities, computers, peripherals, network connections, software) also requires firm commitments to educational technology by the institutions themselves ¾not only financially, but in consideration of the time required to install and maintain these devices. How will the use of such technologies modify the notion of a "university" and how might the tripartite role of computers¾computation, communication, and collaboration¾redefine learning environments? If the promise of the Internet includes the "virtual" university, how can we ensure that the quality of teaching and learning is improved as the mode of education is transferred from a central classroom to individual remote locations? Undergirding the entire discussion of "structure" were issues familiar to non-educational applications of computer technology, namely cost, authentication, access and security.

Information Technology in the Classroom

"Using information technology changes the timing of information flow in a class," noted one participant, citing the example of a question or issue that could be presented at the

[4] The boon of electronic mail and World Wide Web browsers were specifically named by the ***listserv*** correspondents as information technology devices with an immediate and demonstrable benefit to the educational community.

end of one class, then discussed via e-mail or bulletin board before the next class, enabling the use of class time in new or different ways. A counterpoint to this is unreliable or temperamental technology¾such as a teleconference or particular software¾that fails to perform when needed, and consumes class time with technical problems. Additionally, a call for e-mail responses to a given issue may produce more spontaneous replies, but this input is rarely as thoughtful and well constructed as traditional writing assignments. As other examples, graphing calculators, animation software, and video can all be effective for illustrating and engaging students to abstract or complex processes, but the ***understanding*** of those processes is not necessarily revealed on later exams or in group discussion. The assumption that the enthusiastic use of "educational" technology correlates to improved retention and conceptualization is not always valid.

Dissemination and Rewards for Successful Efforts

There was a call for making more effective use of the World Wide Web for disseminating materials, including those products developed with NSF support. In a related discussion, there was a call for proper rewards for those who develop quality materials and concepts that become adopted widely. As with successful practices not based in technology, there is also a need for increased collaboration and sharing of ideas, nationally as well as internationally. The notion that successful efforts ***should*** be disseminated is a popular one; the real issue is ***how*** such dissemination is to occur.

Roles and Responsibilities

Of Institutions and Administrators¾Many instructors are already extremely knowledgeable in the potential and use of information technology in the classroom, and as with any "labor of love," are willing to commit the time and resources required to achieve the desired benefits; this level of comfort and enthusiasm is far from wide-spread on campus, and many ***listserv*** correspondents suggested the need for a commitment by administrators to support technology in education, and reward those faculty who effectively implement such tools. Specific rewards mentioned included: hiring/promotion, tenure qualification, funding, and administrative encouragement¾each contingent upon clear evidence that use of the technology provides an educational experience that enhances and extends the use of traditional textbooks and lectures.

Of Instructors¾It is the purview of instructors to ascertain how information technology can be used by instructors to maximize the benefit of the students. Is information technology seen as an inevitable replacement for traditional instruction methods, or a tool used primarily to facilitate understanding of complex or intangible subjects? Instructors must not allow their principal role in the classroom to become little more than a monitor of workstations, providing assistance in interpreting the output of educational machines.

Of Students¾In consideration of the rate of change in information technology, how can students be instructed on the use of today's currently available tools and also engaged in the design, creation, and application of the next set of such technologies? Increasingly, students will need to apply evaluative and critical thinking skills to select useful tools and quality content from the ever-increasing deluge of "data" purveyed to them.

Of Society¾How will the widespread use of information technology in undergraduate education be understood and accepted more broadly in the social, political, and ethical context of society at large? How will the new generations of "knowledge workers" from a technology-based curriculum be viewed by those (faculty, employers, parents) who

presume a college graduate should have a thorough tutelage in "fundamental content" in addition to current and relevant technology skills for the workplace?

The volume and variety of commentary in the pre-meeting exchange presented workshop organizers with a formidable task: producing a short (but representative) list of issues addressing the most critical concerns and issues for detailed discussion. Finally, however broad-based or point-specific the conclusions and recommendations on the use of information technology in undergraduate education intend to be, the caveats accompanying them are not without historical precedent. As Steve Ehrmann[5] suggested:

> "It's useful to think about the impact of previous technological innovation on the education of their day (e.g., the impact of writing on the oral education of Socrates' day; the impact of the invention of the campus on education that had depended on individual tutors.) You don't need to be a historian to see just how wonderful and destructive those earlier innovations were. The issues they raised are similar in many ways to the issues raised by this newest round of technology: some people gained access while others lost, power was transferred from some people to others, some intellectual abilities were emphasized while others were de-emphasized, some faculty jobs were threatened while others were created, the nature of "content" itself changed, etc. …"

[5] Then with the Annenberg/CPB Projects, currently with the American Association for Higher Education.

II: The 1996 Information Technology Workshop

The workshop was convened on Thursday, April 18, 1996, at the National Science Foundation (Arlington, VA) and opened with exhibits and demonstrations by several participants (see Appended list).

Opening Remarks and the Charge from NSF

This meeting will continue the discussion already begun on the use of information technology in the educational experience of undergraduate students. What is really meant by "information technology"? What are the unique needs, concerns, and desired outcomes required of information technology from educators and students? What are the costs, benefits, and necessary requirements involved in wide-scale, long-term implementation of information technology in our colleges and universities? How will such advances change the quality of the students' experience, not only while on campus, but as they move on to become employees, parents, educators, business leaders, politicians, and the future leaders of this country. Finally, how can NSF best serve this community to ensure that its programs and activities adequately represent the collective interest, as represented by its allocation of resources and the direction of future programs and initiatives?

These are among the questions to be considered over the next few days. At the end of the process, we hope this exchange helps all of us craft some tangible recommendations for "next steps" and future discussions on this subject.

Description of the Breakout Groups

Workshop participants were assigned to one of six working groups, which met over four thematic breakout sessions. Each group was charged with preparing and presenting a summary of the group's deliberation. For three of the sessions, this discussion was based on a set of guiding questions provided by the workshop organizing committee; in the fourth session, items of particular concern to the group were discussed. A group leader then presented the breakout group's findings to all participants during the plenary sessions.

- ***The following sections summarize the outcomes and recommendations of free-ranging, multifaceted discussion directed by the groups themselves. For clarity in presentation for these proceedings, the groups' comments and conclusions have been combined and organized into the resulting common, overriding themes. The subheadings and division are therefore those of the participants, not an itemized list prepared by the workshop organizers.***

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April 18-20, 1996

National Science Foundation
Arlington, VA

Workshop Agenda

Thursday, April 18

5:30 - 6:30 PM	Reception.
6:30 -7:30 PM	Demonstrations/Exhibits.
7:30 - 8:00 PM	Welcoming Remarks and the charge from NSF.
8:00 - 9:15 PM	Breakout Session I: ***Background-specific working groups for initial discussion and group "calibration" on important categories of information technology use.***

Friday, April 19

8:00 - 8:45 AM	Plenary Session ***Reports from Thursday evening breakouts***
9:00 - 11:15 AM	Breakout Session II: ***Groups meet to consider initial set of questions/themes. Evaluation of effective uses of Information technology for teaching and learning and evaluation of effective uses of information technology for disseminating material and information.***
11:30 AM - noon	Plenary Session ***Groups report on preliminary recommendations and criteria, and identify 2-3 themes for further discussion in the afternoon session.***
1:15 - 3:30 PM	Breakout Session III: New "thematic" groups convene
3:30 - 4:00 PM	Plenary Session ***Summary reports from thematic working groups***
4:00 - 5:30 PM	***Further discussion by thematic groups, initial development of recommendations.***

Saturday, April 20

9:00 - 9:15 AM	General Announcements
9:15 - 11:30 AM	Breakout Session IV: ***Breakout Session II groups reconvene to consider future directions for information technology and develop recommendations.***
2:00 - 3:30 PM	Plenary Session ***Final summary reports and discussion.***

Figure 1: Workshop Structure, Exchange of Ideas, and Constituents

Day 1

Breakout Session I - ***"Birds of a Feather" Discussion***

Students | Faculty #1 | Faculty #2 | Faculty #3 | Publishers | Administrators & IT Professionals

Day 2

Breakout Session II* - ***Thematic "Drive" Discussion (diverse composition)***

Overlying Assumptions | Evaluation Criteria | Research Issues | New/Revised Paradigms | Review of Effective Practices

- What are effective uses of IT in teaching and learning?
- What are effective means of information dissemination using IT?

Plenary Session/Review Discussion

Breakout Session III - ***Further Thematic Discussion (diverse composition)***

Faculty Development for using IT | Defining Outcomes of using IT | Sustaining a Community of IT Users/Developers | Standards for Reviewers | IT Influence on Learning Paradigms | Dissemination of IT-enhanced education

- Development of Preliminary Recommendations

Plenary Session/Review Discussion

Day 3

Breakout Session IV* - ***Future Directions***

Stages of Systemic Reform | Critical Issues in the use of IT | Current Issues in IT use | The Needs of Academic Institutions | Faculty Development | Campuses and the IT infrastructure

- Reconsideration of Individual Assumptions/Perspective
- Draft of Recommendations

* Composition and membership of groups in Sessions II and IV was the same.

Breakout Session I:

Perspectives of the Constituencies

Thursday, April 18 (PM)

Overview

This initial "birds of a feather" session brought together participants with similar perspectives in the use of information technology to build on the pre-workshop electronic correspondence and identify some basic categories for organizing and classifying the use of information technology relative to teaching and learning. A specific intent was to define a common vocabulary that could be carried forward in the subsequent workshop discussion.

Guiding Questions

- ***What comprises information technology and what are some organizing categories?***
- ***Within these categories, what is an example of "effective use" of the technology?***

Outcome of the Discussion

Defining Information Technology¾

- ***Information technology*** broadly includes the computing infrastructure, the communication infrastructure, and by extension of these, the institutional infrastructure (e.g., multi-campus consortia) and the instructional infrastructure (a range of courses from small classes taught by one faculty member to large, team taught or distance learning courses).
- ***Educational technology*** includes the application of information technology to assist in the delivery of information within the educational system.
- Within the designation of educational technology, ***learning technology*** specifies applications centered in the experience of the student, while ***instructional technology*** is centered in the delivery of material by the instructor.
- Categories derived to organize or differentiate the above should be based on the function of the technology, its intended user, and the goal of its use.
- Other considerations include the process of the tool (directed/open-ended), mechanism of delivery (synchronous/ asynchronous), and medium for carrying information.

Note: The generic "information technology" is used throughout these proceedings, however as applicable to the workshop discussion, it should be considered equivalent to "educational technology," as defined above. Learning and instructional technology are mentioned only relative to specific tools or applications.

Information Technology is Used to Enable¾

- Communication, interaction, and collaboration.
- Computation, visualization, simulation, and data modeling.
- Instruction, tutoring, and mentoring.
- Gathering and filtering of data, consolidation of information, and derivation of knowledge.
- Combinations of the above instantiated as multimedia, multimodal applications.

Information Technology has the Ability to¾

- Provide access to world-wide resources.
- Facilitate the accumulation, generation, and presentation of data.
- Provide tools for analysis and modeling of more or deeper and more realistic examples in a short time.
- Enable inquiry and extend the human capability to visualize, organize, and analyze data.
- Provide immediate feedback to the student, either from the technology itself or the facilitator/instructor.

Effective Use of Information Technology is Characterized by Applications that¾

- Stimulate students and engage them with the material, such as role playing simulations.
- Illustrate the workings of complex systems by exploring cause-and-effect relationships, or demonstrate microscopic, molecular, or hypothetical scenarios.
- Encourage collaboration with other individuals, teams, or institutions to coordinate a group effort while exposing students to different ideas and perspectives (e.g., electronic mail for communicating with classmates or instructors).
- Foster development of critical thinking skills, visualization, conceptualization, integration of disparate data and resolution of patterns within data.
- Utilize the World Wide Web for research, advertising, and posting material.

The above are possibly best used to extend, supplement, or re-enforce more traditional presentation formats, not to replace them. A basic pedagogical principle carries across all levels of technology: ***involving*** students in the process and design of exploration in all fields.

Other examples of effective use include: tutor/mentor applications, modeling, electronic publishing, independent and non-linear processes, and global access to information.

“Effectiveness” is determined by how the application defines and achieves the intended outcomes of its use, the ease with which its use is facilitated, and by extension, a minimum of learning or set-up requirements by the user. However, the increased use of technology does not necessarily equate to more effective teaching.

Ineffective Use of Information Technology is Characterized by Applications that¾

- Assume or require advanced levels of technical expertise, or are vague or counter-intuitive to the user.
- Are unreliable or require continuous, extensive, or unreasonably precise maintenance.
- Provide only "high tech alternatives" to traditional materials such as textbooks or blackboards
- "Promote interaction," but deliver one-way or broadcast presentation of material.

Similar effective and ineffective attributes could be applied to the ***implementation*** of applications.

Suggested Indicators of Effectiveness¾

- Intuition/satisfaction of the instructor.
- Student evaluations.
- Reduced attrition/failure.
- Increased grades and test scores.
- Revelation and correction of misconceptions.
- Students "turned on" to the ***material***, not to the technology for its own sake.
- Retention of fundamental/essential material.
- Increased opportunity for exchanging feedback between instructors and students.

Additional Issues Raised¾

- How do we evaluate and support the development of lifelong learning, especially in light of the potential of the World Wide Web to enable "anytime and anywhere" access. For example, more attention should be paid to "just in time learning" and the role of colleges (if any) in providing it.
- Campuses are increasingly using resources off-campus and serving students who are off-campus. Many issues need to be addressed by campuses, for example, broadband net access in the surrounding community, redefining what their students do while on campus, and what those same students do when studying off campus.
- Community colleges typically have few students living on campus so broadband Internet access in the community will become more important for working adult learners than for students living in residential institutions. Without this broadband access, information technology uses will tend to be restricted. Student ownership of computers (or the lack thereof) are similarly more important to community colleges and comparable commuter institutions since students cannot afford to spend much time on campus. These are

perhaps half of all undergraduates, so, as information technology use increases, serious equity problems may well emerge.

- Smaller colleges, facing increasing information technology costs and other costs, will face pressure to specialize their offerings and use information technology to collaborate with other, sometimes distant institutions to collectively offer a broad curriculum to their students.

- Large institutions will need to expand their markets. Well-known institutions will face increased, net-based demand (worldwide) for their services. Fixed costs can be more easily amortized with larger numbers of students.

- Institutions will have increased opportunities to employ high quality, part-time staff at off-site locations.

- Administrators need to be convinced of the positive benefits of using information technology in higher education. Tangible and practical plans for uniting the effort, training, and pedagogical missions across entire institutions must be found, and demonstrated.

- New technologies should employ new techniques that best utilize them. Information technology should not be considered as a “one size fits all” panacea.

- Overarching challenges include those of curricular coherence, quality, and control.

Breakout Session II:

Evaluation and Dissemination of Information Technology

Friday, April 19 (AM)

Overview

Workshop participants from a wide variety of constituencies in the use of information technology met to discuss the notion of effectiveness and dissemination of best practices. Of particular interest were the mechanisms by which information technology resources can be critically reviewed, then easily adopted and implemented elsewhere. The context of this evaluation should extend beyond defining "what works" to a critical assessment of which information technology resources are in need of further development, and how these successes can be used in the construction of a national infrastructure for the use of information technology in education, and potential governance of its use.

Guiding Questions

- ***What assumptions about the modes of learning or teaching underlie what is thought of as an effective use of information technology?***
- ***What criteria are, or should be, used when evaluating the impact on learning or teaching of a given information technology tool?***
- ***What criteria are, or should be, available to assess the degree to which student determination of their own learning process is enabled by information technology?***
- ***What research questions or issues are implied by the above questions?***
- ***What criteria should be kept in mind when evaluating a dissemination mechanism that proposes to exploit information technology in some way? Do these criteria change in the face of possible future directions that information technology might take? If so, in what way?***
- ***Are there new publication/dissemination paradigms afforded by the use of information technology? If so, what criteria should be used to evaluate their effectiveness?***

Outcome of the Discussion

Characteristics of Effective Modes of Learning¾

- The experience is centered in the student and relevant to his/her experience and expectations.
- The expectations/goals of the instructor are articulated clearly and rewarded appropriately.
- Collaboration and effective communication is needed between students and each other, their instructors, and their teaching assistants.
- While the individual is independent and self-reliant, work should be collaborative and team-based, with unique and balanced contributions by all members of the group.

- Inquiry is non-linear, guided by the interests of the user. However, frequent testing and assessment of the student's progress should also be included.

- The material should provide a choice of representations, cognizant of a variety of learning styles. Such things might include how the material is depicted, the level of background knowledge assumed, or the depth of possible inquiry. This is one way in which "high level" topics can be included in "lower level" courses.

- The experience should inspire further or life-long inquiry.

- Authentic learning and social interaction are included as part of the process.

- Although several participants felt that fundamental or essential topics should be delivered and understood before being supplemented or enhanced with information technology, the use of information technology as a means of enhancing the primary learning experience was also viewed as an area with great potential.

Identification of Effective Learning Materials¾

- The identification and rejection of bad products is much more obvious than differentiating between good and ***very*** good products.

- Web site "traffic," number of product downloads, content and volume of feedback to the author can all provide indications of a product's merits.

- The technology is appropriate and applicable to the problem or concept being addressed.

- The ease of use, compatibility, expendability, adaptability, and authoring/development support of the technology should also be considered.

Methods of Classifying Effective Learning Materials¾

- The desired outcome of exposure needs to be defined and evaluated. If desirable skills include problem-solving abilities, teamwork skills, communication skills, etc., these aspects must be what is evaluated, as by standardized tests.

- The problem, process, and outcome of the procedure is clearly presented.

- It is probably acceptable that not all products are peer reviewed, but where review occurs, the process is reliable and consistent.

- Is the technology cost-effective? Does it add value to the educational experience? Is the assessment of learning consistent with the approach and presentation of the material?

- It is difficult evaluating the true effectiveness of any teaching method until a satisfactory definition of ***learning*** is implemented.

- Can the expectations and experiences using information technology at different types/levels of institution be expected to differ, as it does for traditional teaching methods? Is any learning tool equally effective in a wide range of settings, or like other pedagogical methods, does its effectiveness depend not only on product design, but on the efficacy of the instructor, the context of the presentation, and the learning style(s) of the individual

student.

Participatory Design in Innovation¾

- The students should be considered not only as “end users,” but also as developers, field testers, and evaluators/reviewers.
- Developers and purveyors of information technology should never lose sight of the excitement of discovery and revelation on the part of the student.
- The technology should be transparent relative to presentation of the material. The user cannot be expected to learn computer skills in lieu of the subject matter.
- Publishers need to redefine their traditional role, become more involved in the development of products, and in the project cycle.

Innovation Must be Developed and Sustained¾

- Interest in information technology is currently experiencing an upsurge of public support and interest, however this will be short-lived unless the technology can deliver demonstrable results in a cost-effective and productive manner.
- “Celebrate what resonates.” Successful innovation needs to be passed to a larger community, for example, via professional societies to their members.
- Would-be innovators should first be well-familiar with previous efforts in their area of interest.
- As the next generation of faculty, graduate students have an important role in the process and should be included as developers, educators, testers, and disseminators.
- User friendly “tool kits” that allow the translation of various materials onto a common platform would be a valuable asset to the academic community.
- Collaboration that fosters partnerships and links together similar or complementary initiatives should be encouraged.
- While such features as “engaging the student” and “inspiring life-long learning” are considered desirable, there exists little in the way of longitudinal studies to evaluate this kind of impact for programs using information technology.

Guidelines for Effective Dissemination¾

- Be wary of catch-all solutions leaving the issue of dissemination to one technology, or waiting for “market forces” to drive adoption and implementation.
- Ensure that appropriate faculty training is included at testing sites.
- Encourage presentation, as appropriate, to professional organizations, conferences, and workshops. The dissemination process and partners should be identified in the early stages of “product” development.

- The World Wide Web is an effective mechanism for dissemination for such things as images, text material, and technical support. Conversely, most software is still “too fragile” for Web distribution.

- Provide feedback to the authors/developers over the Web. While the Web offers instant and comparatively inexpensive publication of materials, too many products are allowed to become “stale” or out-of-date due to a lack of maintenance or revision of the content.

- Web-based products should be modular in design, and available to be monitored or reviewed. Further, will the peer review process slow the process significantly, or will it focus attention on the quality work being done while weeding out the “junk.” Could a newsgroup consisting of experienced users provide a more timely and relevant review than a single recognized adjudicating body?

Breakout Session III:

Thematic Discussion

Friday, April 19 (PM)

Overview

The theme of this breakout session was identified by the participants themselves in the course of the discussion.

Guiding Questions

- ***Two-to-three important issues and/or questions were identified by each group the previous day, for further discussion at this session. These issues are summarized below.***

Outcome of the Discussion

General Issues in the Use of Information Technology¾

- There is more research needed on how people learn, certainly from information technology, but also from each other, and how these systems really compare to the traditional methods that some argue are inadequate.

- Increased research is required into the effectiveness of information technology in the classroom.

- How is information technology-enhanced learning different than other learning programs? And, if such enhancements are demonstrably better, how can these benefits be communicated to other faculty, institutions, and the potential employers of undergraduates?

- Any set of prescriptive recommendations will depend upon the intended 'user group,' and the breadth of that group¾as across an institution, a particular discipline, or as a requirement for a given course.

- A three-to-four-year process in implementation and dissemination may be too slow to make the best use of whatever information technology is available.

- A cadre of developers and users must be sustained, and coordinated between institutions. Publishers should help to find and define an "author pool."

- For innovations to "survive," it will require a more concerted effort by professional societies, journals, and the support of agencies such as the National Science Foundation.

- Performance, quality control, and standards for information technology developers deserve further attention.

- The specific economic benefits and profitability of information technology-enhanced teaching and learning have to be presented to faculty, academic institutions, and industry alike.

Local Implications for Institutions¾

- Outcomes must be defined, including measurement, assessment, and standards for effectiveness and competency. This competency must be evaluated both in terms of generic improvements in learning facilitated by technology, as well as specific skills in the use of technology (e.g., database design, statistical analyses, systems administration).

- These outcomes should be consistent and coordinated between all stakeholders in the production of graduates competent in the use of information technology.

- If faculty are encouraged to adopt or adapt information technology tools, the institution must allow faculty time/leave for training, research, support, and follow-up activities.

- The new or unique teaching and learning paradigms inherent in the use of information technology must be recognized and addressed. Restructuring of the institution both locally and globally is implicit in such considerations.

Global Implications for Institutions¾

- How can the "learning curve" of institutions that have successfully and widely implemented information technology be communicated and emulated by other institutions?
- Best practices in information technology-enhanced teaching and learning must be disseminated, as well as details on the lessons learned from implementation of ineffective practices.
- Evaluation of information technology must include not only the educational content of the materials, but its effectiveness at various types of test sites and over the long term, as determined in longitudinal studies.
- With the proper encouragement, boundaries between institutions and courses will lessen. Access to primary sources of effective information technology-enhanced material, as in a national "library" with a common user interface, would greatly facilitate and expedite this convergence.
- NSF endorsement or recognition of the successful integration of learning technologies into the curriculum will be an effective catalyst for change on campus. Funding efforts to communities may be more effective than to large, individual projects.

Faculty Development¾

- Information technology must be made more accessible to faculty, and facilitated not only by proximity and ease of use, but also by professionally recognizing its use, and supporting or rewarding these efforts accordingly.

- There is a need for information technology that assists faculty, such as authoring or communication applications.

- Support for faculty development beyond individuals¾ to departments, colleges, and whole institutions¾ is also required.

Implications for Students¾

- More students, and a more diverse representation of all students, need to be prepared in

the use of information technology. This preparation necessarily includes exposure to modes of learning enhanced by technology, as well as specific skills to be used in further study and in the workplace.

- Student access and exposure to information technology has benefits that extend well beyond the classroom.

- Benefits and desirable skills resulting from an information technology-enhanced education should include: the ability to address complex problems, communication, teamwork, critical thinking, motivation, professional intuition, and a desire for inquiry.

- The success of a given application of information technology should be evaluated not only on the degree to which the student is engaged by the technology, but also in the learning/work skills it develops, notably such things as problem-solving, teamwork, and a desire for life-long learning.

- Industry needs to be more consistent and longer-term in the base of general technology skills they expect graduates to possess, as well as specific skills in the use of information technology, if relevant.

Issues for "Effective Dissemination"¾

- For an information technology tool to truly be widely implemented, a common, cross-platform user interface must be defined and implemented. Single- or specialized-use Information technology should be examined especially critically.

- Products that are under-used, employ a different language, are user-unfriendly, or ineffective obviously exist. Rather than hiding these shortcomings, make them known and propose how it could be improved.

- Dissemination should be a consideration of information technology products from the outset. Promising proposals should incorporate projects ideas for effective dissemination, and prepare for a long-term commitment.

- Publishers should be involved sooner in the product cycle, but should not be expected to fund the entire process. Recognition/funding by NSF of quality products could initiate a partnership with publishers early in the development.

- ***Dissemination*** can include such low-tech methods as word-of-mouth, Web broadcast, and "freeware," but proper support and instruction on the use of the product is also necessary if it is to be adopted and implemented easily and without repetition of steps.

- Support for successful innovation should include second-stage implementation grants.

Breakout Session IV:

Future Directions and Recommendations

Saturday, April 20 (AM)

Overview

In the second generic breakout session, participants were given the additional charge, to develop a set of "goals for the undergraduate community" with regard to the use of information technology, perhaps targeting its various constituencies (e.g., students, faculty, industry/business, campus administrators). These goals would be developed under the assumption that they would present areas or opportunities for NSF to exercise leadership in the use of information technology to improve teaching and learning in science, mathematics, engineering, and technology.

Guiding Questions

- ***Identify 4 or 5 important needs/issues to be addressed by or impacting the various constituencies in the undergraduate enterprise, given the*** current ***state of information technology.***
- ***Identify 4 or 5 important needs/issues to be addressed by or impacting on the various constituencies in the undergraduate enterprise, given the possible*** future ***directions of information technology.***
- ***What research is needs to be done to give validity to what might be termed an "appropriate" use of information technology?***
- ***What are the implications of widespread use current information technology on an institution's infrastructure, both human and capital? What will be the implications inherent in the possible future directions of information technology?***

Outcomes of the Discussion

Research Efforts Should¾

- Determine which components of the learning process are enhanced by the application of and information technology tool.
- Identify the potentially negative aspects or impact of using information technology in learning.
- Determine how information technology may change certain learning styles, or foster new ones.
- Study existing successful models and determine what makes them successful.
- Study information technology products potentially adaptable to a variety of learning styles.
- Determine the impact of information technology on student assessment.

- Compile and categorize these results.

Evaluation Efforts¾

- Must be open to unexpected outcomes, and consider both the positive and negative implications of using information technology for teaching and learning.
- Should begin early in the product cycle, with test sites, pilot programs, prototypes, and mock-ups.
- Can be created by continuing feedback on appropriately designed products.

Table 1: Information Technology on Campus

	Infrastructure/ Equipment	Access/Usage	Required Staff/User Support
Communication	· Telephone · Voicemail · Electronic mail · Videoconferencing	· Electronic addresses · List servers · Website URL	· Telecommunications
Instruction/Research	· Network Connections · Display Capabilities	· Electronic homework · Electronic collaboration · State-of-the-art labs · Plug-in classrooms · Paperless courses	Models and training n: · Equipment · Software · Graphical/technical
Administration	· Faculty/Physical Plant	· Course Descriptions · Research Opportunities · Records	Coordination · Across Departments · Among Institutions
Libraries/ Research Collections	· File Servers · High-level connections · Virtual sites	· Search/Retrieval · Office, classroom, and public/off-site access	· Electronic journals · Electronic references

The discussion identified the minimum currently-available technology that should be available to all undergraduates throughout the country, suggesting the future developments to be built upon this structure. Answering machines, e-mail, and list servers can facilitate communication among students and between students and faculty. Access to the World Wide Web allows enhanced potential for research and permits an economical venue for posting class materials. Faculty have access to presentation/graphics software, A/V projectors and screens, and support/training for such things as Web authoring and telecommunications. Laboratory presentations present the best (most effective) examples of demonstrations, while “plug-in classrooms” allow full connectivity to workstations and laptop computers. Remote access from dormitories, public facilities, and home is also assumed.

To Facilitate Widespread Impact of Information Technology¾

- The response time of faculty and institutions to changes in tools and applications must be reduced.
- The need for up-to-date technology should not assume increased equipment costs.
- Duplication of equipment and resources must be reduced.
- Access must be dependable, and consistent among providers.
- Departments and programs must become integrated.
- The roles and responsibilities of faculty, students, and administration must be redefined.
- More collaboration is necessary between academic institutions and industry.
- Prevailing social, ethical, and professional attitudes of all constituents need to be revised to consider the use of information technology in education.

Issues for Education-Based Constituencies to Consider in the Use of Current ***Information Technology¾***

- Support for the development of classes/laboratories that engage and interact with students.
- Faculty enhancement and student development in the use of information technology through training/learning centers and educational support technicians.
- Authoring/development tools that facilitate translation of materials more easily, and support for the use of these tools.
- Guided, organized, and intuitive access to information.
- Inequity of access to information technology-based learning.
- The true costs of information technology and who bears these costs.
- Small colleges will face pressure to specialize their offerings, and network these to partner institutions.
- How will quality be maintained as prestige institutions face disproportionate demand for their services?
- How will institutions respond to the opportunity to hire distance faculty, and will this lead to increased faculty employment, an increase in part-time or as-needed assignments, or a concentration of employment of those faculty most in demand?
- All institutions will be challenged in terms of lowering the boundaries between courses, curricula, and institutions, control and accountability.
- Access to information technology must be broad-based, extending off campus. Commuter

institutions will face more rapid and substantive changes than residential campuses.

- The expectations and process of learning off-campus versus on-campus must be addressed.

Issues for Education-Based Constituencies to Consider in the Use of Future ***Information Technology***¾

- Cost of the future information technology infrastructure.
- The role/mission of the university.
- The role of the professor¾ to that of a leader/coach in a dialogue or problem solving exercise, more cognizant of societal needs and those of the workplace.
- Universal and equal access to learning, and how this will affect the leadership of the United States in education and research.
- Information technology as a facilitator for interdisciplinary integration and communication.

Faculty Development in Information Technology¾

- Information technology increases the variety of needs for training, including: the use of information technology itself, applications, teaching techniques, evaluation of available materials, indexing, and the training of graduate students.
- This development requires multiple sources of support, including individual faculty, departments, institutions, professional societies, industry, government, and foundations.
- Faculty development must be long-lived via communities of support.
- Innovators must aspire to, and be rewarded for, increased efforts for dissemination of effective technology to commercial publishers and via professional societies.
- The change in culture and infrastructure required can only succeed through long-lived support groups and communities that span institutional and disciplinary boundaries.
- Wherever possible, the training should include hands-on use and application of the technology being discussed¾ don't lecture about the evils of a lecture!
- Beyond the innovators and those willing to implement information technology (with or without proper support), there will invariably be a certain class of faculty who will resist any kind of change.

Courseware¾

- The costs of information technology (and non-information technology) courseware must be reduced.
- If costs cannot be reduced (as by smaller/cheaper books, Web-based "freeware"), can the use of texts and software be extended beyond a single course or laboratory by a more

seamless or sequence-based curriculum?

- What is the potential for server-based shareware, databases, etc., either between classmates or institutions? What is the potential for using the employee education model of the corporate community, or having them share/subsidize the cost of producing graduates with the skills they most desire?

- Industry and academe should communicate and collaborate on which forms of information technology are used, and at what level of proficiency the student is expected to perform. These expectations should be realized in the use of compatible platforms and a more coherent transition in the use of information technology between school and the workplace.

Issues of Coordination Among Stakeholders¾

- User groups, faculty, institutions, publishers, employers, professional societies, and funding agencies are all involved, and equally responsible for, the evaluation, appropriate use, and implementation of information technology in support of learning.

- If institution-wide reform is a desired outcome, the parameters for proposals and their review must be considerate of more disparate collaborations, as with schools/colleges outside the SME&T ranks (business, the humanities), and shared fiscal responsibility with industry and the community.

- Tele/videoconferencing and access to the World Wide Web provide good examples of such coordination with contemporary technology.

- With the promise of distance learning, and the presence of students on campus increasingly part-time, the influence and access to information technology must extend beyond the academic institution into the community.

- The reform process might be described as a four-stage process: ***Initiation***, which for information technology included the innovators and visionaries of the 1960's and 70's; ***Contagion***, or the promotion of information technology as "a good idea" through the 1980's and 90's; ***Coordination***, where the use of information technology becomes standardized and widely available; and ***Integration***, where the cost becomes nominal and access to the technology becomes assumed, even commonplace.

Other Issues Related to the Use of Information Technology¾

- The balance between the use of technology and "the human element" of pedagogy must continually be considered, and determined relative to the true effectiveness of teaching and learning.

- Will information technology ultimately enhance integration between disciplines, departments, institutions, and reduce the amount of inequity in the access to higher education; or

- Will it amplify existing disparities, and create increased competition?

- How can the benefits of information technology be increased while reducing the costs of using it? Is subsidized R&D required? Models for affordable technology should be

presented widely.

- While the use and perceived need for information technology is soaring, the requisite budgets for support and maintenance are not keeping pace, and the problem is becoming a crisis.

- The information technology infrastructure is not free. The funding and competition for funds is a certainty; the direction of this financing is less certain. Profitability and cost-effectiveness do not assume a reduction in staff and other human resources.

III: Follow-up to the Workshop

The Post-Workshop *Listserv* Discussion

Within days of the workshop, participants resumed their correspondence on the ***listserv***, based on the major issues and themes arising from the discussion. Among these were:

- the need for faculty development, both for users and creators of information technology resources;
- the increased need for a human and capital infrastructure associated with information technology and their associated costs;
- evaluation of the use of information technology; and
- the need for more research on the learning process as well as learning technologies.

NSF organizers provided "seed questions" for the discussion, including

1. ***Given these issues (above), what subsets of the various constituent types representing the undergraduate enterprise ought to be included in this discussion, and how might these partners work together effectively?***
2. ***What are the different scales (both temporal and administrative) for possible solutions?***

Defining Information Technology in Higher Education¾ Pace University's Jeanine Meyer broadly divided information technology into ***discipline-specific tools***, ***general productivity tools***, and ***instruments for pedagogy***. With discipline-specific tools (e.g., engineering, data modeling, and "bench science" programming) the issue of faculty development then becomes more discipline-specific, and dissemination/training/evaluation could be facilitated and coordinated by professional societies. A caveat to this designation is not to make this pipeline too discipline-specific. Often a given technology is equally, if not more, effective in an entirely different realm than its "intended" one.

General productivity tools (e.g., e-mail, listservs, presentation software) are widely available, but still require proper technical support and instruction to be widely adopted. Much of this kind of technology includes "business" software, which has experienced its own learning curve in being disseminated and implemented in the business community¾ collaboration between industry and academe could do much to reduce the amount of "reinventing the wheel" to be done. Instruments for pedagogy, for their part, could be evaluated by research on learning and disseminated/supported through national and state teaching associations and accreditation boards. Except for the discipline-specific technology, it is essential that the provision, training, and implementation of information technology extends beyond SME&T faculty to include all educators at all types of learning centers.

Faculty Development¾If faculty are expected to adopt information technology in their teaching, then the added value of using the information technology must be clearly evident, and easily facilitated. One problem, a correspondent offered, is that too much information technology fails to provide a "manual for delivery" to assist the faculty using it, which provides user insights into applications of the technology and its inherent strengths and weaknesses. While dissemination of effective products was a major concern, it was also recognized that access to the technology far exceeds proper training on its use, caveats

on its limitations, and other details that can reduce time-consuming frustrations involved in implementation of the product. The purpose of faculty training should not be only technical competence (though this is an assumed side-effect), but rather how to extract the greatest results from the available resources.

Departments and institutions, for their part, require a major reassessment in how they recognize innovation using information technology if they expect faculty to adopt the technology into their teaching. One participant drew the analogy that, if access to the technology is the "carrot" to initiate a change in practice, the pressure to keep up with other faculty efforts serves as a "stick." Or, as Skidmore College's Robert DeSieno observed:

> "… For most faculty, working in their discipline is challenging and time-consuming. Engaging digital technology is rarely as simple as using the telephone. Modern software is sophisticated, complex, expansive, and detailed in its requirements for useful application to substantive disciplinary problems. In my view, it is this interaction of disciplinary substance with digital technology that justifies consideration of this technology in education. But building the link is difficult, requiring mastery of detail that is time consuming, and worse, constantly changing as the marketplace drives the innovation in software."

Faculty development activities should have ***improved student learning*** as their primary mission, focusing on new or effective, established teaching/learning processes enabled by the use of information technology tools, rather than creating high-tech versions of the same bad practices. As one publisher of educational software remarked, "we are asked 'how do I change my course' much more often than 'how do I work this thing.'" One participant remarked, "some of the most effective uses of information technology have been ones in which faculty in diverse disciplines are collaborating in, or at least communicating about, their work in information technology. Projects involving writing across the curriculum are good examples, as are combined science/humanities courses."

In talking candidly with their colleagues, educators have at their disposal a means to greatly reduce the trial-and-error aspects of using information technology regardless of the amount of technical support and training provided by either the institution or the information technology manufacturers. Tool kits of user-friendly authoring/design applications that allow educators to easily package their own materials in a manner more engaging or illustrative to the student were proposed as a necessary and useful item for wise dissemination. Finally, there was a call for graduate students to be included in faculty development activities, serving to enhance and nurture the next cohort of educators.

Infrastructure¾ The World Wide Web was lauded as a mechanism for delivering the materials to a diverse population. However, the benefits of this delivery is contingent upon an accompanying training and support system for end-users. For there to be continued and more substantive "community action" on the use of information technology, a greater focus of effort is required¾ whether it be in a particular discipline, a given area of technology, or in response to an established national need for such development and implementation.

While institutions and faculty have a paramount role in the use and application of the technology, professional societies and associations were suggested as extremely important organizations required to coordinate evaluation and dissemination, particularly within a particular discipline. There was also a call for more research into the actual or realized costs for various information technology scenarios to assist institutions in their planning and budgeting. In turn, institutions could do much more to assist their distance

learning constituents by providing integrated access of things such as record keeping, articulation of credits, and billing. Government sponsorship at the state and federal level was also viewed as essential to providing coherence and credibility to the large-scale, national implementation of these technologies. Several participants specified the involvement of NSF as essential to coordinating this task - not only as a guiding hand or federal policy maker, but also in "adding respectability" to local efforts while serving to coordinate a system of nation-wide dissemination.

Dissemination¾ One participant divided the community addressing educational applications of information technology into two camps: inventors and users. The inventors "are at best a fragmented community," and this intrinsic lack of communication can seriously impede the dissemination of good ideas. Beyond its invention, innovations in the use of information technology in education are not generally regarded as research at all, but rather, as course development, service, or faculty development. There is little incentive for faculty to invest time in the study and implementation of information technology to improve teaching unless these activities are given equal credibility and potential for reward and recognition as any other form of professional research. For their part, the user community needs to be enabled, as by providing more comprehensive training¾ the role of the users should not have to replicate or supplant that of the inventors.

To assist in the dissemination of information technology materials, the concept of a peer reviewed, electronic journal was proposed. A good journal, many felt, would benefit educators who want to improve their teaching capability, but do not want to become experts in the technology (i.e., "become reinventors"). The ***Journal of Geological Education*** and the ***Journal of Chemical Education*** are examples of discipline-based publications which have long featured discussions about information technology applications and improved pedagogy. Others titles submitted included: ***Interactive Learning Environments***, ***Cognition and Instruction, Machine Mediated Learning, Human Communication Research,*** the ***Journal of the Learning Sciences,*** the ***Journal of Educational Multimedia and Hypermedia***, ***Computers & Education***, the ***Journal of Educational Computing Research***, the ***Journal of AI and Education***, and the ***Journal of Science Education and Technology***. Certainly there are countless more publications, bulletin boards, and conferences which could claim a mission of disseminating information about information technology in education. But, as with so much of the material ***available*** to potential users, it is unlikely that any more than the most interested among them would have the time and inclination to stray beyond their discipline to discover and research these products. Encouragingly, more professional conferences are making room for presentations about teaching and pedagogy, and in turn, these sessions increasingly present issues and results on the use of information technology. However, this still misses the sector of educators who have limited time or inclination to "keep current," especially outside their own discipline.[6] The sense of "preaching to the choir" that these sources of information suggest may be one reason that their effect is not more noticeable in the broader community. Again, the lack of recognition for producing or researching such materials was cited as the main reason for their limited group of followers. The ***Journal of Chemical Education***, at least, has its information technology/education contributions indexed in the Chemical Abstracts, hence these kinds of publications receive the same credit as any other research paper.

While the community is calling for such means of effective dissemination of information technology, NSF and other funding sources must appreciate that there are very real start-up costs to such ventures. Similar concepts have been suggested¾ and attempted with

[6] As one participant remarked, those faculty most in need of seminars about teaching more effectively are usually those who least feel they need such professional development.

varying degrees of success¾ with numerous storage media (floppy disks, videotape/disks, CD-ROM), and we would do well to learn from the successes and failures of these attempts.

Evaluation of the Technology¾Quality and standards for acceptable educational technologies were major considerations in the post-workshop discussion, and the development of appropriate review criteria was suggested as a theme for subsequent workshops. The users of information technology in education should communicate "what works" to their professional societies and collaborate more closely with for-profit publishers to assist in the dissemination of their work.

Correspondents agreed that the educational experience of the student should incorporate more learning tools (both technology- and non-technology-based) that are ***open-ended***, ***inquiry-based***, ***group/teamwork-oriented***, and ***relevant to professional career requirements***. While information technology was viewed as a powerful and promising means to accomplish most, if not all, these goals, the best method to review and evaluate the technology was less clear. More detailed information is needed on the most recent generation of educational learning technology, including whether specific products are commercially viable, educationally effective, or uniquely valuable in some way that would suggest further development of upgrades and related applications.

> "'Distance education' in the past has typically meant broadcasting video of lectures, but that's not really what an undergraduate education is all about. Universities also offer the opportunity for dialogue, for community, for sharing of resources, for new experiences. Current information technologies allow for a kind of heightened interaction (compared to video), and if high-prestige universities were offering this kind of interaction, then I certainly think the competition would be stiff. Who wouldn't want to attend a chat session with a Nobel prize winner, with relevant papers, digital videos of lectures, and other resources on-line and linked-in? But on the other hand, it's still very expensive to offer this kind of interactivity … It's hard to keep up with the discussions, post new and relevant materials, connect the virtual to the real world lectures and assignments, etc."
>
> **Mark Guzdial**
> **Georgia Institute of Technology**

Such evaluative information could in turn be used to assist state and national policy on the implementation of information technology in support of better SME&T education. Moreover, the technology should be evaluated over a range of situations and circumstances. As with any instructional resource, some educators will make better use of it than others, and some applications will benefit certain learning environments more than others.

> "State and national decision makers need a set of indicators, too: about the needs for change, the readiness (carrying capacity) of their states or regions for certain uses of technology, the current process of using technology, and the outcomes of the new educational strategies that the education is supporting. For example, regarding carrying capacity, they would need to know the degree and character of current technology use by both students (current and potential) and educators; when use reaches certain thresholds, it ought to be much easier to implement new strategies than if one tries to do that prematurely. Another example relates to software: decision-makers currently have little information about the market

> viability of certain types of courseware¾thus they don't know if it's appropriate (or useless or counterproductive) to try to fund pilot grants, to fund upgrades, to fund marketing, to fund staff development ... The market's logic is not necessarily education's logic: right now, by letting the "unhindered" market decide the fate of different families of courseware, we're also letting the courseware market decide local educational strategy. If we knew more about the dynamics of the market, we could decide whether and how to use regulatory and funding policy."
>
> **Steve Ehrmann**
> **The Annenberg/CPB Projects**

Rate of Change¾Academe is generally viewed as slow to change, and reluctant (or at least constrained, for a variety of reasons) to adopt new methods and technologies. The professoriate and their support personnel is a large community to coordinate, and any type of significant faculty development may take at least five to seven years to implement. The most optimistic discussion produced a vision of technological amplification, wherein innovation builds on innovation, adoption fosters further innovation, and community platforms build on aggregations of innovators. Yet such notions ultimately require long-term commitments of resources, with evolution occurring at a pace slow enough to allow monitoring and constructive evaluation along the way. Events need to be aligned with the academic calendar, and take advantage of intervals of lesser academic activity, when faculty have the most time to participate.

Student Participants' Views on Information Technology following the Workshop

Like their faculty counterparts, students identified the greatest benefits of information technology not as the provision or demand of technical skills, but as a means of retrieving information easily and reliably. Secondly, information technology that provides practical skills (critical thinking, finding patterns, understanding complex processes) to assist the student in their later lives was also considered effective. Students found information technology materials useful as supplements to the traditional texts and lecture, and of great benefit to self-guided exploration. Included within effective self-guided inquiry was the provision of a range of depth and complexity in the presentation, to accommodate a variety of comfort levels with the material. The potential to offer a wrong answer in comparative anonymity to a show-of-hands or in-class answer was also considered a benefit of some forms of information technology. While some students are comfortable, experienced, and adept in using computers, the majority still claim not to be, and there can be a perception in "high-tech" curricula presentation that grades are assigned on the basis of computer skills, not understanding of the subject matter.

The information technology students were most familiar with included software and video products. Access to the World Wide Web is another popular, though less prevalent, form of information technology. Instructors were seen as valuable in explaining the non-intuitive or shortcut aspects of the technology, which might not be obvious to novice users. But at the same time, many instructors were perceived as being uncomfortable with explaining how to use the technology and assuming a baseline or background understanding of these "common" technologies. Many instructors, the students said, presume a certain degree of technical ability (e.g., using the e-mail system, accessing the Internet), and the less experienced students learn to use the technology from trial-and-error, other students, or computer center technical support staff.

Although electronic mail has been widely lauded as a facilitator of "immediate" student/instructor communication, at least one student found e-mail exchanges to be a

depersonalized alternative to the classroom experience. Students who felt less confident of their ability to write down a question somewhat expectedly still prefer to ask questions anonymously in class than to present it in writing, signed with their e-mail address. Related to the issue of "assumed knowledge," an instructor who encourages class correspondence via e-mail but provides no instruction on how to log-on and use the system is not engaging students unfamiliar with the process. Instead, s/he may be perceived as favoring some students while disadvantaging others. Among students comfortable with e-mail correspondence, the technology was viewed as being much more immediate and offered "around the clock" access to the instructor, a tremendous advantage over the traditional office hours.

Technology that allows ***interaction*** by the student, manipulating complex systems with "what if" scenarios was also considered useful. Discussion groups via e-mail, newsgroups, ***listservs***, or teleconferencing were viewed as useful applications, but rote presentation of a lecture or other text materials using information technology was decidedly uninspiring. Students often find questions or comments among the postings that address their concerns or inspire new questions, and can benefit from browsing the material even if they have no specific concerns and do not participate directly. Not unlike class discussions, electronic groups can be dominated by a small number of enthusiastic participants, hence this "passive learning" aspect of electronic discussions may still benefit those members who prefer to "sit and watch." Requiring all students to participate in a discussion group was also not seen as an effective way of generating quality discussion. A few students also expressed frustration in trying to present mathematical, chemical, or similar formulae via a medium which operates primarily in monochrome and ASCII text.

Among other specific examples given, the use of video clips to engage, inspire, or immerse the student (as in an historical event) was also considered effective. Many students still prefer standard texts or watching a television monitor to watching video clips or reading from a computer screen. Access to the World Wide Web and word processing/printing facilities were considered beneficial[7]; regarding peripheral technology and software, user-friendliness was considered important. Reliability of the system is also an important criterion¾system crashes which confound a lecture or laboratory relying on the technology are still too common. The start-up or booting/rebooting of many technology products was also viewed as frustrating, too complicated, or a waste of instructional time.

Overall, most students reported having experience with "low tech" applications such as e-mail, newsgroups, Web browsers, and videotape/disk, far fewer felt they had been exposed to "high-tech" information technology, perhaps a subjective designation given the rate of change in the industry, the disparity of resources among academic institutions, the chosen field of study, and the student's personal experience. There is still a perceived predominance of techno-phobic or computer-inexperienced students that presents an uneven platform for presenting information using technology. However, on campuses where the use of computers had been expanded and encouraged, the number of students "lagging behind" was much less. Significantly, while most students considered information technology to be useful for engaging their interest or helping them conceptualize complex

[7] ***Cautiously*** beneficial, as such access may, however unintentionally, encourage clip-and-paste plagiarism in student assignments, and the use of URLs or other "fleeting references" may make source material especially difficult to reference at a later date.

processes, there remained a strong sentiment that there is no substitute for personal interaction with a competent and enthusiastic teacher.

IV: Recommendations

Overwhelmingly, the response to the question of "who should be responsible for developing the use of information technology in the classroom" was ***everyone***. This includes: government, professional societies, faculty, teachers, librarians, students, publishers, and designers/manufacturers of learning technology products. It was particularly interesting to note that, by the end of the discussion, the term ***information technology*** had been virtually replaced with ***learning technology***, indicating the direction in which these resources should be applied.[8]

This section summarizes the main observations and recommendations deriving from the workshop, including the group's recommendations to NSF for further action and activities on this subject.

Define the Use of Information Technology

Three areas were determined as fundamental and essential to the use of information technology.

Need—

- **Address the needs and requirements of future or currently excluded markets.** The most important indicator may be one of ***need***¾is the technology really meeting the needs of its entire, and intended, audience? Barriers may include proximity of the learners to the providers, schedule constraints, physical handicaps, assumed baseline knowledge, cost/affordability, learning style, and native language.

- **Accentuate the teaching and learning attributes unique to information technology and its use.** Desirable attributes of information technology tools and their use include: the ability to construct knowledge, consideration of disparate user background knowledge, self-guided, goal identified, encouragement of communication and collaboration, and peer instruction.

Scope—

- **Define the involvement of current users and predicted or probable future users.** There is a need to see what, exactly, the current use of information technology is. Is there support for such systems? To what extent do the learners of interest actually rely on the use of computers, video, and telecommunications¾not only in the classroom, but in their everyday lives.

- **Define the current and proposed role of information technology in the classroom.** Is information technology used at the level of a "luxury," a "tool," or a "necessary resource"?

[8] We are reminded here of the folly in being too clinical in our approach. "Shouldn't a mission to provide 'student-centered education,'" as one correspondent observed, "be as self-obvious as 'diner-centered restaurants' or 'passenger-centered airlines'"?

Efficacy—

- **Consider, and be willing to adapt or revise, paradigms in teaching and learning.** Different approaches to education are possible, and we must consider at what point the tools of one approach become the foundation of another.

- **Define desirable outcomes, then design and utilize instructional learning in a manner consistent with those outcomes.** What are the outcomes noted by, and expected of, the graduates of technology-enhanced curricula? Are they better able to fill jobs based on their ability to use technology effectively in their work?

Promote Faculty Development

In order for all faculty at all types of institutions to adopt and broadly utilize information technology, it is necessary for faculty (as well as graduate students, teaching aides, and other complimentary instructors) to be recognized for their efforts in learning and implementing such technologies.

- **Provide recognition and rewards.** An emphasis on using information technology (and teaching in general) should be viewed not as an additional requirement, but as a shift in attitude in the most professionally rewarding use of the available time. All attempts to utilize more engaging teaching methods should be recognized, and the most effective of these should be rewarded on par with comparable gains in research.

- **The outcome of faculty development should readily impact and improve the learning experience of the student.** Faculty development projects should have improvements to pedagogy as their primary consideration, and focus on teaching/learning processes unique to the use of information technology, rather than creating high-tech versions of the self-same ineffective practices.

- **Don't require users to reinvent the wheel.** The use of tested and reliable components can simultaneously lower the development costs and increase the quality of new curriculum material and resources. Authoring and development tools need to be more user-friendly and better supported. The learning and adoption process should not be a repeat of the original design process.

Encourage Dissemination

- **Recognize extant avenues for dissemination.** While several mechanisms for disseminating these ideas currently exist (e.g., journals, conferences), the contributions of research in the use of information technology is not widely taken-up; one significant reason for this is the lack of credibility ascribed to experimentation with information technology, and research on effective pedagogy in general.

- **Develop new forums that best illustrate and showcase noteworthy efforts.** In the short-term, an electronic journal of these kinds of instructional technology–peer-reviewed and interdisciplinary in scope, could provide a nucleating agent for these ideas.

- **Implement adequate professional review.** Professional societies should develop the high quality journals (multimedia), conferences, and awards in information

technology applications to education. Quality standards need to be developed so that each contribution can be judged consistently.

Implications for Institutions

- **Recognize innovation in the design and implementation of information technology.** Administrators and faculty need to recognize inventors and innovators, and consider this work credible research. Methods of assessment need to be better defined–as do quantitative evaluations of the learning process to assist in these determinations of effectiveness.

- **Position the campus as part of the larger electronic community.** In implementing the information technology infrastructure on campus, the links to other institutions and to part-time or distance learners off-campus must also be considered.

Recommendations to the National Science Foundation

- **Continue to support and advise on this discussion.** NSF should develop within discipline centers a critical mass of expertise to help faculty at all institutions develop and adopt information technology-based tools for improving learning. Included in this mission should be increased support of research into the learning process itself, as well as "technical support" that not only provides access to quality instructional products, but also assists faculty in its implementation at their home institution.[9]

- **Promote systemic reform and multidisciplinary efforts.** As part of the national dissemination efforts, NSF might do well to publicize projects and technologies that are more akin to "community building," emphasizing the cross-fertilization of ideas resulting from a common technological platform.

- **Support and recognize the use of technology in teaching and learning.** NSF should allocate funds and resources to support research in information technology applications to education, and recognize/reward successful innovation with grants for development and implementation.

- **Concentrate Foundation efforts.** In general, NSF would do well to focus on

  - ***Training***¾ efforts should focus on faculty, but where appropriate, should extend to graduate students and other faculty support personnel.

  - ***Accommodating diverse audiences***¾ by supporting projects that "target" or attract more than one audience or group in the use of information technology.

[9] This "local performance," mentioned one correspondent, tells little about how well the technology will behave and achieve elsewhere, but it "can at least flesh out the envelope of possibilities."

- ***Research the learning process***¾ through increased support of research into empirical ways to test/measure the various teaching and learning modes, as well as the comparative success of information technology in enhancing these processes.

- ***Provide recognition***¾of the innovators and leaders in the effective use of information technology.

- ***Provide guidance and reputability***¾ by coordinating, and funding if appropriate, a mechanism for collating, reviewing, and promoting the dissemination of quality information technology products, uses, and ideas.

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