

# Technology, Learning and Scholarship in the Early 21st Century

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## Abstract

*The integration of wireless, distributed technology into the classroom has only just begun. To date we have primarily focused technology at the classroom lecture environment imitating the traditional activities there. We are only now beginning to explore new models for advancing education based on a new generation of interactive technologies. New methods for immersive hands-on learning, learning by doing, and interactive collaboration portend an evolution in classroom instruction. Technology today is opening new horizons for expanding the learning process. With recent advances in conferencing, network technologies, and visualization technologies we now stand at the brink of a new frontier for advancing the human learning process. Low latency, high bandwidth video conferencing coupled with wireless TabletPCs, simulation and gaming, and embedded technologies promise an exciting vision for expanding the learning process with new compelling environments for lifelong education and personal growth.*

## I. Introduction

### A. The Opportunity

In the United States alone, the estimated technology spending for K-14 education in 2002-2003 is estimated to be 12.1 billion dollars and worldwide corporate external training spend is forecasted to grow to more than \$80B by 2006<sup>1</sup>. Many countries around the world are making similar substantial investments suggesting that education is committed to understanding the value of using technology to learn. Following the money, we find that much of it is dedicated to effectively adhering to government sanctioned academic standards, building interoperable learning objects, promoting staff development and identifying macro e-learning strategies for the 21<sup>st</sup> century. Is this enough? Have we adequately researched the possibilities?

Our quest is to research and prototype pedagogically sound technologies that offer international engineering educators an advantage in using the exponential raw power of emerging hardware and software. We envision introducing a learning research

platform into engineering instruction through our relationship with universities. The key is to integrate modern learning methods (especially active-based learning methods) into scalable software designs and build reliable software that uses emerging communication, collaboration, and integrative programming solutions such as Web services. Through prototyping and dissemination for experimentation, we hope to contribute to a clear well articulated research agenda and technology roadmap to chart our e-learning futures.

### B. The Challenge

We must start with creating learner centric technologies and shifting away from only lecture-based environments with pen and paper assessment. William Graves in his Framework for an e-Learning Strategy states that “indeed, the needs of a learning society will not be met until virtual technologies are used, not just to make instruction more convenient and accessible, but also more effective. This final shift to a learning-centric perspective will require instructors and their institutions not only to share traditional content resources in online formats, but to support enriched col-

laborative learning environments that can transform today’s online correspondence courses into opportunities to increase the learning outcomes of instruction. This is the most immediate and pressing challenge for most campuses in “engaging and supporting faculty” as part of the Dot.edu challenge to traditional Higher Education”.<sup>2</sup>

The underbelly of integrating technology into the classroom is the ability to capture the learner’s experience and provide adequate feedback and response. This vision requires us to develop technologies that encourage immersion and exponentially engage the user in multiple activities, capturing both implicit and explicit knowledge interactions. It is the preamble of learning by doing and capturing the learning experience for personalizing education that may dominate the best designs.

### C. The Scope

We suspect that we will need to integrate technology into our collective learning experience, spanning beyond our initial



A UNITED ENGINEERING  
FOUNDATION CONFERENCE  
Davos, Switzerland 11-16 August 2002  
<http://www.coe.gatech.edu/eTEE>

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experience in K-12 science, through university engineering education through industrial education and into lifelong learning. As Grossman and Minow state in their Digital Promise<sup>3</sup> proposal, “In the new century, as the recent Kellogg Commission on the Future of State and College Land-Grant Universities pointed out, learning environments must reach beyond the school walls and directly into the home and workplace. Continuous learning for working adults requires technologies that support alternative delivery of educational programs<sup>4</sup>. Exploring this achievement is the goal of this paper.

### II. The Connected Learning Community

Given the rapid advances in hardware and software development, we are seeing the world’s universities develop compelling new learning environments for engineering education. CPU power advances have already provided unprecedented computational power for problem formulation and solution presentation. Graphics power has enriched our worlds in laboratories and in visualizing engineering phenomena. Storage and networking have enabled digital libraries, instant communication, and wireless classrooms. If we have come this far with our current technological capability, imagine what this kind of power will enable for 21<sup>st</sup> century scholarship and academics. It will connect people together in unique ways, help us manage complex problem-based learning environments; bring federated resources together for analysis, synthesis and interaction. It will liberate us to create connected learning communities.

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**Bottom Line: We’ve achieved access to content and people!**

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### III. Current Classroom Technology Falls Short

But have we achieved rich collaborative experiences, pedagogically sound technology integration, embedded assessment,

shared Internet-based laboratories, rich video conferencing technology, immersive constructive environments, or even a methodology for integrating technology into the classroom that is not disruptive, nor socially handicapped—most likely not yet.

Senator Maria Cantwell writes in her Amendment to America’s Bill on Education: “A February 2001 Net Day study shows that 97 percent of teachers have access to some computer technology, but only 32 percent were integrating computers in classroom learning”<sup>5</sup>. Introducing technology into the classroom is one thing, introducing it effectively is another. Perhaps we concentrate too much on recreating the classroom rather than using wireless distributed technology to extend the classroom, making instruction more flexible for the learner, the mentor and the instructor while focusing on the experience of learning.

#### A. Traditional Classrooms

Traditional classrooms today fall short of providing sound engineering education because they lack the flexibility to create a scaleable environment in which the students continually practice their art (or science in this case) in either simulated reality or in real world situations. In fact, most instruction today (with a few exceptions of those using project-based instruction models such as MIT’s iCampus Physics laboratories<sup>6</sup>), repurpose teacher centric presentation models, videotaping the instructor with either Mylar or PowerPoint as a presentation mechanism. Students take notes on paper or computers or disappear altogether (Figure 1). Classrooms that look anything like industrial environments rarely exist and students don’t have customers or community environments for solving problems. When they do, they’re not scaleable.

The interaction models are slow-paced and repetitive, hardly challenging to the “twitch speed generation” who are used to



**Figure 1.** Computers in many classrooms today.

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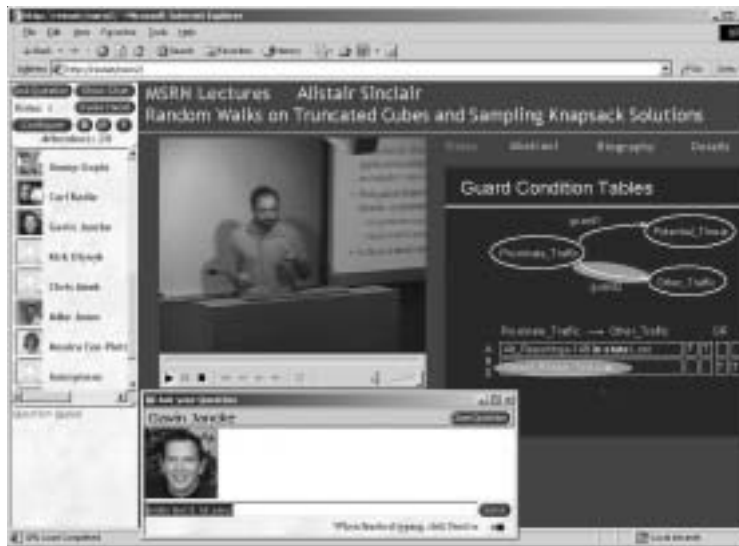


Figure 2. Electronic classrooms in industry.

navigating both visual and textual data as rapidly as star fighters. Usually, in most learning environments, the teacher lectures, the student interrupts occasionally to ask a few questions, and dialogue is usually minimal, unless class size is restricted. Students read textbooks and work on textually-based problems. Teacher office hours are the only way to talk to the faculty member or teaching assistant. Assessment is comprised of tests with long feedback loops or long lines waiting to get into laboratories.

## B. Industry Shortcomings

Industry hasn't really achieved great gains in e-technologies for learning either. They've designed similar teacher centric electronic, distance learning environments, using lecture-based technologies as the design model. E-learning applications in industry still focused primarily on the instructor as the active participant, and the learner as the passive participant (Figure 2). They have encouraged presence awareness but only simulate learner passivity. Tools for interacting with the instructor or each other are extremely limited. They're not designing e-learning systems to meet the skills required for problem solving in engineering work environments.

## C. Methods for Employability

Neither university, nor industry has utilized the technology yet to enable our engineering workforce to enhance their skills for employability. According to the National Standards Skills Board those skills include "listening, speaking, using information technology and communications, gathering and analyzing information, analyzing and solving problems, making decisions and judgments, organizing and planning, using social skills and adaptability, working in teams, leading others, building consensus,

and self and career development"<sup>7</sup>. These employability skills are universal. They are currently being designed into accreditation and certification boards worldwide through either ABET or the Bologna Accord. So how can we take these requirements and build e-technologies to accommodate?

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Bottom Line:

We're focusing on the technology, not the learning.

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## IV. Pedagogical Soundness

### A. What do we mean by pedagogical soundness?

Pedagogically sound e-learning environments take advantage of tried and true traditional formats for learning, but need to extend them to accommodate for increased interactivity. Lecturing is important and economical for conceptual transfer, but learning by doing requires students to improve their performance to achieve certain tasks. Project-based learning that involves problem solving is learner centric and can be enabled with today's communication and collaboration software.

David Merrill, one of America's leading pedagogues, provides us some fundamental principles that all educational theories espouse and examines these fundamental principles against all modern educational theory. In short, he identifies the following elements which must be present to make any educational system effective. He states:

- Learning is facilitated when learners are engaged in solving real-world problems.
- Learning is facilitated when existing knowledge is activated as a foundation for new knowledge.

- Learning is facilitated when new knowledge is demonstrated to the learner.
- Learning is facilitated when new knowledge is applied by the learner
- Learning is facilitated when new knowledge is integrated into the learner's world.

Much of the current work in cognitive psychology has shown that students learn better when engaged in solving problems. Problems should be authentic, real world, and, if possible, personal. Problem-based learning is well represented by a number of recent instructional models including: Collins et al (1989) Cognitive Apprenticeship; Schank et al (1999) Goal-Based Scenarios; Jonassen (1999), Constructivist Learning Environments; Savery & Duffey (1995) Problem-Based Learning; Clark & Blake (1997) Novel Problem Solving; and van Merriënboer (1997) Whole Task Practice in 4C/ID Model.<sup>8</sup>

Existing technology can be used to create a shared portal that allowing individuals to publish freely wherever they are on the Internet. Establishing such an environment allows project definition and project management for quarter or semester long projects. Instant messaging allows users to communicate instantly encouraging work group participation. Web-based programming leads us beyond HTML and makes it possible to program interactivity. Once accomplished we can annotate real time, synchronize real time, federate databases real time and bring scholars together in new ways.

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Bottom Line:

We must focus our e-technology on learner centric problem solving.

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### B. Building Communities of Practice

Building the equivalent of professional societies in which social networking and knowledge transfer are superior supplements to education allows us to improve more than our engineering skills in problem solving. It also improves the employability skills of listening, speaking, using information technology and communications, gathering and analyzing information, analyzing and solving problems, making decisions and judgments, organizing and planning, using social skills and adaptability, working in teams, leading others, building consensus, and self and career development.

Laplante and Wiesner<sup>9</sup> identify several requirements for a community of practice. Observing these requirements in the design of interactive learning environments will result in enhancing a student's full learning experience.

1. The community's members should be able to locate or be directed to relevant people and stored information.
2. The community should foster community spirit so that members feel they belong to a group with an identity.

3. The community must offer services that maximize the information benefits to its members while controlling information overload, promoting member interaction and maintain community involvement for the benefit of all members.
4. The community must regulate the amount of communication and information flow intelligently so that the burdens of membership do not become greater than it benefits.
5. The community should allow members to locate and be informed about other like-minded members.
6. Selected members of the community should control the information flow either by one-on-one communication or by broadcasting to the group.
7. The fruits of the community must be peer-reviewed. The outputs of the community such as the concept modules, curriculum, tests and so on must be subject to review before release. Potential new (voting) members need to be approved by some (non-unanimous) mechanism-based on their professional merits.
8. Information must be accessible. Voting members and non-voting members of the community must be able to read and comment by anyone on any discussion (subject to moderation).
9. The community must be secure.
10. The community must have authority. Accrediting bodies (such as ABET) and professional societies (such as IEEE) must be well represented.
11. The community must be diverse. The community must attract researchers, industry stakeholders and practitioners and not just professional society members or academics.

It is essential to examine social computing technologies for inclusion in sound e-learning environments. We must build our research agenda for learning into software components that contribute to compelling and effective social interactions with a focus on user-centered design processes, rapid prototyping and scenario-based design. Research should include multi-user social applications on the Internet, wireless applications, scripted social interactions, virtual worlds, trust and reputation, collaboration, and story telling.

Community building software solutions enable us to work together more effectively, showing unforeseen social transactions between people and projects, establishing trust relationships for collaboration, modeling our users to reduce cognitive overload, context monitoring disparate streams of content and focusing on improving the human experience in information and learning.

### V. Scholarly Applications of e-Technology

Today, the way, scientists and scholars are using computers is to gather data directly by observation, process that information

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into a computer, analyze it and publish the results. We have access to this scholarly information through shared on-line publications. We can examine scholars data through shared FTP and HTTP downloads. Our data formats are usually implicit, but each researcher has his/her own data located in their unique environment. This could be UNIX-based environments, Windows, Mac, and other emerging environments such as Palm, Windows CE, etc.

The applications that are designed to manipulate and represent this data often run on individual computers, making sharing, validation, or even access very difficult. We are challenged with innovating and advancing our knowledge of scholarship and science and problem solving with this current configuration.

Given the computing power we've addressed, the software innovation in speech technology, computer vision, embedded technology, storage capability, and the ability to program for a single platform (the World Wide Web using Web services) we can build rich environments for scholarly consumption. Like emerging business applications that are sharing data through XML, SOAP, WSDL and UDDI, we can build scholarly environments that open up access to a new form of international academics.

Web services promise to provide the ability to discover what learning resources are available today, find them, retrieve them and then integrate them back into a course, a curriculum, or an individual's scholarly pursuit for innovation. The benefit is that the end user doesn't see the access to the multiple databases and Web sites all around the world; instead, they see a contextual interface, keeping them in their domain without cognitive overload. This is a very powerful notion demonstrated both in business literature on web services for e-commerce and through emerging Web services for education literature<sup>10</sup>.

### A. Learning Web Services

Higher education has not achieved the same level of connectivity that industry shares today, nor have they achieved a complete articulation of how web services can impact higher education. Nonetheless, we can learn from the industry models for sharing transactional information and explore how we can use web services to improve our scholarship systems for learning (Figure 3). Connecting data, communication and interaction through mobile, wireless, Internet-based technologies has changed not only the way knowledge flows from individual to individual, from computer to computer, from service to service, from industrial strength software to rich business applications, but in the future from learning experience to learning experience.

In the recent U.S. publication the President's IT Advisory Committee on Using Information Technology to Transform the Way We Learn, the collective authors suggested that "industrial experience over the last two decades demonstrates that successful information technology-assisted process improvement almost always requires that information technology be coupled with a careful rethinking of the targeted processes and social institutions".<sup>11</sup> We can learn from industrial reengineering and use these new processes to help us change the way that students interact with teachers and administrators.

We are shifting away from a centralized computing environment to a distributed environment in which we can take advantage of moving information from multiple sources, enhancing the content with annotation, with rich graphical libraries, with storytelling, with video conferencing, with access to experts located in the same visual environment, with project management and data mining capabilities undreamed of before. This enrichment allows us to interact with scholarly material and exchange business information across multiple clients, servers and services.

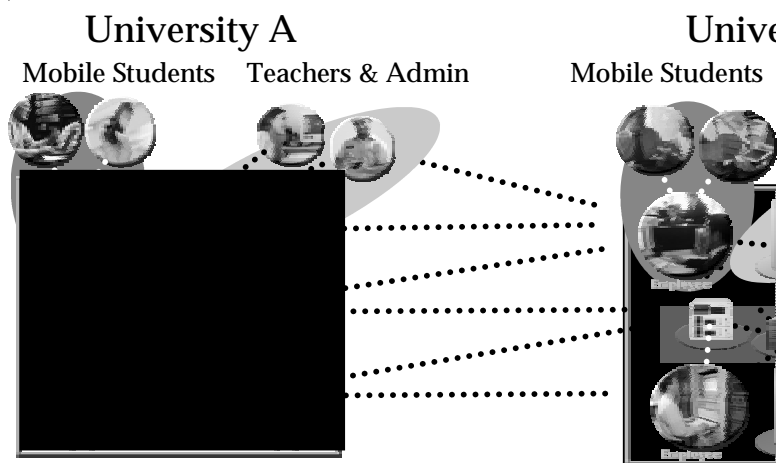


Figure 3. Distributed educational environments.

Web service technology allows us to federate databases more easily to improve access to Internet-based learning materials. We can utilize communication technologies to teach, learn, debate, summarize and theorize. We can build project-based environments with various form factors that receive and send data and learner interactions to extend teaching beyond the classroom. We can build systems that play into larger integrated solutions inviting industry, textbook distributors, commercial supporting services and an international community to create virtual universities, extending our capabilities, research dollars and revenues. Along with these capabilities comes a new set of tools to help orchestrate these changes.

### B. Web Service Programming for Scholarship

With tools emerging such as Academic Visual Studio.NET we are able to program the World Wide Web, enabling rich, interoperability, security, experience and innovation. With telecommunications technology, we're now able to wire campuses, where every student is working with the device of his/her choice, accessing databases worldwide, in shared collaborative environments that enhance the depth of the learning experience. Bring these two together, and we are able to design pedagogically enabled tools for improving scholastic collaboration.

As we envision the next generation of technologies for education in a wired, programmable environment, we see students working on-line in visually rich environments, building things, communicating with guest lecturers and co-developers. We see learning adapting to individual learning styles and maintaining a lifelong learning portfolio that tracks all student activity, projects, collaborations and learning issues so that students can receive and exchange constant feedback from teachers,

partners and peers. The promise of sound learning Web services with emerging computational power, new devices, and wireless, high-speed Internet connectivity in rich visual environments will change the way we learn.

### C. Accelerating Scholarship with Technology

Imagine if you had the ability to access all the geographic data through one Web service and a rich visual client served up that data for you depending on how much you knew about a topic? You could explore the environment, managing the data as well as your expertise allowed. As you learned more, the client interface would access more federated data and serve up more to you, always keeping you at your level and building your knowledge bit by bit. Not only could you see all your data in one location, but you could see experimental results kept in a database anywhere in the world directly associated with that geographic data and work with individuals on problems as a result.

Imagine working in shared publications on-line with others, annotating publications, videos, communications, learning experiences and creating a second set of knowledge around the scholarly material and interactions. The combined set of experiences of individuals reacting with scholarly data can be as compelling a learning environment as the actual outcomes for achieving those scholarly gains.

Imagine self describing data structures that would be accessible remotely by distributed applications. We are able to share common schema for well understood data, federate large data sets around the world, and share applications over the network via self describing interfaces. Examples of these kinds of learning Web services include the TerraServer (Figure 4) and the



Figure 4. TerraServer, a learning Web services.



Figure 5. Federating databases.

National Virtual Observatory<sup>12</sup> (Figure 5) which improves the ability to teach geology and astronomy by aggregating world-wide information into one location for analysis.

Our next grand challenge in engineering education is to continuing building next generation learning exemplars like these to enhance scholarship and academics, taking advantage of the rich tools for programming the Web, accessing databases, increasing feedback and responses systems, and augmenting community and interactive learning experiences.

**D. The Learning Experience Project (LearningXP):  
A Research Project**

Currently, we envision a set of core research technologies for building high bandwidth and optimal bandwidth learning Web services. The core technologies include a) low latency, high bandwidth video conferencing, b) gaming technologies for simulation-based environments, and c) emerging embedded technologies for building learning experience into physical objects for psychomotor development. Around these core technologies sit a set of pedagogically sound learning services for the student, the teacher, and the mentor. As a container for these services, we envision a ubiquitous user interface for managing Web parts and capturing embedded learning experiences for improved assessment.

*1. ConferenceXP: The first core technology*

Over rapid networks such as Internet 2, we are developing a learning research core technology for low latency video grid conferencing to allow for enriched immersion in a lecture-based environments across multiple venues. Imagine being able to see live lectures and student interactions in those lectures across multiple universities. This visually immersive learning research technology is designed for ease of use, with rich educational experience, and scalability using wireless PocketPCs and TabletPCs. It uses a simple, configurable archival system enabling individual participants to record and playback conferences and student and teacher interactions.

This technology is built on single-machine architecture capable of scaling to handle large, group-to-group-to-group conference scenarios, relying on simple software installation and hardware configuration. No conference session operator is required. Cameras, microphones and other peripherals are configured for a ‘best fit’ default configuration and a published Conferencing API enables the development of custom user interfaces and automation with existing systems.

Its architecture scales from large rooms down to personal nodes (laptops), enabling a wide range of collaborative scenarios. ConferenceXP uses Windows Media codec’s which are highly optimized for bandwidth and CPU utilization. Advances in computation power (Pentium IV) and graphics processing speed (nVIDIA GeForce or ATI Radeon) enable the deployment of high-



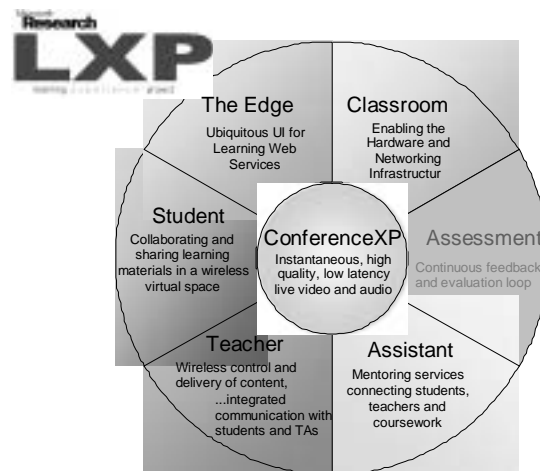
performance collaboration on a single desktop machine. The network transport can adjust for poor network conditions or less than optimal network bandwidth (including wireless).

The rich instant messaging client side interface provides a singular interface for supporting full screen video at 30 fps, with 250 ms latency. FireWire cameras enable high quality, efficient video capture with five way conferencing < 2 Mb/s

We imagine this ubiquitous interface for learning Web services to help contextualize information in one location

on the edge of the screen. With the ability to persist interaction, video experiences, annotations, communication, we see Web-based student portfolios emerging in this format to carry student activities such as notes, project schedules, and video-based experiences all in a single location.

The aim is to point the technology at collaborative working groups meeting in classrooms, conferences, workspaces, in the field, etc. and couple it with wireless technologies for accessing scholarly data anywhere, anytime. We envision building a set of learning Web services that address the pedagogical needs of the various users in the learning experience around ConferenceXP with wireless Tablet PCs. We can enable other universities and partners to co develop these sets of services such as Internet-based laboratories, Internet-based essay evaluation, etc. We then imagine a set of services for the Student, for the Teacher, and for the Assistant/Mentor (see Figure 6. LXP, a learning experience research project at Microsoft Research).



**Figure 6.** LXP, a learning experience research project at Microsoft Research

Using the upcoming new form factors such as the wireless TabletPC we're able to create a more project-based environment that allow students to move around, receive instruction, aggregate project work, integrate with others and take notes in their normal handwriting. Our prototype LXP project is seen in the following form factor (Figure 7).

Video technologies do not have to simply imitate the lecturer standing in front of the class. Instead, it can be used as a way of participating in a classroom, conference room the field, or a laboratory. When used effectively, we see gains in student achievement. Gibbons, for example, has found that students who viewed videotaped university-level lectures in an active discussion group performed half a grade-level better than those who attended the lectures in person.<sup>1</sup> The capability is here, the future users are for you to develop.

### 2. The Student Experience

The student experience must enhance the student's ability to communicate and collaborate. In lectures, students need to be able to interact with the content either during presentation or during reflection and review. Annotation, note taking, commenting on content and interacting with others during the exploration of the content must be facilitated. Summarization capabilities must be made available to aid students in working through not only teacher generated content, but student generated content as well. Inquiring management tools must facilitate student question and answering, especially using excellent natural language processing inquiries so students experience the equivalent of mentoring.

Application sharing is required wrapped around groupware applications enabling collaboration. Multimedia search must be available. Social filtering for collaboration enables matching and pairing students working together. Personalized libraries will help contextualize the user's experience. Modeling tools for conceptualizing scientific and mathematical models is essential and knowledge representation tools will enable students to brainstorm, prioritize and visual workflow. Participatory simulations, virtual laboratories and ultimately intelligent-based tools that embed learning in physical objects must be made available to students.

### 3. The Teacher Experience

The teacher experience focuses several requirements: active presentations, individual assignments, assessment, and group formation. Active presentation learning services provide delivery and feedback between faculty presentation and student response. For example, students should be able to write directly on PowerPoint type applications during lectures, or during review of materials. Teachers should be able to receive this feedback either real time or post lecture and make adjustments to their instruction, to their materials or to their student's learning behavior. Individual assignments build on teacher's observing how students understand facts, concepts, procedures, processes and principles as they're introduced. Such software must help teacher's visualize how students are demonstrating critical thinking and skills acquisition while engaged in a project using new knowledge.

**Figure 7:** The student's experience.



Learning services that enable teachers to break students into groups, brainstorm, interactively share work in context, provide communication structures, and model users for working together effectively are essential for building next generation learning systems. Teachers need tools for producing scientific visualizations for understanding difficult concepts such as Faraday's Law or other physics principles. Teachers need to be able to use remote instrumentation, sensors, recording devices, and knowledge management tools to create exciting engaging curriculum for students.

This is just the beginning of the interactivity, feedback and delivery systems needed to enhance the teacher experience.

#### 4. The Mentor Experience

Mentors need similar learning tools for building the learning experience for students. They need a very similar set of software infrastructure to support working with students either during their on-line learning experience, during their classroom experience, or while working on individual or group projects. Many of the tools that faculty use will also be useful for the mentor experience. Managing discussion groups, grouping students together in collaborative workgroups, and providing people to people communication instantly when students are engaged in on-line activities are some of the key features needed for appropriate mentoring.

#### 5. The User Interface

In order to contextualize learning, keeping the student focused around the elements of learning, the association of content to activity, the communication structures for working in collaboration, students need a single interface that stores all the learning Web services for their learning experience. This interface needs to be programmable. It should allow students to store individual "Web parts" into a student portfolio for managing cognitive load and for providing a foundation for assessment. Since this vision of technology includes storing not only content, but interaction with content in a single location, such an interface would not also serve as a virtual reminder of what a student is working on, but a software infrastructure for providing personalized feedback on competency management.

#### 6. The Assessment Experience

Underlying an infrastructure for managing student performance is no easy task. Best assessment comes from working with the student person to person, and assessing in a holistic fashion. As students immerse themselves in the digital environment, we envision taking advantage of the interactions, decisions, collaborations, and communications and storing them in a single, personalized location for evaluation. If each of the learning objects contains information about the topic as a metatag, then we're able to aggregate that information, use natural language processing algorithms to process the information for evaluation and provide feedback to students against a set of defined

learning objectives. Exploring this area of research will be fundamental to building effective learning systems for education.

You can possibly guarantee learning outcomes by embedding assessment in software that models users and provides contextual monitoring to ensure learner styles are observed, learning disabilities are accommodated for, and content is relevant to the user. You can create electronic portfolios that provide deeper evaluative data, capture real time experiences and track student progress over long periods of time. Through AI models and people to people connections you can increase interactivity and learning experience.

#### 7. The Classroom Experience

The classroom experience has changed significantly. Richard Katz mentions in *Dancing with the Devil*, "We should also recognize that classroom instruction is a relatively recent form of pedagogy. Throughout the last millennium, the more common form of learning was through apprenticeship . . . it is simply too labor-intensive for the mass educational needs of modern society<sup>149</sup>". Our research model accommodates for the classroom, for the conference room, for the single PC, laptop, PocketPC, TabletPC or any emerging device that will generate XML-based content. In order for education to persist through lifelong learning, the Internet becomes the central repository of content, the warehouse of interactions with the content, the communication medium for interacting together, and the new schoolroom.

## VI. Next Core Technologies

Quality video-based conferencing coupled with a set of learning Web services to increase interactivity and pedagogical soundness will enable us to build sound lecture-based learning and supplement it with a rich set of services for interaction. These learning Web services can be reused other sets of technologies as well. We see visually-based immersive simulations and gaming technologies emerging as an environment for constructivist activities for engagement. We see physical simulation environments powered by embedded and MEMs-based learning technologies as another potential core technology that can be used to improve the learning experience with technology.

### A. Simulation and Gaming

Gaming and visually rich simulation technologies provide scaleable models for engaging in the learning by doing component of education especially if we can deconstruct each individual visual element and program functionality into that object.

Interacting with animation that requires critical thinking and construction of visual elements with rich feedback and incremental levels of difficulty is very promising. We have seen high levels of interaction like this in the gaming environment. These emerging media hold promise for increasing motivation among

learners and keeping them focused on activity-based tasks.

Henry Kelly from the Federation of American Scientists sums up “Computer simulations can let you see a heart beat, look inside to see fluids flowing, and find out what happens when things go wrong. Instead of reading about how the heart works and seeing diagrams on a page, these dynamic tools open extraordinary new possibilities in learning. They bring up-to-date ancient learning techniques-based on apprenticeship, problem solving, and mentoring.

Imagine developing a digital human model. The human body is the most complex machine we know, and the most fascinating. Mechanical, electrical, fluid, and chemical communications operate at scales from the molecular to gross anatomy. The body has information systems, energy systems, and manufacturing systems. Most of what we know about these systems can be represented in clear visual ways, but doing this requires an unprecedented investment in developing a functioning model—tools more complex than those used to build the Boeing 777. Once built, however, the system could be used to help students from grade school to medical school; help physicians explain procedures to their patients, and serve as a tool for research<sup>15</sup>. Imagine the software environments, APIs, and learning infrastructure to scale models such as these.

### B. Physical Simulation Technologies

Embedded technology is promising for another set of core technologies for designing an extensible learning research platform. When software is embedded into physical objects, we can conceivably extend our learning environment into these objects. We can build intelligence or learning into the various components and potentially observe psychomotor skills as students are connecting objects, allowing us to potentially provide real-time feedback and responses to the students. If the student doesn't understand the feedback, he can be moved to a visual environment for better visualization of key engineering concepts. If the student still struggles with the visualization, he can sent back to the original set of lectures and exercises through the video conferencing environment.

Imagine a core set of technologies that enable the development of interactive, smart objects for constructing a bridge, a router, a motor. Imagine integrating these capabilities with learning Web services for enhancing collaboration, interaction and assessment.

Lecture-based conferencing, visual experience simulations and physical simulation technology powered by embedded technologies and MEMS technologies promise to enable engineering education in an integrated model for building in learning science with technology and enhancing scholarship through flexible models.

## VII. Call to Action

### A. What can you do?

By using available hardware and software technologies, you can plan for and build on broadband, wireless, massive storage technologies. You can incorporate electronic ink, speech recognition and computer vision to create interactive models that will enhance student and faculty experience. You can build inter-university tools by federating Internet-based laboratories either allowing students to integrate real time data from expensive instrumentation, or actually controlling it from a distance. You can distribute curriculum between departments and universities by building digital libraries and grid-based tools that allow students to come to other locations through high bandwidth, low latency video conferencing.

You can start designing your learning systems with pedagogically sound tools that enable project-based learning, learner centric environments, rapid response and feedback systems. You can build community environments that extend the learners experience into the real world environment of project management, customers, user requirements, negotiation, critical thinking, and working with others. You can build simulations, gaming environments for education, and inquiring management tools to create better interaction models between students and content.

### B. What can the government do?

Findings from the Web-based Commission report composed of 16 members who were selected by the President, Secretary of Education, and congressional leadership, conducted a detailed study of the critical pedagogical and policy issues affecting the development and use of Web-based content and learning strategies to improve achievement at the K-12 and postsecondary levels. The recommendations that follow are important for policy decision makers and institutional leaders worldwide.

- 1) Make the effective integration of information technology with education and training a national priority.
- 2) Establish and coordinate a major research initiative for information technology in education and training.
- 3) The Federal government should collaborate with industry, state governments, and private foundations to aggressively pursue the information technology research program required to advance education and training.
- 4) Enable educators and related professionals to use information technology effectively.
- 5) Work with industry and academia to develop technical standards for extendable component-based technologies and infrastructures that can be widely used in online education and training.

### Endnotes

- [1] IDC, Gartner, ASTD, Accenture, Microsoft analysis.
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### Author's Biography

Randy Hinrichs is the Group Research Manager for Learning Science and Technology within Microsoft Research where he is developing learning Web services for education, managing a large scale Learning Science and Technology research project at MIT called iCampus, and is one of the pioneers of the Learning Federation, a consortium of industry, government and universities focused on an international research agenda for LST. He has been working as an educational technologist researcher for 25 years. He delivered the first World Wide Web at Sun Microsystems in the early 90s and wrote two ground breaking books on using the Web for education: *Web Page Design: A Different Multimedia* (cognitive and interactivity design), and *Intranets: What's the Bottom Line* (creating learning organizations with intranet technology). He has testified before Congress for the Web-based Education Commission, participated in the PITAC Subcommittee on Learning, keynoted at many international Web education conferences and appeared in many articles both as an intranet strategist and visionary on Web education. He is Microsoft's industry board member on the Accreditation Board for Engineering and Technology, IEEE Learning Task Force, the National Science Foundation's Corporate Foundation Alliance, ACM's eLearning Board, the American Society of Engineering Education and the International Network of Engineering Education and Research. His penchant for technologies in education is simulation-based technologies that enable activity-based learning, discovery learning and game-based learning.