THE LEARNING FEDERATION: ESCALATING LEARNING SCIENCE AND TECHNOLOGY RESEARCH AS AN INTERNATIONAL GRAND-CHALLENGE

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Where are the Evolutionary Learning Tools?

What characterizes the 21st century learning environment?

Innovation, evolution, global communities, integrated media, navigation in digital space as a core competency, competition, institutional metamorphosis, and diversity. A core enabler: media technology, web technology, cell phone technology, mobile technology. And the applications: messaging, telepresence, collaboration, gaming, knowledge management, just to name a few. And the greatest benefit: a renaissance in learning. Everyone seems to really care about learning, both as a competitive differentiator and a way to prepare the 21st century engineering workforce. Why? Because our new technology landscape has changed how we work, how we play and how we learn.

Where is all of this headed?

Clearly, technology has enabled access to education across distances? We are able to present a video lecturer with presentation and exercises across the Internet. We, as enabled web authors, can automatically create database generated learning web portals with little effort, putting up class notes, syllabi, discussion groups, and richer visualizations. We can distribute messaging over global networks, share video annotations across multiple media. We can use the secrets of AI to prioritize messaging and recognize voice, eye movement, and handwriting. We can visually collaborate in rich visual gaming environments. But, can we teach with technology yet? Can we accelerate our learning with technology? Can we improve human performance? Can we motivate learners to value? Can we scale our human experience beyond the classroom? Yes we can.

How?

We’ll all admit here though that almost all e-learning we see today is boring? K-12 have created some fun edutainment software selections. E-learning vendors have populated us with learning management systems. We can all access material, we just can’t do anything with it when we get there, but read it and talk about it. How do we then prepare end users to be active learners, project based critical thinkers, and solution providers? How do we accelerate our ability to knowledge transfer? I’ve seen some examples, but none with the power of a distributed, highly scalable supported network system. Well, that’s not true, I’ve seen a few incredible potential learning environments that show promise: but most of them look like computer games. Asheron’s Call. Flight Simulator. The Sims. Black and White. Zelda, Physicus, and Mind Rover. The question I have for you: are you ready to start creating immersive, interactive, intuitive learning environments that enable us to share community, exchange assets, accredit quality engineering education and enrich your experience and reputation as a 21st century engineer?

How do you evolve from an electronic classroom to an interactive, immersive learning environment?

Many of us, and you all know who you are focused only on how to use technology to deliver a “classroom experience”, to take a quiz, or to communicate your class notes, your lectures, your publications, and other reading materials. I don’t know about you, but I personally can’t sit and listen to anyone lecture to me with a presentation for very long? I believe it works sometimes – it’s economical for communicating policy, or financial results, keynotes, or bad news, but it doesn’t allow for much interaction, much activity building, or much time on task. It makes us listen, think and wander. We are the streaming generation, and we’re capable of multiple, simultaneous streams at the same time. So, what I really want to know is can we use technology to teach me so that I can transfer new skills into real action immediately? I want to be able to do something after I sit through a learning experience, not just stand up and stretch. But, we continue to assess human competency through audio technology and textual representations. Why? Why? Why? Why? Why? Why?

Why can’t we extend our digital persona to the learning persona?

What amuses me about our ancient learning technology is that we spend most of our real time in front of televisions, radios, computers, cinema screens, pouring through visual
content just to relax. We’re going to have to figure out how to do the hard stuff called learning with this same technology. We rarely use that visual media or the power of its instant collaboration and communication to create learning environments. We’re stuck on the PC plugged into the wall and we rarely think of how to use our technology to enhance our mobility, or provide in the field rapid, iterative feedback while we’re engaged in a project. Instead we build electronic classrooms, textbooks, and tests. My son told me recently that school was nothing more than a cut and paste exercise. As a 15 year old who plays video games for fun like Civilization, Age of Empires, or Caeser III, he complained to me on that same day about a history course in high school that he told me was so boring. He said, “why should I study Rome, when I built it. Not only do I know how to protect my granary, but I know how to build a Senate to protect my investment”.

Can we change?

We have pointed technology at the lecture based classroom with its 30 students all staring at the same page for far too long. We cleverly built assessment engines that could automatically grade multiple choices and other pattern matching quiz models. We have rushed headlong into a textual based page turner, digital photo album, and filing cabinet to store all of our references. We have done no more to education with technology than the PC has done to the desktop. It’s increased our workload beyond cognitive capacity. The upside of this, however, is that we’re all on-line at the same time, and that’s something that we can start taking advantage of for building learning systems. Why? Because it’s more about people to people connections, interactions and expert communities than it is about digital libraries. We need those too, but we need the human part of learning put back into e-learning. We might, we just might, have the possibility of turning this power, this ubiquity, this instant global supply and demand into a place where knowledge is truly the competitive differentiator and depth is more important than breadth.

What is our call to action?

So, our call to action here at EdMedia 2001 is to start going beyond this conference and start connecting our communities of learning. Now it’s time to use our collective innovation and evolve our global communities by integrating the media, standardizing on knowledge objectives, racing toward visual integration, simulation building and mapping back to core competencies. We need to stretch our organizations and advance us toward a connected learning community.

What are the challenges we face?

Some serious challenges face us: cultural differences, technology visions, tools, breakthroughs, and distribution of technology and expertise to all members of society. We lack good tools for enabling the education provider. We struggle with reinventing infrastructure for building our learning systems. We lack standards for ensuring that our content and the richness of your experiences cross over into my environment. We lack a global, clear, integrated articulate vision of a global learning environment that is shareable, scalable and pervasive. We need to work together during this conference and in our future partnerships to accelerate the revolution in tools for learning. Let’s start with the pedagogy.

What do we need to do first?

We need mechanisms, infrastructure, and organizations that enable lifelong learning based on just-in-time, on-demand, pervasive learning. We need exemplar instructional environments. Picture Engineering World on-line, Chemistry World, IT World, and Human Anatomy World. We need organizations that will build visual objects that are shareable across platforms. We need to break away from traditional courses, course sequences, or perhaps even, curricula. For example, instructional modules may only involve prerequisite chains for any given topic and be arbitrarily interlinked with related modules. We need to take into account learner style and learner preference.

We need learning environments that focus on active critical thinking and problem solving skills.

Current educational practices, particularly in the sciences, mathematics, and engineering, produce far too many graduates who can solve standard academic problems but can't solve real problems, much less problems whose nature and solution spaces change during the process of attempting to solve them.

We need technology and education to focus on more constructivist principles, "learning by doing" using real problems that are appropriately scaled-down. This process often involves multi-disciplinary approaches. For example, solving a simple problem dealing with the environment may involve chemistry, biology, climate, population dynamics, etc. Thus we see case-based and problem-based approaches, typically demanding team efforts, and studio courses replacing traditional lectures. Let’s build environments that engage research, university and industry in a single point of engagement.

We need embedded assessment technology that constantly maps our knowledge needs, captures what we are doing and relates it back to our goals and objectives for learning.

We need new devices for both receiving data and outputting data. What do the tools look like that will enable us to take live multimedia data and integrate it into any computing device so others can interact with the data across the other side of the world? Imagine building a bridge through a virtual technology enhanced experience.
We need far more research in learning science and technology, and we need it on a grand, global scale.

**What enabling technologies will get us there?**

- Distributed networking is simply a requirement, we need it wireless, robust, international and responsive to high bandwidth.
- Form factor explosion allows pervasive computing because interconnected computers can exist not only on the desktop but also in our buildings, our furniture, clothing, transportation and bodies. We are here at EdMedia 2001 to explore how we are moving closer to the dream of a continuous computing environment that seamlessly follows us wherever we are.
- 3D graphics chips and cards create revolutionary improvement in the performance of real-time display of dynamic, interactive graphics. Real-time streaming video and audio can now be handled through proper compression even on commodity machines and low-bandwidth connections and so are no longer confined to higher-end machines.
- Collaborative technologies allows us to mentor, assess, annotate, construct, deconstruct, and share common contextual learning objectives over any platform or form factor.
- We can contemplate running sophisticated simulations in real-time on commodity desktop and laptop computers, showing rich sensory information - graphics and audio in particular - that were not possible even five years ago.²

**What will the institutional impact be?**

- **Institutional distance education** which just a short time ago was viewed by the educational establishment to be of marginal interest is now becoming a mainstream activity. For example, the ambitious EU European Commission's "eLearning Action Plan" reflects the strong European experience and interest in open and distance learning. America’s Web Based Education Commission which conducted a year long study on technology in education for the U.S. Senate concluded we need powerful new internet resources, especially broadband access, that is widely and equitable available and affordable to all learners. Early successes in this area can be seen in such institutions as the 40-year-old Open University of the UK.
- **Removal of outdated regulations** that impede instructional innovation in favor of approaches that embrace anytime, anywhere, any pace learning.³
- We will see a huge need for sustained funding for development of these new environments. We are proposing one today called the Learning Federation to stimulate new research on how people learn in the Internet age. Other consortia include the European Federation for Open and Distance Learning, Universitas 21, and the Swiss Virtual Campus project. This interest is also reflected in pioneering educational infrastructure projects such as Fraunhofer CRCG’s Modular Training System (MTS) project.
- **Traditional universities, consortia of universities, and companies** (often partnered with universities) are focusing their attention on web-based distance learning. In the U.S., for example, Unext and GEN are well-funded and trying to develop partnerships, courses, and a clientele. Microsoft has created a learning science and technology group in their research labs and partnered with MIT in the world’s largest industry university joint research project in technology in education called iCampus. IBM is inspired to create a similar group in their research labs. The objective for these new enterprises is to revolutionize the learning experience with technology especially in science, math and engineering education, where complex problem solving, critical thinking, and conceptual learning is the most challenging.
- **Free course material over the Web, MIT** has recently announced that they are putting their instructional materials, including syllabi, course notes, and textbooks on line, as well as offer streaming video of lectures with correlated lecture slides. What a proposal. This means of course that they will default to the textual model of web based instruction, because the tools for creating rich MIT like experiences just simply don’t exist yet. This is where our research there is focusing their attention: on a framework that enables interactivity, collaboration and on-line embedded assessment.
- **Open Standards Learning Environments**. If we are expected to create environments that span across institutions, we’ll need to create software and platforms that use today’s open standards for creating content and web based applications. We’ll need to work together to ensure that our customers, the global

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² Of course, the fact that one can get a well-loaded PC in the US for under a thousand dollars doesn’t alter the fact that developing countries are still a long way from having an affordable solution on their economic terms. However, in the same way that TV has penetrated even remote disadvantaged regions, so too will PCs and the Internet when they become sufficiently commoditized and compelling.

learners are able to reach each other, explore each other’s content and remain in persistent communities where they can grow their reputations, expertise, and economies.

- **Create experiences and opportunities for working and learning together.** There have been some radical proposals that combine research labs, the workplace, and the learning environment all in the same location building a new metaphor for our economy: the knowledge supply chain that Bill Hanson discusses at MIT. If we want to move from the technology to the laboratory, this is exactly the kind of institutional configurations that we should expect to see in the future.

**What is Learning Science and Technology at MSR?**

LST recognizes that several studies have been done across multiple universities, government agencies and industry. We believe that many of the evaluations that were conducted looked mostly at existing CBT/CD-ROM technologies with long development cycles, and very little integration of results into the mainstream of instruction. We recognize as well that distributed web based computing, easy to use content authoring tools, and processes for interactivity are all fairly new concepts in the learning science research community. Therefore, our group looks at using web based technologies, rich collaboration, ubiquitous communication and other mobile technologies for enabling technology based learning in all sectors. We wish to promote, fund and conduct quality learning effectiveness with formal assessment, coordinating with the LST research community.

We want to go one step further than talking about next generation pedagogy. We are convinced that the lecture based classroom is headed for significant enhancements, if not even cancellation in some areas of content. So we are interested in implementing what we know from learning science research and begin to experiment with web services that are based on cognitive, neuroscience & constructivist pedagogy. We have the opportunity to conduct research in high bandwidth environments, wireless campuses, and cultures where computing has become a standard of living.

So, we’re looking to stimulate the development of Learning Web Services. These are educational services built on a .NET based collaborative framework with MIT, extensible to all learning institutions. The framework will be the infrastructure platform for any postsecondary engineering education institution that seeks an environment where the individual contributor is able to either utilize existing services like authentication, presence awareness, notification, scheduling, on-line labs, etc. We are looking to help higher education build services for embedded assessment, rapid feedback, and highly interactive mentoring and tutoring environments for learning how to solve problem and critically think. We are leveraging int’l learning standards (IMS, IEEE, W3C, IETF, OKI), building strategic reusable learning component modules with partner universities to operate on the framework, and working with the accreditation bodies to ensure quality control of technology use entering engineering education.

We are extremely interested in helping universities and industry interact where appropriate. We know that students coming from active based learning environments, or project based environments are able to work effectively in 21st century digital companies. The demands for being able to work virtually, changing teams often, balancing a portfolio of projects, innovating in unsheltered waters, all the while project managing large budgets, authoritative customers, and a diverse resource pool is a challenge that can be tackled during the post secondary years. So, we are interested in supporting projects that are using technology to enable activity based learning.

We are also interested in helping to build a framework for mobile collaborative technologies. Our vision is to build a connected learning community using open standards technology in an environment where the individual user is empowered to create reusable services. We want to extend this model to a mobile platform to free the use from sitting in front of a PC to learn, or freeing a community to openly share communication, issues, problems, solutions and celebrations. In moving away from the desk, we are also interested in what the next generation of I/O devices look like to enhance education in the field.

**What can MSR and MIT do with iCampus**

**Engineering World** is a vision of the next generation university learning experience. Instead of lectures and testing, students will enter into Engineering World on the World Wide Web. Engineering World will look very similar to many of today’s internet based gaming environments. Students will be represented as avatars, and will engage in the building of objects that require engineering knowledge and expertise. They will work in tandem with tutors, mentors, peers, experts, and industry participants. They will attend project based courses where they will engage in problem solving in groups. They will log onto EW, see a profile of their projects which will include simulations, internet based laboratories, audio based presentations defining concepts and procedures, multimedia demonstrations of the way things work, 3D object oriented environments in which they can build things, and an assessment engine underneath that tracks their performance and provide rapid, iterative feedback in various formats.

One of the formats that is crucial to the learning experience is collaboration, which includes mentoring, tutoring, peer evaluation and faculty evaluation. These experiences are designed to be accessible 24x7 in a wireless, distributed connected campus: including dorms, buildings on campus, and potentially homes (given bandwidth and telecommunication constraints). Content will be widely available through MIT’s Open Courseware project, partnerships with other universities and industry. The framework for Engineering World is being designed on open
standards specifications (HTML, WML, Voice XML, XML, WSDL, and SQL). Its implementation will be built on .NET. The framework is the foundation for other project proposals at MIT’s iCampus Lab World, DotBots, Games to Teach and Engineering World. We want to extend the user experience to the mobile world and increase the motivational aspects of the environment by leveraging off of gaming technologies.

The architecture strategy for the framework is based on pen standards, leveraging 3rd generation Web technology (web services – 2 way-internet). It is a loosely-coupled, modular architecture allowing use of some or all components for any course development. Its use of models (meta-data) will allow the system to adapt without coding. It will be architected on an application server farm for redundancy and scalability.

Like web services, it is layered: an infrastructure layer, web services, user experiences and multiple devices.

The framework supports the user experience in the following way: course delivery and course management support for student, instructor/TA, and admin with a portal format, using modular content “portlets” in XML rendered based on device and user role/preferences. For example, the end user will see: “my courses”, “my labs”, “my collaborations” and will experience rich multimedia and 3D avatar virtual interactions. It will also integrate with instant messaging and NetMeeting.

Students will be able to View active courses, assignments, and links to course content. They’ll be able to view lab assignments, run experiments, and check experiment status. They’ll be able to interact with a “Virtual TA” - online persona that helps students submit experiments and analyze the results, engage in sync or async interactions with instructors, TAs, and other students and they’ll be able to get notifications of important events sent to them instantly. We’re also conceptualizing virtual interns in industry.

The infrastructure consists of Web application servers hosting user experience sites and Web services, database servers maintaining state, external servers providing services and an ASP-model allowing hosting for multiple organizations.

Learning Web Services. Once the framework is built, anyone will be able to write learning web services to enhance the experience and share in all the rich tools and services that enable next generation interactive, immersive learning environments.

What can a Learning Federation do?

Provide large libraries in all the various disciplines of interoperable clip models embedded in their hyper textual context and integrated with real-time evaluation and assessment is a project of Grand Challenge scope - involving unprecedented, huge, international commitments of time, personnel, and money. The reasons that it is a Grand Challenge-level project are:

- It is intrinsically open-ended and is likely to dramatically grow as the possibilities become apparent to increasing numbers of people.
- Fundamental research is needed, with all that that implies. For example, how do you develop models that can be parameterized and that can have questions asked of them from different levels of knowledge, age, and experience? How do you develop physically-based models for the heart, or an ecosystem? What parameters should be exposed?
- The infrastructure and user interface design issues have only begun to be addressed.
- The clip models must be designed for the growingly diverse federation of devices that will become the educational vehicles. How is this to be accomplished?
- In short, we must supersede today's repurposed print-based textbooks enhanced with a few additional multimedia bells and whistles. To create next-generation materials centered on interoperable clip models requires a new design discipline for what is essentially a new medium. This design discipline requires collaborative teams of experts from cognitive science, social sciences, the arts and traditional design disciplines, film and other story-telling media, information structure design, and other previously under-utilized fields, collaborating with teachers, domain experts, and computer scientists.

To deal with these long-term basic research issues we are proposing the formation of a new foundation to be called the Learning Federation. The Learning Federation would be a non-profit, industry-led, industry-governments foundation to fund research partnerships that focus on closing the education and skills gap through stimulating rapid advances in learning science and technology, as well as the rapid application of these advances. The Learning Federation's initial target will be post-secondary education in science, mathematics, engineering and technology (SMET). The insights gained would clearly be applicable to many other areas and levels of instruction.

The Learning Federation would fund pre-competitive basic and applied research, including the development and assessment of prototype, next generation courses and learning environments that would be tested with large numbers of students and teachers. It would fund world-class interdisciplinary teams that have sufficient size, longevity and resources to achieve major advances and research institutions to identify and test concepts that could be moved into practice. It would provide flexible and efficient management designed to identify key research priorities and research providers, manage intellectual property (IP), assess return on investment (ROI), help to disseminate results, and would encourage the formation of new research teams and consortia as appropriate.

Research Strategy
Initially, we propose to pursue seven tightly interwoven research areas:

1. **Learning Science Research**: new approaches to learning and pedagogy, enabled by technology

2. **Content Research and Instructional Design**: build 10-20 revolutionary "exemplar courses" and "exemplar environments" for continuous learning

3. **Evaluation**: judgment about the quality or worth of a student's or a program's performance or progress.

4. **Assessment**: observations, measures, and/or tests made to obtain the information needed for evaluation.

5. **Learning Tools and Technology R&D**: develop software tools that enable the implementation of learning science concepts in courses and advanced assessment strategies (this is in itself a major research challenge).

6. **Learning Management Systems**: reengineer the business processes of education and develop the appropriate networked learning environments for conducting both the delivery and the business of education.

7. **Monitor Innovations in Hardware and Software**: ensure that LF work takes full advantage of innovations made in all sectors.

The core of Learning Federation activities will be the first four research areas which form a "virtuous cycle." Instructional concepts developed by the learning science research teams would be immediately put to use by the instructional design teams in a variety of SMET topic areas. The evaluation and assessment teams will develop methods for evaluating individual student progress using innovative, performance-based metrics that measure real gains in understanding (instead of simply measuring skills in passing standardized tests.) And the learning tools and technology R&D teams will develop key software tools that make the other work possible.

Building real materials, and working with real teachers and learners is essential both for discovering problems worthy of further research and demonstrating the effectiveness of the research results. Donald Stokes [ref] points out that researchers like Louis Pasteur working to solve very practical problems achieved some of the most dramatic research discoveries. The close coupling of research teams with people working to develop and test real instructional systems is designed with this strategy in mind.

The research teams will cover the following kinds of problems:

- The **learning science research** teams would focus on innovations in learning made practical by emerging technologies. This would include exploring strategies for using learning by discovery and learning by doing, finding how best to use the time and talents of teachers and experts (when to lecture, tutor, coach, counsel, guide, how and when to intervene), learning how to adjust instruction to meet individual students needs, and determining when learning is best achieved in groups.

- The **content research and instructional design** teams would support development of collections of interoperable learning objects, as well as complete experimental course units and courses in a variety of different subject areas. They are likely to take dramatically different approaches but will share a number of requirements that will provide challenges to the teams developing learning tools. Developing next generation interactive courses with all their options and possibilities will require multiple millions of dollars per course, an investment at least as large as that needed to develop today's massive multi-player simulation-based games. These large costs can be amortized over a large number of learners.

- The **evaluation and assessment** teams will provide independent evaluations of innovative courses in experiments involving increasingly large numbers of learners and teachers. All of the courses would be designed for continuous improvement and the Learning Federation would facilitate a continuous and expanding cycle of new research, new materials, and new assessments with each cycle of assessment involving an increasing number of students. These teams will also investigate new forms of assessment - including embedded assessment that can track the progress of each student. Embedded assessments can guide the simulated environment to match each individual's level of interest, competence, and learning style and call upon human tutors at appropriate points.

- The **learning tools and technology R&D** teams will provide resources for building visually compelling and scientifically accurate simulations, easy-to-use P2P tools for connecting groups of students and teachers, and other critical components. The tool designers can also ensure that components can be shared and reused by different groups because they are based on architectures supporting interoperable components. The tools will include authoring systems which make it easy for instructional designers to develop systems based on powerful immersive environments, and that adapt to different learning styles, capabilities, and backgrounds. The tools should be easy to learn and easy to use, letting instructional designers focus on content, instructional design, and teaching.

- The cycle of invention, testing and improvement will be supplemented by work on improving systems for **learning management** and a group that will provide continuous intelligence on developments in **hardware and software** throughout the economy. The new learning management and administration tools will
allow a learner to participate in a wide variety of new learning experiences from many different learning providers. They will also permit uniform tracking of such things as the student’s records, intellectual property, and payments, subject to appropriate privacy protection mechanisms. While a variety of such tools are being developed commercially, enormous opportunities remain untapped. The hardware and software intelligence team will ensure that the Learning Federation teams are able to take advantage of advances being made outside the field of education.

**What you can do now?**

- You can stop using technology to only lecture.
- You can start integrating technology into your daily experience.
- You can stop using technology to quiz yourself.
- You can start using technology to express yourself.
- You can stop using technology to read.
- You can start using technology to experience

**Conclusion**

In this paper, we have discussed how there are no real evolutionary learning tools that take advantage of multimedia, web technology, interactive, collaboration, people to people communication. All these components exist, but they are not working together to provide a maximized learning experience for the lifelong learner. I discussed that we need to focus on attention on institutional changes, critical thinking and problem solving, not access to textual information. We call for a focus on constructivist paradigms for software and research in next generation devices for education in a ubiquitous mobile world. We suggest that the institutional impact will be driven by institutional e-learning, consortia, free quality content over the web, standardized open learning objects, and creating incubators where research, working and learning all fall under the same roof. We discussed Microsoft Research’s interest LST and hinted at using next generation gaming environments, collaboration systems, and basic research in CS into educational tools. We offered a framework created with a major engineering institution, MIT, to work together to form the foundation upon which we can possible build a set of learning web services. And, finally, we discuss an idea for an international consortium of governments, universities and industries to accelerate the research agenda for learning science and technology. What we hope will be a success from my keynote for EdMedia 2001, will be a realization that we are in a Learning Renaissance: there has never been such a focus on learning and building tools for learning in our history. What each of you can personally do is to focus on the future and start building tomorrow. As we conclude often, the best is yet to come.