eLearning in Engineering:

The Interplay of Technology and Pedagogy

Jack M. Wilson, CEO UMassOnline, One Beacon Street 26th Floor, Boston, MA 02108; email: jackmwilson@jackmwilson.com; phone: 617.287.7160.

Abstract

Over the last decade in the United States and throughout the world, the progress in computing, telecommunications, and the cognitive sciences has led to major changes in engineering education at all levels. It has changed undergraduate education through the introduction of new formats such as the Studio Courses or Computer based courses in Engineering and Science that have been adopted at so many schools. Even when the format of undergraduate courses has not changed, the courses now incorporate the use of sophisticated computing tools that had only been available to the research engineer or the practicing engineer working at the leading edge during the 1980's. The change in technology also led many universities to make changes in curriculum as they experimented with far more integrated programs that introduced engineering students to engineering early in their course of study and thereby provided a tangible justification of the study of the sciences, mathematics, and computer science courses that provide the tools for the engineer.

The most profound changes may be occurring in the continuing education of engineers. The rapid change in technology epitomized by Moore's Law and Gilder's Law makes continuous learning an imperative for all practicing engineers. Paradoxically, the rapid pace of change both makes continuous learning more necessary and far more difficult.

The author will review how computing, communication, and cognitive science advances have driven change in engineering education from his perspective as a faculty member for 33 years, as well as his service as Director of a Research Center, Dean, and Provost at Rensselaer Polytechnic Institute as well as his new position creating a fully online university for the Commonwealth of Massachusetts.

About the author:

Jack M. Wilson is presently serving as the Founding Chief Executive Officer (CEO) of UMassOnline, the online university for Massachusetts. He has had a career of 33 years as a professor, department chair, research center director, dean (4 times), and provost.
Prior to joining UMassOnline in 2001, he served as Provost (interim), Dean of Faculty, Dean of Undergraduate Education, Acting Dean of the Graduate School, Dean of Professional and Distance Education, and Director, Center for Innovation in Undergraduate Ed at various times from 1990-2001 at Rensselaer Polytechnic Institute (RPI) in Troy, NY. At RPI he was the J. Erik Jonsson ’22 Distinguished Professor of Physics, Engineering, Information Technology, and Management. He has also served Chair of Physics Department in a prior appointment.

Dr. Wilson, also known as an entrepreneur, was the Founder (along with Degerhan Usluel and Mark Bernstein), first President, and only Chairman of LearnLinc Corporation (now Mentergy), a supplier of software systems for corporate training to Fortune 1000 Corporations. LearnLinc is now known as Mentergy Corporation and is listed on the NASDAQ stock exchange as a successful eLearning Co

He has served as a consultant to many computing and communications firms including IBM, AT&T, Lucent, Ford, GM, Hewlett Packard and others. Dr. Wilson served as one of 16 International Consulting Scholars for the IBM Corporation. Research interests include innovation, knowledge management, the Learning Corporation, eLearning, and the value chain of technological entrepreneurship from research to new ventures. Wilson has authored over 55 scholarly articles, wrote or edited five books, and given over 200 invited lectures. He has enjoyed over $23 million in funding for his research and scholarly activities.

He has also served on the U.S. Army TRADOC Advisory Committee, co-founded the Pew Center for Academic Transformation ($8.8 M), and was one of founders of the National Learning Infrastructure Init. (NLII), chaired the New York State Task Force on Distance Learning, served as the Executive Officer of AAPT (Physics) in Wash. DC for 8 yrs. He was a member of the National Acad. of Science/National Research Council committees on Information Tech., the Physics Decadal Overview Committee, and the National Digital Library Committee, which he chaired

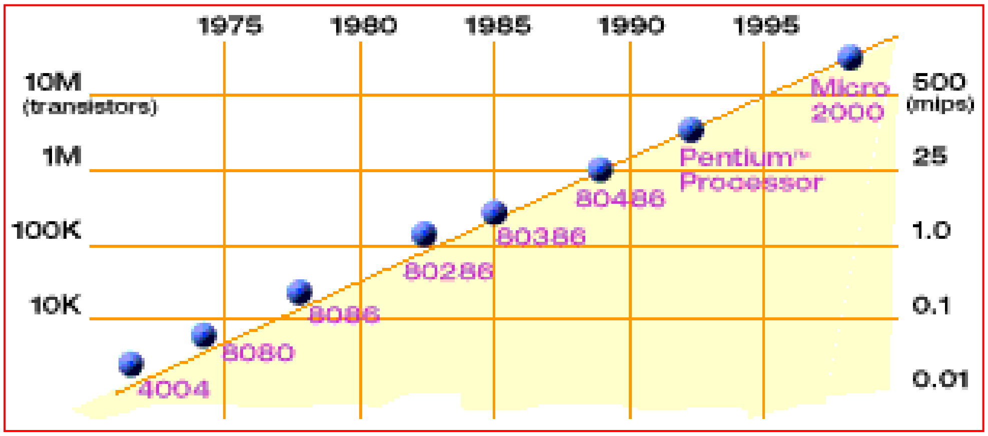
Wilson began career as a research physicist working on the physics of liquid crystals and biological materials. His research required the make extensive use of high performance computing. This led him to ask: “Why are students not learning about this? How can computers help learning?” Hi focus on Computing, Communication, and Cognition led to a series of projects involving restructuring physics and engineering education. He is known as the innovator who created the studio classroom in partnership with other Rensselaer faculty.

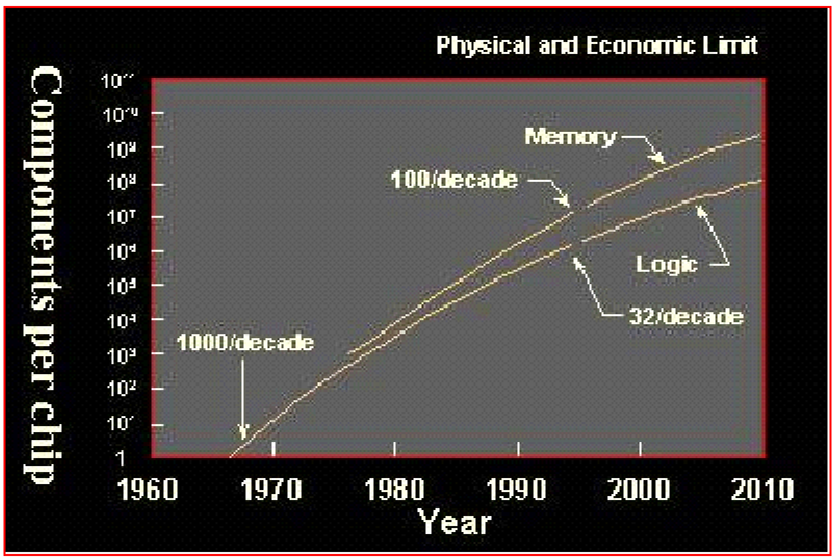
His work at RPI in restructuring the undergraduate Program stimulated an interest in how the studio experience could work at a distance and eventually to how online education could serve the needs of the working professional. His research in these areas allowed him to found LearnLinc and eventually brought him to UMassOnline.

Computing, Communication, and Cognition

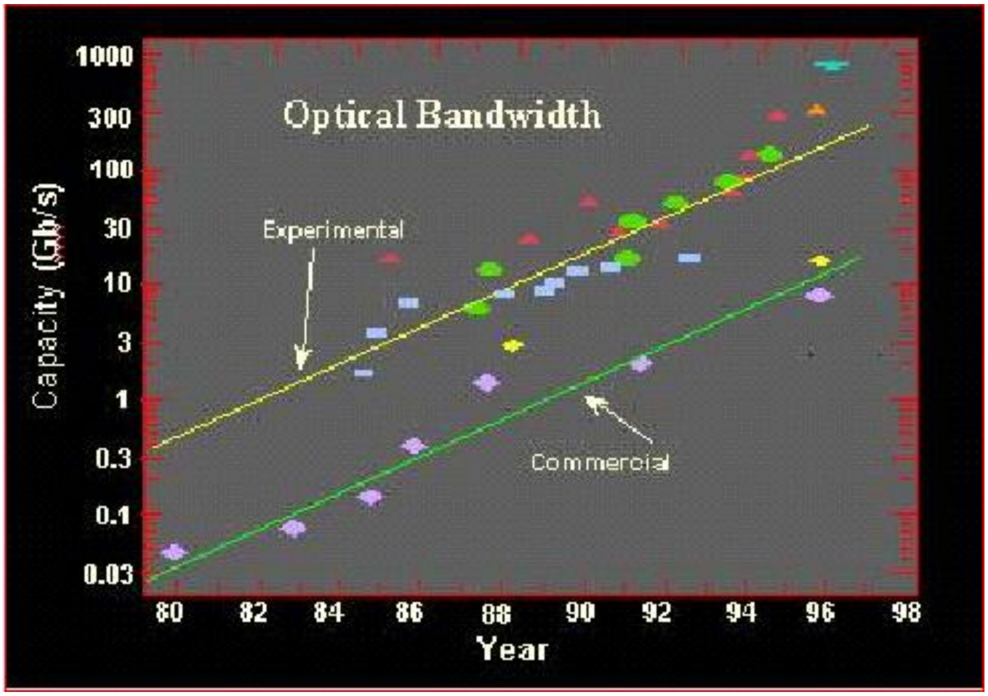
The past two decades have seen some of the most remarkable advances in the areas of Computing, Communication, and Cognition. Three main laws can be used to sum up the progress in the first two of these:

I. Moore’s Law: CPU performance doubles every 18 months. This means that the cost of equivalent computing power halves during the same time period.



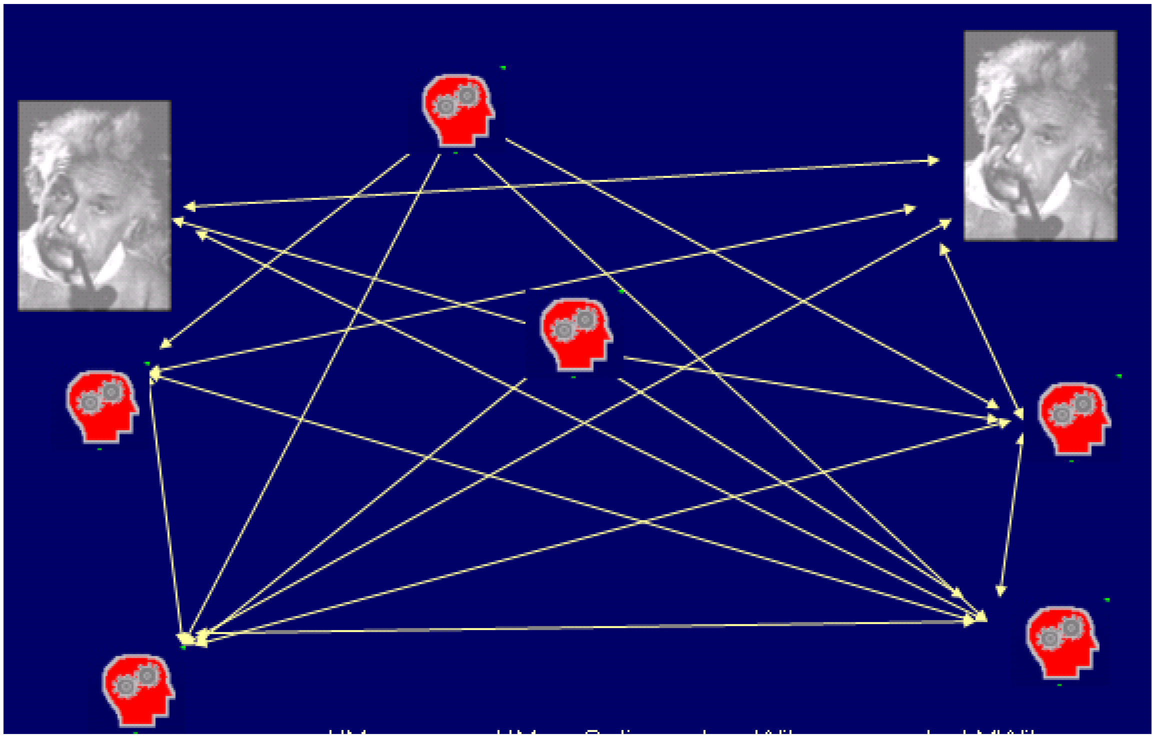


II. Bandwidth law: Bandwidth is doubling even faster! Note that the commercial deployment of bandwidth tracks the experimental advances in bandwidth with a lag of approximately 6 years. This suggests that we can expect the bandwidth doubling to continue for the foreseeable future, since the experimental doubling has continued up until the present.



III. Metcalf's Law: The value of a network scales as n^2 where n is the number of persons (computers) connected. This follows from the mathematical expression of the number of interactions between n interacting objects which leads to an expression of n(n-1). Since n is large in most cases, this can be approximated by n^2. The law is named for Bob Metcalf, former MIT scientist and founded of Ethernet and the 3Com company. He was focusing on the value of networks of computers, but Metcalf's Law appears to hold true for many different kinds of value: economic, social, computational, etc.

Metcalf's law drove some of the most foolish kinds of behaviors in the recent eBusiness frenzy. Some interpreted this to mean that companies should focus solely on creating large networks of users rather than focusing on how to extract economic value from the network. Many businesses from Netscape to Amazon.com found that Metcalf's law was not enough to overcome a poor business strategy.



Research in the cognitive sciences on how people learn was a direct result of the increasing interest in computing during the last two decades of the 20th Century. This led many universities to reconsider their approach to educational innovation. Rensselaer was one of the most prominent examples. The innovations driven by computing, communications, and cognition inevitably led to efforts to develop virtual universities. UMassOnline is one of the most successful examples of this. Others include: the Penn State World Campus, the University of Illinois, and the University of Maryland University College.

UMassOnline, The online university for Massachusetts, is a collaborative campus project that involves the faculty, staff, and resources of all University of Massachusetts campuses to provide undergraduate and graduate degree programs, special certificate programs, and other non-credit programs to working professionals who could not otherwise attend one of the physical campuses. The total enrollment in the Academic year 2001-2002 of 9164 includes only the new students who attend the virtual university only. There are also tens of thousands of students on the campuses who also participate in online programs. UMassOnline generates tuition revenue of $ 6.94 million that can be used to support the research and educational programs of the University. It is growing at a rate of 56.3% per yr. UMassOnline has also attracted grants of $ 2.43 million. There are 17 undergraduate programs and 12 graduate programs available.

During the 1990's RPI was one of the most active universities in the U.S. in the deployment of new technology enhanced learning environments. The resulting RPI restructuring strategy from 1990-99 included efforts to:

- Replace Large Lectures with Studios
- Create a 4 X 4 Curriculum of fours courses each semester.

- Expand into new markets with Distributed Learning
- Student Mobile Computing: Require each student to have a laptop.
- Institute a Technological Entrepreneurship Curriculum

There is a challenge inherent in any effort to innovate in education: The restructuring of the curriculum cannot be allowed to disrupt the students' experience. This has been compared to the difficulty of building an airplane while it is flying. Systematic evaluation, both formative and summative is imperative.

The Studio Classroom

The philosophy of the Studio Course is to convert the classroom from a place in which the faculty member does most of the work to one in which the student does more of the work. What do you does a student normally do in a lecture hall? (In the U.S. at least)? The better students listen and take notes, perhaps even asking a few questions. Many students are not so diligent. They may day dream, read, or even fail to attend the lectures. What is different about a studio? In a studio, the students are expected to be the "actors." They "perform" instead of having the teacher perform. This is a simple but profound difference.

In engineering and science, the "performance" means that students are working on problems, team discussions, laboratories, or other activities rather than listening to lectures. Engineering studios combine analytic, simulation and experimental approaches. Studios de-emphasize (but not eliminate) the lecture. They combine lecture, recitation, and laboratory experiences in one facility. They often use a constructivist approach and may incorporate multimedia courseware in special classroom facilities such as the Theater in the Round Classroom. Distance versions of these courses use multipoint video, audio, and collaborative systems.

One might describe traditional approaches to class as the mainframe approach, by analogy to computer systems. The mainframe is seen as having all of the power while the students are the equivalent of "dumb terminals" that get their power from the mainframe. The lecture and other face to face programs are often like this. Many distance learning courses use this same approach and are the intellectual equivalent of pushing out the back wall of the lecture hall for a few thousand miles.

We now know that there are better ways to organize learning environments, whether face to face or at a distance. The distributed collaborative model builds on Metcalf's Law to create a network of learners or a learning community engaged in interactive learning.

When one hears stories of how difficult it is to teach students in online learning environments, it is often because the speaker has organized his or her course in the old model. The Chronicle of Higher Education recounts several such stories in "The 24-Hour Professor"; [Chronicle of Higher Ed; May 31, 2002]. This is a perfect example of how not to organize online learning.

Better designed learning environments make far more use of collaborative learning and peer learning and try to create interactions among the students rather than simply between student and faculty.

The Rensselaer strategy of studio classrooms, distributed learning, and other innovations attained many kinds of national recognition including:

- The Hesburgh Award 1995
- The Boeing Outstanding Educator Award 1995
- The Verizon Award, 1996
- The Pew Prize 1997
- An award of $8.8 million for Pew Center for Academic Transformation

In order to have the maximum impact on the student experience, RPI focused on the introductory courses with largest enrollments. These include:

- Calculus (1100 students)
- Physics (750)
- Chemistry (650)
- Introduction to Engineering Analysis (650)
- Economics (~300)
- (in the beginning)

Later the Studio model was extended to many other undergraduate and graduate courses, especially in Electrical, Computing, and Systems Engineering programs.

The original large enrollment courses were often organized with 2 lectures, 25-30 recitations or tutorials, and 30-40 laboratories. The Studio model envisioned replacing these with studio classrooms using 12-15 Studio sessions with 48-64 students each. Each Studio was 2 hours in length organized in a pattern like:

- (20 min) Problems Due - Discussion
- (40 min) Hands-on Group Activity
- (10 min) Discussion
- (15 min) Another Group Activity
- (15 min) Mini Lecture: Formalism
- (5 min) Conclusion

Comparing the traditional classroom to the Studio classroom one can see that the Studio classroom actually decreased the number of hours spent in class while increasing the level of interactive learning.

Traditional	**Studio**
Credit Hours: 4 Contact Hours 6 2 Hours Lecture 2 Hours Recitation 2 Hours Lab	Credit Hours: 4 Contact Hours 4 4 Hours of Studio (includes laboratory, problem solving, etc.)

In the late 1990's the Electrical, Computing, and Systems Engineering department decided to move all large enrollment courses (>50) to the Studio format. Timing was to be determined by facilities availability. This would eliminate the traditional lab courses, but would not eliminate the laboratory experiences themselves, but instead incorporate these in the Studio. It would merge the labs with the theory courses. More importantly, the change would add Hands-On experiences to courses that had NO associated labs. According to William Jennings, former Chair of Electrical, Computing, and Systems Engineering, the courses that were to be transformed included:

- Circuits Studio - 1500 ft2- 42 Students
- Instrumentation Studio - 1200 ft2 - 36
- Computer Studio - 1200 ft2 - 36
- Control Studio - 1500 ft2 - 44
- LITEC Studio - 3600 ft2 - 72
- 12 More Around Campus
- plans for many more

Some other examples include:

- Computer Components and Operation
- Computer Architecture, Networks and Operating Systems
- Laboratory Introduction to Embedded Control
- Electric Circuits
- Analog Electronics
- Microelectronics Technology
- Digital Electronics
- Electronic Instrumentation
- Fields and Waves I
- Signals and Systems
- Discrete Time Systems
- Control Systems Engineering
- And more....

Like Physics, the Electrical, Computing, and Systems Engineering program also utilized two hour Studios offered 2-3 times per week. There were several activities in each class including

- Mini-Lectures
- Discovery Exercises
- Simulation Activities
- Interactive Discussions
- Hands-On Experimentation
- Analytic Problems

The Physics Studio was one of the first and largest of the Studio Programs. It included use of special software tools such as:

- Microcomputer Based Laboratories
  - not simulation! Data acquisition.

- Video Tool
- Interactive Lecture Demonstrations
- Simulations
- problem solving

The first day of the Physics Studio, as taught by the author, began with the students running back and forth in front of the computer! They were using Microcomputer Based Laboratory hardware and software (MBL) to measure their distance, velocity, acceleration and time as they moved about. Students were asked to interpret and predict graphs of distance, velocity, acceleration versus time, and were expected to be able to transform form one to another.

The Videotool for Mechanics was one of the most popular tools. One could take a video of a moving object directly into the student computer and then digitize, measure, and analyze this video with the Videotool. They could also use this tool to track and measure movements of objects in two dimensions. The fact that it could be done live in class, was a powerful learning incentive for the students.

We also used simulations, although we are careful not to allow simulations to displace actual measurement of real physical phenomena. We often coupled simulation with real experiments, both to demonstrate the power of theory and approximation and to illustrate the limitations of any mathematical models.
The interested reader may wish to have a look at two examples of web based simulations.

- Quantum Well http: http://www.jackmwilson.com/JavaJackPrograms/SquareWell.html
- The Pendulum: http://www.jackmwilson.com/JavaJackPrograms/Pendulum.html

Many felt that the cost of the studio classrooms would be an obstacle to use of the studio in many universities. In the end, the cost of the Studio was competitive with or even lower than traditional programs at many universities. A typical cost comparison shows that:

- Desktop room: $100,000
- Laptop room: $25,000
- Expected life: 5 years (10 semesters+summer)
- Amortized cost $10,000 or $2500 per course
- Room serves 500 students per semester
- Cost per student $20 or $5.

A traditional course in a traditional classroom costs typically $1000-3000 per student, so this is a modest cost to add to the overall program. In fact, it is less than the cost of the textbook!

It eventually became clear that the best model would be to expect the student to have a laptop computer available at all times. We called this the Student Mobile Computing initiative and it consisted of:

- Laptop requirement
- 4 years of pilot
- cost crossover
- 4 year phase in
- student reaction

- faculty readiness
- key to affordability and pervasiveness

To each of these courses, we applied certain evaluation metrics such as:
- Student performance on traditional tests
- Student attendance
- Student performance on cognitive tests
- Student performance on problem solving
- Student attitudes toward the courses
- Student retention
- Faculty attitude toward the courses
- Student success in later classes

The results were impressive:
- Significant improvement: Student Satisfaction
- Significant improvement: Faculty Satisfaction
- Equal or better performance on regular exams.
- Year long Rutgers led evaluation
- Significant Attendance increase
- Cost containment
- Ongoing longitudinal study

The results specific to ECSE mirrored that in other courses and included:
- Much Better Attendance
- Course Ratings Improved
- Instructor Ratings Improved
- Some Improved Learning
- Improved Computer/Hands-On Skills
- Students and Faculty Love It!!

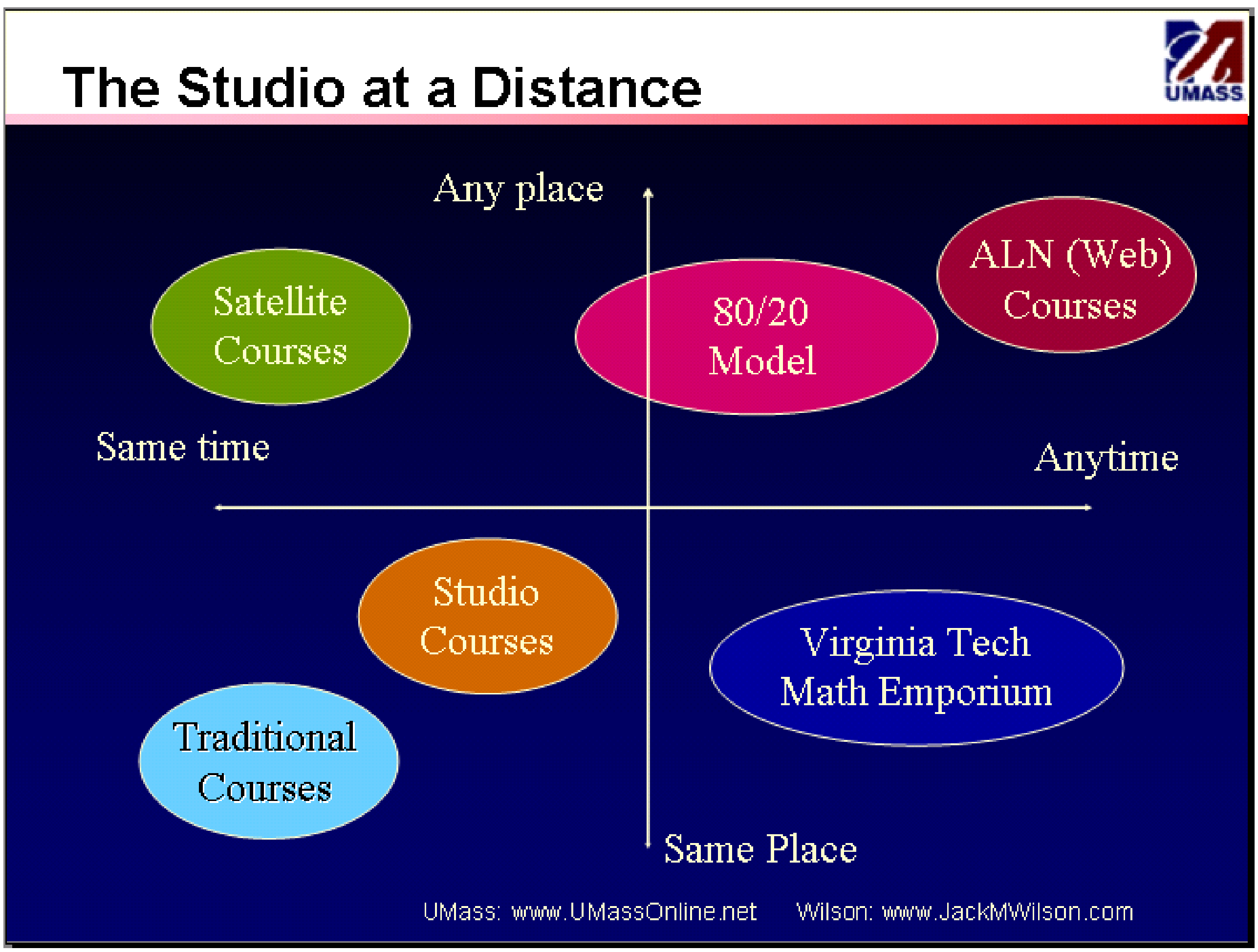
There are many institutions which have adopted some form of the Studio classroom. These include (but are not limited to):
- The University of Amsterdam (http://www.science.uva.nl/research/amstel/)
- Penn State University (http://www.science.psu.edu/facaffairs/strategic.htm) (http://www.psu.edu/ur/archives/news/GE.html) (http://dps.phys.psu.edu/about.htm)
- Arizona State University (http://www4.eas.asu.edu/phy132/)
- Indiana State Univ. (http://physicsstudio.indstate.edu/)
- Cal Poly San Luis Obispo (http://www.cob.calpoly.edu/Evan/polyplan/polyplan.htm) (http://chemweb.calpoly.edu/phys/)
- Ohio State University (http://www.physics.ohio-state.edu/~ntg/26x/2064_pictures.html)
- The University of Amsterdam (http://www.wins.uva.nl/research/amstel/)
- The University of New Hampshire (http://einstein.unh.edu/academics/courses/)
- Curtin Univ. of Tech. (Australia) (http://www.physics.curtin.edu.au/teaching/studio/)
- Univ. Of Mass. Dartmouth (http://www.aps.org/meet/CENT99/BAPS/abs/S3455002.html)

- The Colorado School of Mines (http://einstein.mines.edu/physics100/frontend/main.htm)
- Acadia Univ. (Canada) (http://ace.acadiau.ca/math/boutilie/)
- Santa Barbara City College (http://www.cs.sbcc.net/physics/redesign/final_report/reportb.html)

Distributed, Distance, Online, and Lifelong Learning

In an ASEE Engineering Dean's International meeting, the author (Wilson) was with Christopher Galvin, President Motorola, when he told the group:
"We are not hiring any more graduates with four year degrees. We want employees with forty year degrees."
This statement indicates just how strongly corporate leaders feel that the continuing education of their employees is of paramount importance. This is one of the prime motivators for the development of distance learning, distributed learning, and online learning programs at many Engineering Universities. Corporations have become *Learning Corporations*, and universities stand ready to help with that process.

The author launched a multiyear effort involving several universities and several corporations in developing new learning environments based upon the Studio Classroom at a distance.



The Studio at a distance was one of the most powerful models developed during the 90's. The graphic above compares various models of learning in terms of how flexible they are in time and place. The traditional courses are the least flexible in that they require the students to be at a specific place at a specific time (Same time, same place). A fully asynchronous online course was the most flexible model and would allow the student to work at any time and any place. Satellite or videoconferencing courses could overcome limitations of distance, but maintained the need for synchronous (same time) activity. On the other hand, the mathematics Emporium as developed by Virginia Tech or the Physic Emporium as developed by Rutgers would allow the students to come to a Studio like facility at any time and was thus a model that allowed anytime but required the same place.

The author eventually developed a model for a blended course that combined live on line interaction with the typical asynchronous interactions of the ALN course. With support from AT&T, he implemented this as a model that became known as the 80/20 model. This referred to the 80% asynchronous activity and 20% live on line or synchronous activity. The actual numbers were never meant to be rigid, but merely suggested that a model that was predominantly asynchronous but included a small blend of synchronous or live on line activity.

The author's research in this area, coupled with his consulting for both IBM and AT&T eventually led him to go off on his own and develop powerful software tools for collaborative learning on the network. He spun this off into a commercial company in which he served as founding President and only Chairman. The company grew into the dominant provider of such software in the 90's. He left the company in 2000, but the company continues to operate as a public company registered on the NASDAQ stock exchange as Mentergy Corporation.

The desired vision for such a collaborative learning environment included:

- Delivery on standards based multimedia PC's equipped for live video/audio interactions and connected to a robust ip multi-casting network.
- A mix of synchronous and asynchronous activity.
- Use of Web and/or CD-ROM based multimedia materials.
- Use of professional quality software tools for CAD, symbolic math, spreadsheets, word processing, etc.
- Live audio and/or video interactions among the students and with faculty.
- Email interactions among the students and faculty.
- Small group discussions.
- Collaborative software for application sharing over the network.
- Access to rich resources on the network.
- Ability to "pass the floor" to students to allow them to lead the class through an activity.
- Course administration software to track student progress.
- Classes with a mix of students in traditional and workplace settings.
- Classes with a global perspective and global audience.

In order to implement this kind of an educational strategy, we need to develop a deployment strategy. In essence this was to follow our corporate partners throughout their own globalization process. For example, we followed General Motors into Mexico, Luxembourg and elsewhere. We decided to focus on Engineering, Management and Technology, Computer Science, and Information Technology and offer old, new, and leading edge technologies.

At RPI we were able to build upon the success of the RSVP program which had operated for over 10 years. In 19'93 it was designated by Telecon as the "Best Distance Learning Program" in the U.S. and in 1996 the USDLA cited it for outstanding Industry-University Collaboration. It had 944 Students in Credit/Degree Courses, primarily at the graduate level, and several hundred more in short courses. We were endeavoring to bring education to the workplace, and did so with GM, IBM, Lockheed Martin, AT&T, Lucent, Con Ed, GE, UTC, Pratt &Whitney, Ford, Intel, Applied Materials, Matsushita, Bugle Boy, Albany International, Key Bank, and many others

At UMass we had a similar program called VIP. We were one of the founding members of the National Technological University (NTU). VIP offers programs in:

- Professional Education for Engineering and Applied Science
- M.S. & Ph.D. in Electrical and Computer Engineering
- M.S. in Engineering Management
- M. S. in Computer Science
- Ripples and MANIC (http://manic.cs.umass.edu/)

http://peeas.ecs.umass.edu/fall2002/degreeinfo/index.html

UMassOnline was formally launched in 2000. Wilson was the founding CEO. It was built upon the successes of the existing campuses and quickly became the largest on-line university in New England.

- 9164 enrollments in AY 2001-2002
- Portal: www.UMassOnline.net
- Launched in spring 2001
- Closely coupled to the University mission
- Operates over the M.I.T.I.(Massachusetts Information Turnpike Initiative)
- Received $ 2.25 million IT Bond funding to create statewide platform in partnership with M.I.T.I.
- Eventually open to all state institutions
- Twenty five degree and certificate programs
- Bachelor’s, Master’s, and Certificate programs
- 12 new programs this fall
- Three of our programs have been recognized by US News and World Report as top on-line programs in the October 15, 2001 issue.
- MBA – UMass Amherst
- MEA – UMass Lowell – Ed. Administration
- MPH – UMass Amherst- Public Health

Our programs are intended to serve community needs and focus on specific areas of workforce development and those areas with strong needs for continuing education of professionals such as:

- BSIT BS in Information Technology
- MSIT MS in Information Technology
- M.S. Joint Comp. Science Comp. Engineering

- Nursing*
- MBA
- MPH Public Health
- MS Substance Abuse Professionals
- BLA Liberal Arts
- Degree Completers and many others

Graduate degree programs include:

- Master of Education for Science Teachers Program (Amherst)
- M.S. in Computer Science and Computer Engineering (Amherst)
- Master of Education in Counseling: School Guidance (Boston)
- Master of Ed. in Counseling: Mental Health Counseling (Boston)
- Master of Science (Nursing) Community/School Health (Amherst)
- Master's Degree in Educational Administration (M.Ed.) (Lowell)
- MBA Professional Program (Amherst)
- MPH in Public Health Practice (Amherst)
- Certificate: Adapting Curriculum Frameworks for All Learners (Boston)
- Certificate in Clinical Pathology (Lowell)
- Certificate in Foundations of Business (Lowell)
- Certificate in Instructional Technology Design (Boston)
- Certificate in Photonics and Optoelectronics (Lowell)

Undergraduate degree programs offered:

- Bachelor of Liberal Arts (Lowell)
- Bachelor of Science in Hotel, Restaurant, and Travel Administration (Amherst)
- Bachelor of Science in Information Technology (Lowell)
- Bachelor's Degree in Information Technology: Business Minor (Lowell)
- RN to Bachelor of Science (Nursing) (Amherst)
- Associate of Science in Information Technology (Lowell)
- Certificate in Communication Studies (Boston)
- Certificate in Contemporary Communications (Lowell)
- Certificate in Data/Telecommunications (Lowell)
- Certificate in Fundamentals of Information Technology (Lowell)
- Certificate in Intranet Development (Lowell)
- Online Communications Skills Certificate (Dartmouth)
- Certificate in Multimedia Applications (Lowell)
- Certificate in Community Media and Technology (Boston)
- Criminal Justice Series (Amherst)
- Certificate in UNIX (Lowell)
- Fundamentals of Arts Management Certificate Program (Amherst)
- Certificate in Plastics Technology (Lowell)
- Certificate in Technical Writing (Boston)

Both RPI and UMassOnline use a variety of technologies including:

- Satellite Video
- ISDN Videoconferencing
- CD-ROM Creation
- Mail out materials (including videotapes and/or CD's)
- World Wide Web materials
- Asynchronous Tools: Prometheus and IntraLearn
- Streaming Video
- Live-Online Learning (LearnLinc or Centra)
- Desktop Video (multicast)
- Network based materials management
- Classroom management

Compare the cost of various technologies for distance or distributed education:
- Satellite Video ($500,000)
- ISDN Videoconferencing ($50,000)
- PC Collaborative ($2,000)
- Web Based Asynchronous ($2,000)

This is a dramatic illustration of just how much easier it is to do online distributed education today than it was in the early years of NTU, RSVP, or VIP. Today there are few economic obstacles to delivering education into the workplace, the home, or the community.

Let me cite one example of a program that used all of the capabilities cited above. That is the Introduction to eBusiness Course taught by the author. In the last three years. We used ILINC LearnLinc (from Mentergy) as the main collaborative software tool and the course offered:
- Live Internet Audio (optional Desktop Video -multicast)
- Network based materials management
- Classroom management
- Fall 2000: Tuesday night from 6:30-8:30 pm
  - 50 On Campus Students
  - 75 Off Campus Students
- IBM, Ford, GE, Lockheed Martin, Pratt and Whitney, Ford, Consolidated Edison, NY Power, J. P. Morgan, Carrier, Otis, etc.
- Extensive Website:
  - http://www.jackmwilson.com/eBusiness/Syllabus-Spring2001/
- MBA, MSIT, MS
- miniLectures, Discussion, Student presented cases, & asynchronous interactions
- Spring 2001: 75 overflow students (25 on and 50 off)

The ILINC LearnLinc distributed learning system provided
- Video-audio-collaboration-synchronous-asynchronous
- founded in 1994 by one faculty (Wilson) and two alums (Bernstein and Usluel)
- RPI Research joint with AT&T and Bell Labs
- Began in incubator

- Moved to Tech Park
- Bootstrap start-up and two rounds of venture including one with Intel.

We also taught a remote Physics Course to high school students using faculty and graduate students from the university.

- Introductory Calculus Physics
- Live On-line
- Delivered via ILINC LearnLinc
- Cobleskill High School in rural upstate NY
- Collaborative between the physics teacher at Cobleskill and faculty and graduate students at Rensselaer

One of our largest efforts was undertaken in collaboration with the National Technological University (NTU). The Hands-On World Wide Web course was offered on Feb 10 & 17, 1998 to 8000 participants at 500 sites. According to Lionel Baldwin, President, NTU this was the most successful NTU course ever. He called it "The future of satellite based education."
It included:

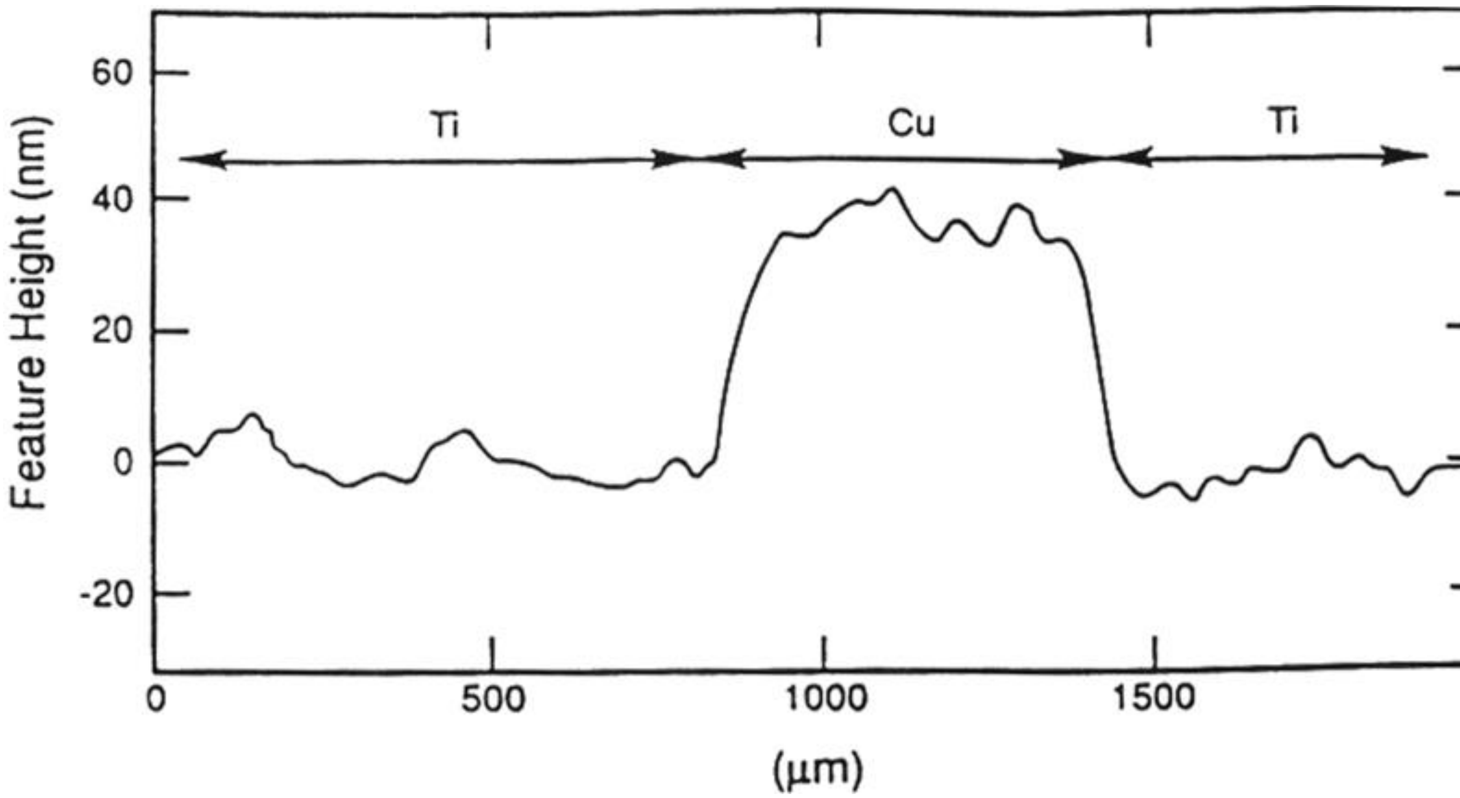
- Satellite broadcast
- Hands On Exercises
- Synchronous Tutoring with LearnLinc
- Asynchronous support

We also taught a course jointly between Rensselaer and Hong Kong City U. "Survival Skills for Astrophysics" was taught by Professor Chun Ming Leung to graduate students in Astrophysics using:

Video/Audio/ ILINC Web Data Conf.
Both ISDN and Internet connection
7 am Eastern (6 Hong Kong)
Student Collaborative Presentations
One Semester length

The Chemical Mechanical Planarization distance learning course illustrated how the result of leading edge research could be immediately incorporated in distance learning courses and then delivered anywhere in the world. Participating organizations included: RPI, Intel, Applied Materials, Matsushita, and IBM. It was taught by the top research team in the world: Shyam Murarka, Leo Schowalter, and David Duquette. A Wall Street Journal article described the process in an Introduction to Copper Metallization. This month long course to engineers and scientists in the workplace was an exciting opportunity. The course used technologies similar to those of the other courses above:

- Video/Audio/ILINC Web data Conf.
- ISDN and Internet
- ProShare, PictureTel, Panasonic multipoint



The Profilimeter trace above comes from the class and shows dishing of the titanium liner relative to the adjacent recessed copper metal. An electrochemical interaction between the copper metal and the titanium accelerated the normally low polish rate of titanium to produce the negative dishing.

The Faculty Experience

Faculties often fear the new technologies and ask "Will the Web or a CD-ROM Replace your <Blank> Instructor?" How foolish. Faculty cannot be replaced by a web site! I often tell then that any that can be replaced by a web site should be replaced as soon as possible. There is little likelihood that faculty can be replaced by any technology.

Nevertheless, faculty fear and some legislators hope that there may be some truth to this. Prism Magazine even asked: *"If a student can zoom the best professors into his or her living room, then what is to happen to the rest of the countries professors?"* (The mainframe model!)

In a word: hogwash.
Presenting is not teaching!

Summary

We have tried to show how technology is transforming higher education and how the result is leading to better universities and better ways to provide for the continuing education of adults. We began with a discussion of the development of the studio courses and then followed that intellectual thread into the development of live on line courses and the 80/20 model. This process is hardly complete. New and better models are being developed every day. That is why it is so exciting to be the CEO of one of the largest and most exciting online universities in the United States.

Appendix

TEEE Ten Commandments

1. Restructure around the learner. Neither over-emphasize nor under-emphasize technology.
2. Build upon research results, which inform design; don't try to reinvent the wheel.
3. Remember that technology has an intrinsic educational value beyond helping students learn better.
4. Do systematic redesign and not incremental add-ons. There is always a tendency to just add on a few computer experiences to everything else. By definition this costs more, is more work for faculty, and adds to the students' burden. An innovative approach changes rather than adding poorly integrated exercises.
5. Benchmark your plans and build upon examples of systematic redesign. Do not automate the lecture. Find the best examples and build upon them.
6. Count on Moore's law ("What is hard today is easy tomorrow"). For example, CPU power and bandwidth have consistently improved.
7. Cost is an important aspect of quality. There is no lasting quality if there has been no attention to cost. There are more than enough examples of expensive high quality solutions. We need more examples of inexpensive high quality solutions!
8. Avoid pilots that linger. Design for a large scale and pilot projects only as a prelude to scaling up. It is easy to design innovative educational experiences that work for small groups. It is harder to address the needs of the 1000 students taking calculus I at the large research university. The Emporium is a great example.
9. Develop a balance between synchronous and asynchronous distributed learning.
10. There is no longer any way to do good scholarship without technology, and there is no longer any way to teach good scholarship without technology.

Useful Links

1. UMassOnline: www.UMassOnline.net
2. Pew Center for Academic Transformation: center.rpi.edu
3. Pkal; www.pkal.org
4. Hesburgh awards – faculty dev. Focus
5. Pew Prizes – institutional focus
6. EDUCAUSE- www.educause.org
7. Technology focus
8. Syllabus – www.syllabus.com
9. EdMedia -
10. TLTR and Flashlight