ENGINEERING EDUCATION IN SHANGHAI JIAO TONG UNIVERSITY

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Shanghai Jiao Tong University was founded in 1896. As early as the 1920 and 30's, Jiao Tong University launched disciplines in engineering for the purpose of "saving the nation by industry"; and in the late 1930's, the three schools of sciences, engineering and management share the university's main parts. After that, because of the readjustment and moving-west in 1952 and 1956 of the major disciplines nationwide, only a few engineering disciplines remained with the Shanghai branch of Jiao Tong University, such as electric and electronic engineering, ocean engineering, etc. In the late 70's, Shanghai Jiao Tong University resumed its sciences and management disciplines, and also established the new disciplines of humanities. Since the 1990's, we have set our target as a comprehensive university, but currently, engineering is still our major and strongest part. Among the 19 schools of our university, 7 are engineering schools; of the 16 national key specialties, 13 are in engineering fields; of the 57 doctoral programs, 41 are in engineering areas; and of the 16 post-doctoral research centers, 13 are of engineering disciplines. We now have an enrollment of 26,000 regular students (including 15,000 undergraduates, 9,400 graduates, 1,200 foreign students), and about half of them are in engineering majors.

Engineering education in SJTU, as an important part of the university's talent-fostering task, shows its good tradition of teaching, and demonstrates a series of significant accomplishments we have gained in education.

I. Carry on the university's educational tradition, and form a definite target of talent cultivation.

In its 100 years' educational history, SJTU has gradually formed its distinct ideas and features of education. Based upon our university's precept, that is "think of the source of water when you are drinking; love your country and give honor to your school", we have kept an educational tradition of "a high starting point, a solid base, a strict demand, and attachment of importance to practice and creativity". These educational ideas and features have set a solid base for our talent-fostering in our university. Take "a solid base" as an example, we emphasize that the task of any undergraduate, including those in engineering majors, is to make a solid base and prepare themselves for the society or further research work in terms of knowledge, learning abilities and thinking capabilities. Jiao Tong University has always attached great importance to basic sciences such as mathematics and physics, and these two subjects are regarded by the students as the hardest ones because of their long credit hours and strict demands. And recently, the university put forward that basic sciences should be further strengthened, hence, increasing its students' knowledge in math analysis and solid physics. Students majored in materials science and EE, etc, shall also be looked upon the same as those in physics major in their grasp of knowledge in basic sciences. Another example is "a strict demand". Our university carried out in 1999 "eight measures of improving the Quality of Ph.D. candidates' thesis", including: proposal's evaluation, mid-term test, pre-defense, veto-by-one-vote regulation, high-level thesis' publishing rules, one-time failure of degree application, evaluation of excellent thesis, and spot testing of theses.

In recent years, to meet the opportunities as well as challenges of higher education, our university has defined the three basic points of educational ideas, that is quality education, lifelong education and innovative education. The core of quality education is to strengthen moral teaching; the core of lifelong education is to enhance the foundation; the core of innovative education is to respect every student's characters and design teaching methods according to everyone's needs. Meanwhile, we put forth the so-called "three changes", i.e. from people with specialized skills to people with wide knowledge, from teaching to educating, and from imparting knowledge to learning knowledge. They represent the changes in the aim, mode and process of talent cultivation respectively. Based upon these principles, we have defined the general aim of talent cultivation, that is, after several years of reform and construction, SJTU will preliminarily form a scientific, systematic and efficient training system of innovative talents. SJTU will become an important site for training talents to possess all-round developments in morals, intelligence, physique and aesthetics, to possess knowledge, abilities and quality, and to possess initiative and practical abilities. In terms of the general level of talents training, we are striving to be among the best in China, most advanced in Asia and ranked among the world's first-rate universities.

II. Widen the teaching platform and create favorable conditions for cultivating comprehensive talents

To reach this aim, we have taken the following measures. First is to revise teaching plans. The university carried out a university-wide teaching plan revision in 1998 and 2001 respectively. In 1998 was a revision after the restructure of the nation's undergraduate majors' catalogue, and its emphasis was to widen and merge specialties. The number of specialties was decreased by 31.4%. The number of specialties in engineering was decreased by 44.1%. The revision in 2001 served the purpose of carrying forward and perfecting the credit system. The new training plan demands that credits of elective courses should account for over 30% of the total credits. The basic teaching platform is composed of subjects such as science, engineering, liberal arts, management and agriculture. Meanwhile, other course teaching platforms have also been set up, which are divided into machine type (machinery, power, material, shipping, and civil engineering), electric type (electronics, electricity, information, communication, control, etc), comprehensive type (biology, chemistry, pharmacy, agriculture and environment, etc.), humanities & management type.

Second is the merging of disciplines and majors. In 2001, the Management School merged its business administration, accounting, HR management and tourism management into the big category of business administration. Our School of Agriculture merged its 8 specialties into 5. At the end of 2001 and beginning of 2002, we merged the two Schools of Information Technology and Electrical Engineering into the School of Electronics and Electric Engineering. We also merged the two Schools of Mechanical Engineering and Power & Energy Engineering into the School of Mechanical and Power Engineering. Such readjustment of disciplines and schools will keep on with the aim of recruiting and cultivating students on a wider platform. In addition, we have established new specialties annually, such as Environmental Engineering, Biological Engineering, Japanese Language, Administration, Electronic Science and Technology, Light Information Science and Technology, Information Security Engineering, Pharmacy and Clinical Medicine, etc. This year the Chinese Ministry of Education authorized the decision-making power of setting up undergraduate specialties in six universities and SJTU is one of them. This will create favorable conditions for us to further adjust the specialty structure, meet the market needs and form an effective mechanism for running this university.

Thirdly, we allow capable students to pursue minor certificates. In the modem society where science and technology has developed rapidly and different disciplines are intertwining with each other, knowledge within one specialty cannot meet the society's demand. Currently about two thirds of the students choose to pursue a minor certificate, and one third can gain dual degrees. Choosing courses across different disciplines is also a very widespread phenomenon nowadays. Almost 90% of the students choose to take "An Introduction to Advanced Biology"; engineering students can also take courses in management, computer science and trade. For the graduate students, we encourage them to do research work in some cross-disciplinary bases like research institutions and centers (mainly in fuel cell, automobile engineering). Recently, the university set up the School of Design and Media, aiming to cultivate students with both humanities and engineering (information) backgrounds.

III. Attach an importance to hands-on experience, and enlighten the students on their creativeness

Supported by the "211 Projects" and "985 Projects", our university has established a group of basic course teaching bases, experiment centers, and modem education and technology bases. Seven basic labs have passed the evaluation by the Shanghai Municipal Education Commission, which was entrusted by the Ministry of Education. The physics base and the math base have passed the mid-term evaluation by the Ministry. The culture quality base is being evaluated. Recently, the Ministry has approved the establishment of a "life science and technical talents training base" in SJTU.

Apart from that, our university tries to raise the proportion of comprehensive and designing experiments. Due to the "211 Projects" and "985 Projects", the present proportion of comprehensive and designing experiments has increased from 17% to over 40%. In PASSCO and LAYBOLD series of experiments introduced by the physics lab, students can conduct free designing to do all kinds of experiments. For example, 23 sets of PASSCO can be combined into about 150 kinds of experiments, which greatly arouses students' interests in doing experiments. The physics lab, electric and electronics lab, machinery lab, and chemistry and chemical industry lab partly or totally allow students to choose experimental subjects and experiment time. The labs are open everyday.

The "Engineering Training Center" of our university, with a building area of over 9,000 square meters, can have 800 students doing field-work at the same time. It now has five modules: mechanical manufacturing, electronics, advanced manufacturing technology, intelligence control, and innovative practice. Every sophomore in our university has to receive training in this center. Except for the traditional technical skills as lathing, clamping, planning, milling, grinding, molding, forging, welding, heat treating, it offers training in CAD, lineal cutting, electric and electronics.

The university arranges engineering students to receive internship in industry in their third year, and to write their graduation theses or perform their graduation design combined with scientific research or industrial practice. In order to enlighten the students on their creativeness, we have opened to them the course of "the History of Science and Technology", set up the physics open demonstrating lab, and planned the museum of maritime and ship-building history. In addition, scientific and technological activities have been widely launched. PRP and PEP Projects have been implemented. Undergraduates, especially freshmen and sophomores, are encouraged to do scientific research and experimental research in order to build up their practical ability and initiatives.

IV. Personality education has been advocated; a new credit system reform has been officially launched.

The university has implemented a credit system reform beginning with the students of 2001. Students were allowed to choose subjects, classes, teachers and class time. The overall results were satisfactory after half a year. It promoted the educational reform and established the "student-centered" concept. Last semester, more than 3,400 students chose their classes by themselves. Courses for the next semester had already been chosen and arranged. Great improvements are also shown in administration software development. It is indicated that the credit system has aroused students' enthusiasm in studying and promoted students' personality development.

Since the credit system began to be implemented and improved over half a year ago, it has made considerable achievements and gained support and cooperation from most teachers. However, the credit system is a revolution in the field of teaching administration, and there exists some risk. The main purposes of implementing the credit system are as follows: Firstly, to respect students' choice, permit students' independent learning and self-development, and bring their personality and potentials into full play so that they will become talented people. Secondly, to mobilize the teachers' enthusiasm in both imparting knowledge to the students, and in teaching reforms. Thirdly, to improve administration standards, administration efficiency and level of informatization, and to set up a new teaching administration system. Fourthly, to optimize and rationally utilize teaching resources in a wider scope. Fifthly, to promote the process of internationalization. However, not enough people or sectors have been called into action; no great progress has been made; we still have a long to go in developing administrative software. All this remains to be improved and perfected.

V. SJTU will carry out substantial cooperation with the world's first-rate universities and promote the process of internationalization

One important aspect in our innovative talents training system, as well as a development strategy of the university, is to carry out cooperation and exchange with the world's first-rate universities, particularly in the field of substantial cooperation to produce talents and of promoting the internationalization process. In August 2000, SJTU and the University of Michigan, Ann Arbor, signed an agreement to co-build the Mechanical Engineering School of SJTU. The agreement has been officially ratified by the Chinese Ministry of Education. In the light of the University of Michigan's training plan and curriculum, we have adopted the mode of "4+2+3" for education in mechanical engineering. 122 students have joined this project in the past two years, and seven subjects are now taught by professors from the University of Michigan. Members of our faculty were sent to the University of Michigan for advanced studies, who have come back with new curriculum. The project has been carried out for two years, and it attracts wide-ranging attention from the Chinese Ministry of Education and other universities. This enhances the status of our mechanical engineering subjects, level of talents training, and process of internationalization. Due to this project, we have obtained support from OACE Project in the form of equipment and software worth USS 220 million. Initiated by Professor Ni Jun and Professor Li Jie, the Mechanical Engineering School has founded the transnational Industrial Innovative Center (IIC). Ten world famous corporations, including the USA's General Motors, RA and JC, Japan's Toshiba, and China's Haier, have become a member of IIC. GM has also established its first vehicle satellite lab in the School of Mechanical Engineering, which is the first one both in China and in Asia.

SJTU requires and encourages each of its schools to cooperate with foreign famous universities, jointly train innovative talents, reinforce the training of qualified teachers, and promote bilingual teaching and internationalized process. So far agreements on talents training have been signed between the Management School and the University of British Columbia in Canada, Hong Kong University of Science, and Nanyang Technological University in Singapore;

between the School of Material Science and Engineering with Queen Mary College of the University of London, UK; between the Department of Computer Science and Engineering of the School of Electronics and Electric Technology with the University of Sydney, Australia; between the School of Network Education with Japan's KEIO University and Korea's Yonsei University. Both sides acknowledge each other's credits and will jointly award degrees.

Meanwhile, a special project in the "985 Projects" supports teachers to use foreign teaching materials and to deliver courses in foreign languages. Now, about 70 courses, including advanced math and college physics, are being delivered in foreign languages. Next year, the number will reach 100. In addition, there has been a great increase in the number of foreign students of our university. There were over 1,200 foreign students on campus by the end of 2001, and the number will exceed 2,000 in the year 2002.

VI. To advocate quality education and to enhance the students' cultural attainment

In order to realize the teaching objectives in a complete sense, SJTU offers selective courses, such as literature, art, music, etc, in addition to education in ethics. SJTU has founded the Cheng Chi Art Museum and supported students in establishing a symphony (representing university students in Shanghai), a wind band, who won the first-prize in the world amateur competition last year, and other organizations. The purpose is to mould their temperament and enhance their personality. In addition, every summer, SJTU organizes students to receive social internship in remote areas to improve their all-round abilities.

The engineering education of SJTU, based on good traditions in running the university, I guided by correct general plans, and with a series of effective measures, has made great achievements with its own characteristics in running the university. In November 2000, the Ministry of Education highly appraised our undergraduate teaching. In January 2001, the Ministry of Education described SJTU as a "university of excellent undergraduate teaching." In 2000, two Ph. D. candidates' essays were chosen into the 100 Excellent Ph.D. Candidates' Essays in China. In 2001, three were chosen into the 100 Excellent Ph.D. Candidates' Essays. And in 2002, four more were chosen in the 100 Excellent Ph.D. Candidates' Essays. Our undergraduates have performed tremendously in the major college students contests both in China and abroad. In July 2001, our students' wind band won the first prize in the 14^{th} World Wind Band Contest held in Holland. In August 2001 at the FIRA2001 Robot World Cup Contest, our robot soccer team won the championship of RoboSot. In September 2001, we won two first prizes, and two second prizes at the National College Students' Math Model Contest. In

September 2001 at the 21st World College Students Games, our table tennis team won the men's team title, the championship of men's singles, men's doubles and mixed doubles. In April 2002 at the 4th Global Business Competition held in Seattle, USA, our Management School on behalf of all the business colleges in China attended the competition for the first time, and won the second prize. In March 2002, our students participated in the 26th ACM International College Students Programming Design Contest. This is the highest-level contest for students in international computer area. 3082 teams from 67 countries attended the preliminary contests, and 64 teams from 27 countries entered the final competition. Our students won the world championship with their excellent performance.

SJTU has made some progress in practicing and probing in the area of engineering education. However, we still have a long way to go compared to the requirements set by the Chinese Ministry of Education, the general objective of our talents training, and other domestic colleges and universities, especially to the world's first-rate universities. SJTU hopes to explore this area with other colleges and universities. Let's work together and make greater contributions to our higher education system and to help our country prosper with science and education.

eLEARNING IN ENGINEERING : THE INTERPLAY OF TECHNOLOGY AND PEDAGOGY

Jack M. Wilson
CEO UMassOnline

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

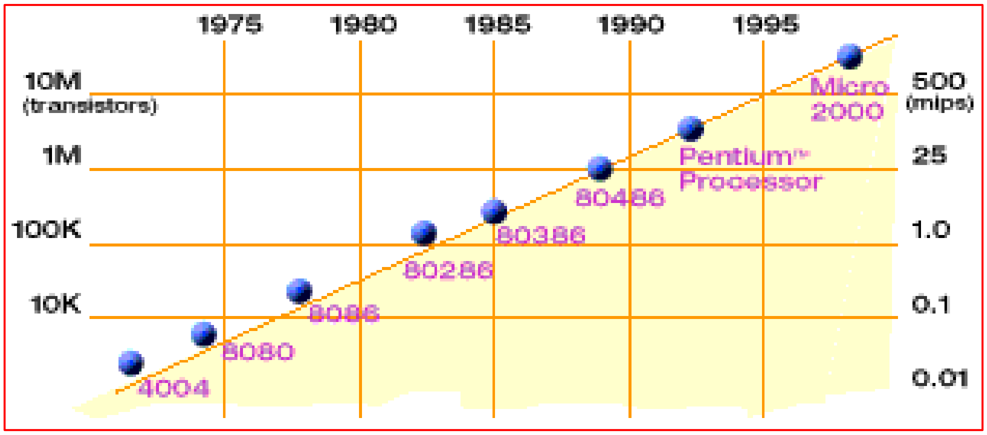
Wilson began career as a research physicist working on the physics of liquid crystals and biological materials. His research required the make extensive use of high performance computing. This led him to ask: “Why are students not learning about this? How can computers help learning?” Hi focus on Computing, 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.

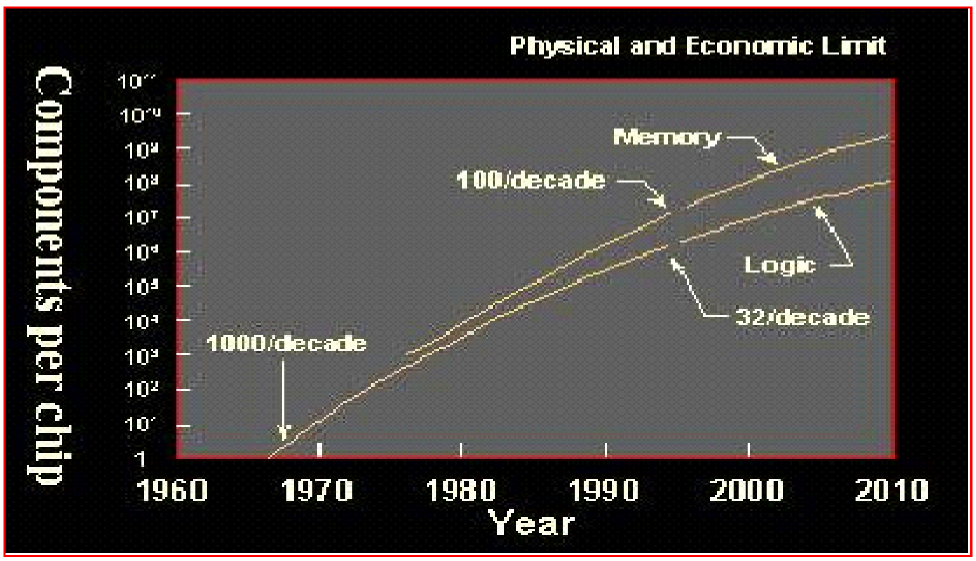
His work at RPI in restructuring the undergraduate Program stimulated an interest in how the studio experience could work at a distance and eventually to how online education could serve the needs of the working professional. His research in these areas allowed him to found LearnLinc and eventually brought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

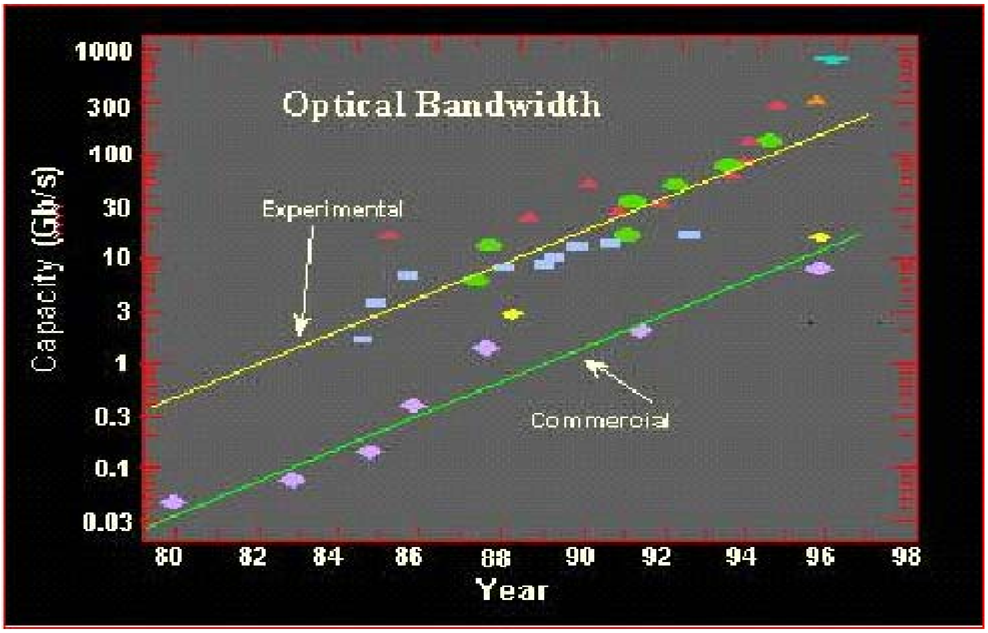
I. Moore’s Law: CPU performance doubles every 18 months. This means that the cost of equivalent computing power halves during the same time period.



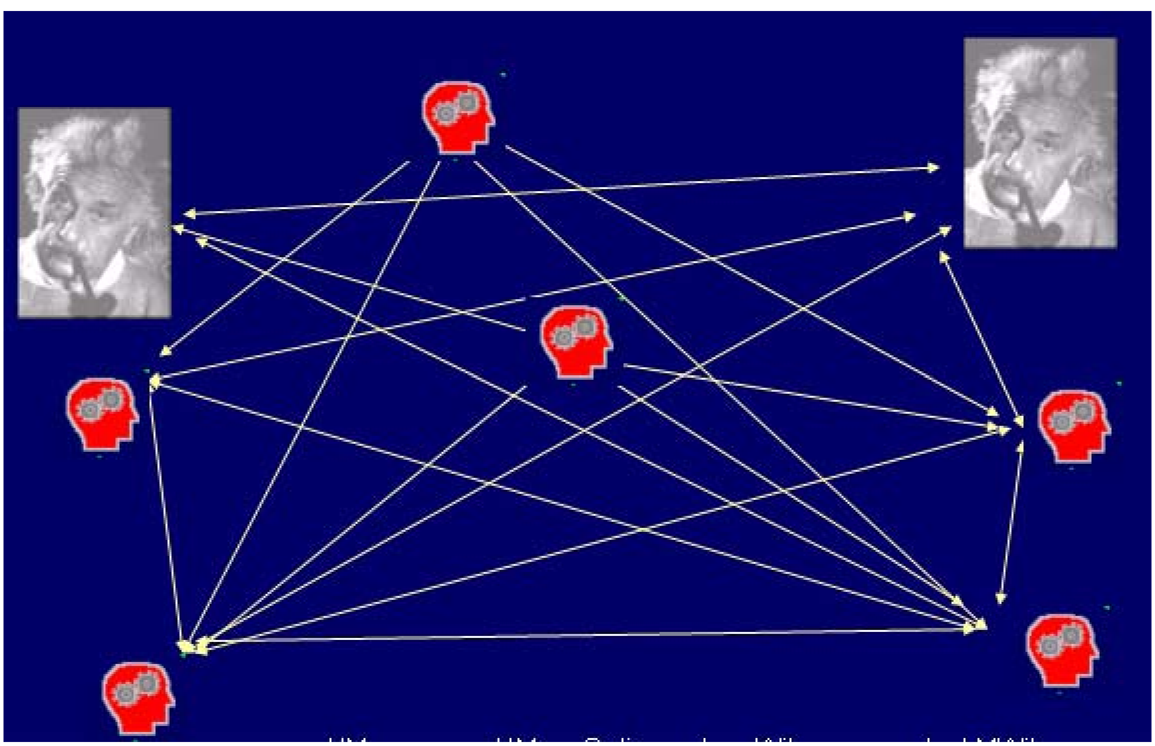


II. Bandwidth law: Bandwidth is doubling even faster! Note that the commercial deployment of bandwidth tracks the experimental advances in bandwidth with a lag of approximately 6 years. This suggests that we can expect the bandwidth doubling to continue for the foreseeable future, since the experimental 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	Credit Hours: 4
Contact Hours 6	Contact Hours 4
2 Hours Lecture	4 Hours of Studio
2 Hours Recitation	(includes laboratory, problem solving, etc.)
2 Hours Lab	

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)

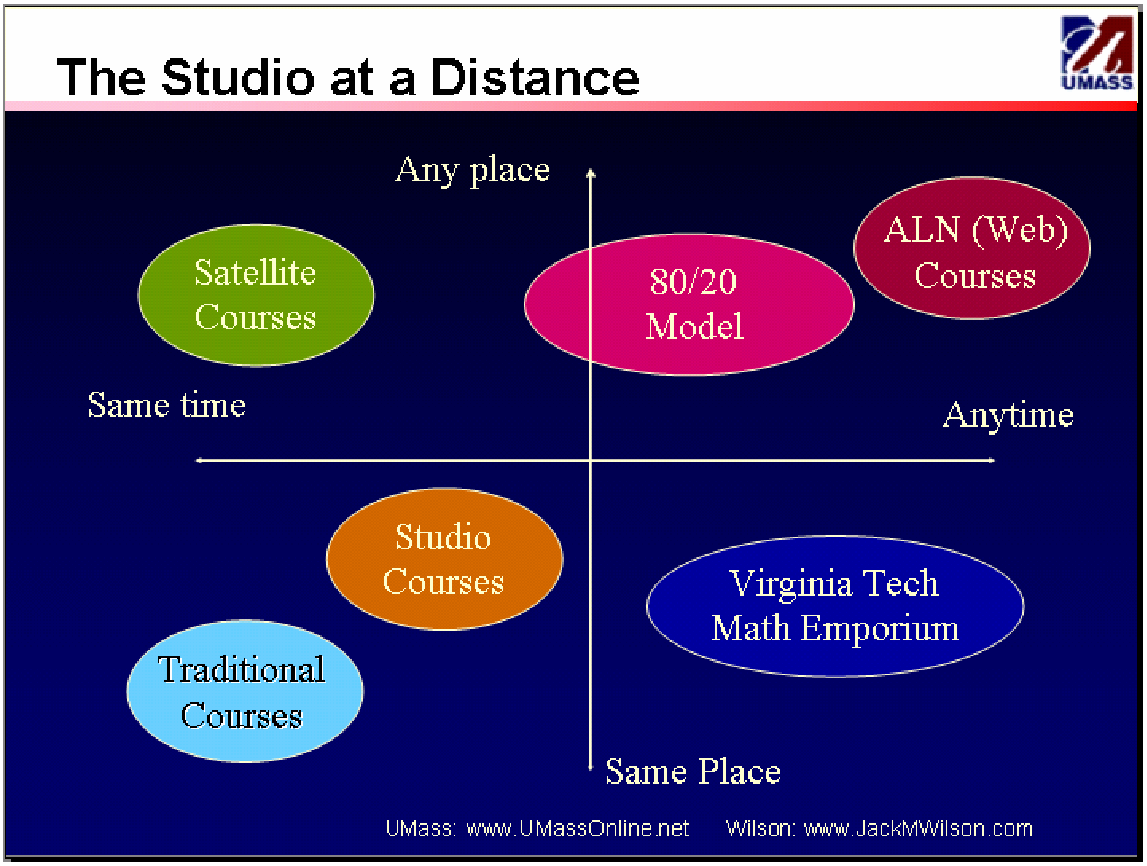
Distributed, Distance, Online, and Lifelong Learning

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:

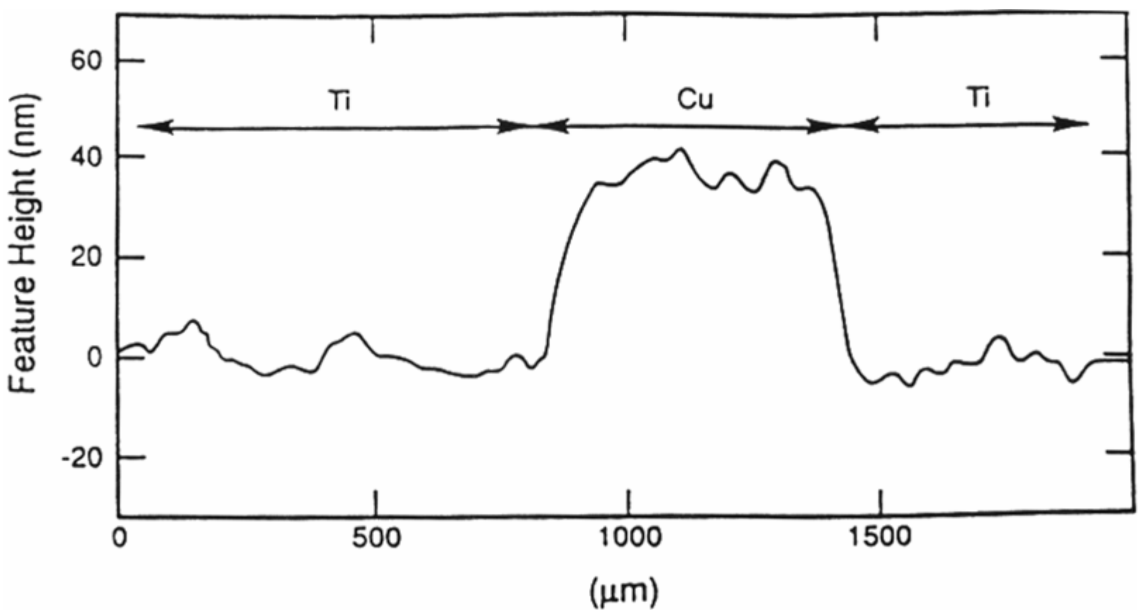
- Satellite broadcast
- Hands On Exercises
- Synchronous Tutoring with LearnLinc
- Asynchronous support

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

ENGINEERING EDUCATION FOR DEVELOPING CHINA IN THE TWENTY-FIRST CENTURY

Tsun KO
University of Science and Technology Beijing

The engineering education has to be reconsidered in order to meet the need of China in the 21st century. It is a challenge to all engineering schools and their faculty to prepare their students for their successful working life of several decades. The world however has changed and is rapidly changing due to scientific, technical, economic and management development. The old economic system and the education designed to meet the assumed need of the old systems has dug its own grave.

In an attempt to redesign the curriculum to meet the need of the developing economy, emphasis is given to the development of the students' individual qualities, ability, capability and adaptability requisite for success in a rapidly developing society of knowledge economy, for life-long learning, new knowledge acquisition and creation ability. Efforts have been made to create a new curriculum, in materials engineering as a pilot professional discipline, but aimed at engineering and technological education as a whole to meet the above needs within the present, more or less universal in the world, higher education scheme, which fits the human life-span for the not-too-distant future. In the recent years, about 7000 students graduated with BSc or BEng in materials science or engineering annually, most of them however came into the departments as their second or even third choice. About 70% of the graduates take jobs to start with or entering graduate schools in materials, but at least 30% of these left the profession in the next few years.

The courses so far offered, although met the need of the industrial development 30-50years ago, when China only produced, for instance, 80 thousand tons steel a year, and the faculties were asked to train the students in a specific discipline to be capable of doing certain production work i.e. "technician" oriented at least in part. For a fair part of the students, they take the courses passively and extracurricular activities submissively. This is now completely outdated for university education due to both the scientific and technical progresses and the change from the "socialistic" planned economy of Soviet model to the market economy under socialistic system.

The restructuring of the curriculum for materials engineering education began in 1996 in the University of Science and Technology Beijing*, is aimed at the following, not only for the education of materials engineers, but also for experience applicable to engineering education in general:

1. A change from narrow training in a narrow discipline to an integrated education in intellectual (classroom, laboratory and extra-curricular research activities), cardinal virtues (fortitude, temperance prudence, etc), and moral conducts, now often looked after by different executive groups in the universities.
2. A change from simple narrow technical training to engineering-conscious education and basic education in fundamental and engineering sciences with basic knowledge in social sciences and

management, sufficient for and capable of further study and research by self-education; a change from technically narrow and narrowly technical education to a broad engineering education.

**Often called the Cradle of Iron and Steel Engineers in China, but also, under the specific conditions of China, produced a number of city mayors and senior administrative officers. e.g.. The Mayor of Beijing and chief organizer of Olympics 2008, the former Mayor of Metropolitan Shanghai, now elected the president of Chinese Academy of Engineering, are graduates of this university.*

3. Emphasis is given to the solution of real engineering problems in production, designing and research in teams from the early stage of the higher education to build up self-confidence and independent self-education, creativity and interest in the materials and any other disciplines. It is also invaluable in acquiring team spirit and capability of team-work, leadership and organizing capability, also subserviency when occasion arises.

4. Change of the roles played by the teachers form that of masters to that of guides, and the students from that of passive listeners to that of initiative learners, thinkers or masters of the learning, so as to change the passive swotting to initiative learning.

5. To improve the students' foreign language ability, English textbooks of best choice are used partly or wholly, if available, even at the cost of reducing the lecture hours, content even the course subjects not absolutely necessary.

To achieve these goals, it is necessary to reduce the lecture hours from the present curriculum, over 2700-3000, into 2000, including 120 hours course work in athletic training, leaving students sufficient time for self-study, free reading and preparation for discussions and presentation of some of the main contents in the class with the help of faculty members.

The lectures are regrouped into five modules: Humanities and social sciences, and management (10% of the total lecture hours); Foreign language (10%); Athletics (7%); Mathematics and Computing sciences, natural sciences (25%); Engineering basics (16%); incorporated scientific, investigative Laboratory work, experimental and Engineering design (16%); Disciplinary subjects (2 main subjects, 3 supplementary) (13%); and selectives.

The students in the three pilot classes (1996-1998): 30 students each, drawn randomly one from every three freshmen or freshwomen, worked in the first or second summer vacations of 8 weeks in the steel making shop of the Baoshan Steel Works, the largest and the most modern steel works in China, joining the steel mill research teams to work on company's or national research projects in groups of 5 or 6. The third summer vacation was spent in one of the national laboratories on their respective projects. Most of them extended the subjects into their final BEng dissertations, some even into their graduate study with the same supervisors. The early participation of research played a very important part in their education, it gives the students self-confidence in their own abilities, in his role in the national reconstruction, and the sense of responsibilities. It improves also greatly their interest in the subject and field he is working. Similar results were obtained in some other universities, e.g. in the Faculty of Arts, Fudan University, Shanghai**.

The last term of the pilot class students was spent on dissertation projects. To test the students' adaptability and ability in self-studying on an unfamiliar subject, normally in an entirely different discipline, the research topics have covered a large variety of disciplines, in different locations. The subjects covered included super-strength low carbon steels, semiconductors, electron microstructures of new quasicrystals, high Tc superconductors, rare earth permanent

***This is in great contrast to a different story. A talented girl of 15 was admitted into a javenile class, and then into the Architecture Department of a famous Chinese university, completed her training in 3 years, further earned her PhD in Architecture in a well known American University, and is now serving the industry. She deplored, however, that she is fed up with the profession (a decision made by her parents and the University when she was only 15),a hopeful genius ruined. In contrast, many brilliant students from physics departments of first class Chinese universities and PhDs from known American universities are happily and brightly serving in the New York stock market.*

magnets, ceramics, artificial diamond film, titanium alloys foundry technology, mechanical forming of aluminium foil, archaeometric analysis of artifacts, environmental engineering study in a chemical works, etc. About one quarter to one third of the students have been accepted to continue their post-graduate studies in the Chinese Academy of Sciences: such as the Institutes of Physics, of Metal Research, of Ceramics; and prestigious university departments, including Tsinghua University (on Microelectronics) and Peking University (Electron Microscopy of advanced materials). The others were employed by a wide range of industries all over China from electronic to car manufacturers.

From these results, the reform seems at least partly successful, although 5 to 10 years may be needed to make a full evaluation from the future development and the successes or failure of the students in their career, academic, engineering, administrative or otherwise.

For the effort to be effective and successful, it is essential that:

1. A fundamental change or adjustment of the concept and aims of education among the teaching faculty, students, and their families and administrative staff, that the basic function of a university is education and research, which is also a carrier of education, not just teaching and book reading for a specific career or occupation; that means, a change from a school technically narrow and narrowly technical to a school for educating and cultivating worthy members of a modern civilized society well prepared for life long sevice to a progressing society and mankind. That is, the curricula, the contents taught and learnt, the deed and practices in education must meet the need of a developing society, the personnel market and the future of students, not those assumed or extrapolated from the past.

2. To apprehend that in a market economy as well as in human nature, student is the taskmaster as well as the patron or client for his learning; the teaching faculty is only the guider as well as a supervisor by exemplary deeds.

3. A devoted professorial member, experienced in teaching and research, theoretical experimental or practical, keen in the principles for educational reform, preferably from a basic course in science or engineering, chosen or volunteer to be a master-teacher for the class, to help the students to organize themselves for studying and research groups, seminars, social activities, etc. plays a very important and indispensable part for the success of the reform.

Similar results have been achieved in the pilot classes organized in the same period under the same project sponsored by the Ministry of education, by the Materials Engineering Departments of Tianjin University, the Beijing Aeronautics and Aerospace Technology, and the Mid-South Technical University in Changsha. The project received a First Class National Higher Education Award from the State Council and the Ministry of Education in December 2001.

Thanks are due to more than sixty members of the USTB facuty and administration as well as the 90 students, who participated in the project for the results, we are deeply grateful to the staff of 14 CAS and ministerial research institutes, universities, steel works, etc., who supported the project by providing research directions supervisors and research facilities, without which the experience outlined would not be possible.

INTERNATIONAL ENGINEERING EDUCATION ACCREDITATION

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There is a growing international awareness of the need for quality assurance in engineering education. The perceived need is being driven by globalization of the engineering profession and the international mobility associated with globalization. The quality assurance efforts in engineering education are very often validated through an accreditation process. There are many varieties of accreditation systems now in use throughout the world, and this paper will address some of those systems and how they are addressing globalization and how they are able to accommodate globalization of the profession. In addition, we will look at how we believe some elements of these systems might benefit the People's Republic of China as it moves forward with implementation of its own system.

GLOBALIZATION

Globalization is a term that is often applied to many facets of everyday life, including such diverse areas as consumer products, music, fast food, and professional sports. There are now Kentucky Fried Chicken restaurants in Shanghai and Beijing, and Yao Ming has recently signed a huge contract to play professional basketball in the United States. Both of these are indicative of globalization. Many of the components of the consumer electronics that we enjoy in the United States have been made right here in China. That, too, is globalization. The world is getting to be a very small place, and engineering is right in the middle of all the activity.

Professor T.P. Leung, Vice-President of the Hong Kong Polytechnic University and Past President of the Hong Kong Institution of Engineers addressed globalization and the importance of change in the following:

"With a tendency toward globalization of engineering and manufacturing activities, nearly all countries face similar problems concerning the further promotion and advancement of engineering education, so as to adapt to the changing world. Any nation or territory lagging behind in nurturing future engineers and engineering leaders risks its economy falling behind, due to a lack of competitive edge."[10]

Engineering is a people business, and as such, globalization of engineering means the international movement of people engaged in the practice of engineering. Judith Eaton, the President of the Council for Higher Education Accreditation (CHEA) has identified three aspects of the globalization of higher education: universalization, new commercialization and internationalization.[4] Universalization will tend to homogenize engineering education and some distinctiveness will be lost.

The aspect of commercializing higher education is well on its way with international branches from distant prestigious universities.

Dirk Van Damme [14] has provided the following examples of internationalization as related to higher education: students studying in a country other than their own country, staff exchanges between institutions in two countries, unilateral hiring of faculty from other countries, and the relatively new phenomenon of higher education institutions setting up business in foreign countries by means of branch campuses, franchising, or other business arrangements. In order for the internationalization of engineering education to occur, there must be some method to evaluate both ends of the arrangement so that both parties are aware of the quality of what they are receiving.

This need for evaluation by both parties, a half of a world apart, makes quality assurance a necessity. An institution builds its reputation very slowly, and the transference of that reputation via a graduate student or the setting-up of a foreign branch must be undertaken with great caution. There is a need for an independent 3rd party to validate that the branch campus is adhering to the same standards of quality to which the home campus adheres.

Similarly, the international mobility of students requires a quality assurance system that permits students to judge the quality of the institution they are contemplating attending, and it also permits institutions with graduate programs to help evaluate the quality of the students that are applying for graduate school. Accreditation systems assist in these types of evaluation. However, the accreditation system must be independent, fair, impartial, and rigorous enough so that the result of the accreditation evaluation has meaning. An accreditation evaluation has no meaning if the end purpose of the evaluation is a self-serving result for commercial or political purposes.

There are many engineering education accreditation systems in use throughout the world at the present time, and the numbers are growing. Are there advantages to China adopting aspects of these systems or even aligning with one or more of these systems? Of course there are. Are there advantages to China continuing development of their own system? Again, of course there are. By briefly looking at some of the systems in use today, it is hoped that this will assist China as they move forward in the implementation of their own accreditation system for engineering education in this era of globalization.

UNITED STATES SYSTEM

The system for the accreditation of engineering programs in the United States is administered by the Accreditation Board for Engineering and Technology (ABET). ABET is the sole provider of accreditation for engineering programs in the US, and it is perhaps the best known and most widely emulated system in the world. ABET was started by five professional engineering societies in 1932 as an independent evaluator of engineering programs. ABET has never been affiliated with the government of the US, although it is recognized by the US Department of Education. It has always been owned by the federation of professional engineering and technological societies that represent the engineering and allied professions in the US, currently 31 societies.

ABET's international activities are coordinated through the International Activities Committee (INTAC). Ongoing international programs of ABET include: mutual recognition agreements, memorandums of understanding, substantial equivalency evaluations, consultation activities, and credentials evaluation. A companion paper in this seminar addresses these ABET activities in more depth, and the reader is referred to the ABET website for more information.[1]

ABET, in conjunction with the American Society of Civil Engineers, (ASCE), participated in an informational and consultancy visit to China in June 2001. We were invited to participate by the National Board for Civil Engineering Accreditation (NBCEA). The NBCEA is a governmental unit within the Education Department of the Ministry of Construction. This visit was intended to open a dialogue between the various organizations to see where it might be mutually advantageous to cooperate in the area of engineering accreditation.

Perhaps the most significant facet of the ABET system is the newly developed reliance on an "outcomes based assessment" process. The switch from the old prescriptive criteria started about 8 years ago, and the engineering segment of ABET has now completed the switchover. The other three segments (or commissions) of ABET (computing commission, technology commission, and the applied science commission) are in the process of switching over to the outcomes based criteria. INTAC has conducted pilot substantial equivalency visits with the new engineering criteria at universities in Germany and Turkey with excellent procedural results. More pilot visits to different countries using the new criteria are planned in the near future.

In addition, a faculty workshop on the outcomes based assessment process was held in May 2002 in Istanbul, Turkey. The results of that workshop indicated that the outcomes based assessment process is relatively independent of cultural differences. Almost 100 faculty from 19 countries attended the workshop and post-workshop surveys indicated a high degree of satisfaction with the experience and with the information gained. Because of the success of that workshop, a similar workshop is being planned for Spring 2003 in Singapore.

ABET, and the universities and member societies it serves, have been pleased with the adoption of the outcomes based criteria and the results achieved. We believe the ABET model can be adapted to use within China because of the great flexibility inherent in an outcomes based assessment process. There is tremendous diversity in the universities within China, with leadership being provided by the world class engineering programs available in Shanghai, Beijing, and other large cities. By adopting some of the methodology of the ABET outcomes based assessment process, each university can tailor the goals of the individual programs to the needs of the program's constituents, consistent with the resources available, and each engineering program can ultimately maximize their effectiveness.

A EUROPEAN MODEL

This is a time of significant change for higher education in Europe. There are several reform movements that are in process throughout the countries of Europe. The Bologna Accord, and the changes envisioned in the Accord, have received significant attention in the higher education community. National and international accreditation systems are being developed or strengthened. The traditional European five-year degree program is giving way to a bachelors/masters or 3+2 system. And, maybe most significantly, the universities of Europe are adapting and trying to take advantage of the opportunities inherent in the globalization of engineering education.

Historically, accreditation of higher education in European countries has been directed and/or controlled by government agencies of the respective countries. In addition, funding of the universities and the individual programs has been closely tied to their accreditation status. This paradigm is also in the process of change.

In 1998, the education ministers from France, United Kingdom, Germany and Italy, met in Paris to develop what is known as the Sorbonne declaration. The main theme of the declaration was that collectively, the European countries had to work together in the development of a "European Area of Higher Education". Some of the key words used in the declaration and the supporting documents were "mobility", "transparency", "compatibility", and "comparability".[8] These words provide an indication of the direction the education ministers were heading.

The impetus for this collective declaration was a common feeling that "…apart from (the) United Kingdom and Ireland, (Europe) seems to have lost its position in the world as a destination for overseas students."[8] The realization of the economic implications of this changing trend made the higher education industry in Europe nervous. As a result of the Sorbonne declaration, in July 1999, the education ministers from 29 European nations met in Bologna to develop and sign the Bologna Accord.

The essence of the Bologna Accord can be summarized in 6 points:

1. "Adoption of a system of easily readable and comparable degrees...

2. Adoption of a system essentially based on two main cycles, undergraduate and graduate. Access to the second cycle shall require successful completion of first cycle studies, lasting a minimum of three years.

3. Establishment of a system of credits – such as the European Credit Transfer System (ECTS) – as a proper means of promoting the most widespread student mobility.

4. Promotion of mobility (of students and teachers)…

5. Promotion of European cooperation in quality assurance with a view to develop comparable criteria and methodologies.

6. Promotion of the necessary European dimensions in higher education…" [8]

Thirty-two countries have now signed the Bologna Accord and there is movement on all six of the items noted above.

SEFI, the European Society for Engineering Education, which is based in Belgium, is the leading trans-national organization in Europe in engineering educational reform. With regard to Item 5, above, SEFI's Task Force on Accreditation and Engineering Education published a position paper on March 10, 2001. Some of the relevant points from that position paper are:

- "The creation of a European Accreditation Board similar to ABET is neither feasible nor desirable;
- A European Accreditation should respect the cultural rich diversity among European higher education universities and other institutes;
- A European system for accreditation should work on the basis of cooperation and mutual recognition between existing national accreditation authorities. The Washington Accord as well as the Paris Accord could in this respect serve as one possible model;
- Countries or groups of countries today not having accreditation authorities should be encouraged to create such bodies;" [11]

The importance of these positions relative to the globalization of engineering education is that Europe will continue to be fragmented and will not be necessarily able to speak with a common voice around the world. In the SEFI position paper, they note "There is also an increasing demand for transparency and for international mobility of students and engineers. A definition of minimum criteria on the European level would therefore be most valuable."[11] There is certainly the realization that some form of standardization in the quality assurance area is needed if European engineering programs are going to compete on an international basis.

Even when the other barriers to mobility are resolved, such as implementation of a common transfer credit system (European Credit Transfer System – ECTS), the lack of a common accreditation system will still remain a barrier to mobility and full participation in the globalization of engineering education. Mutual recognition agreements within Europe, similar to the Washington Accord, would certainly assist in the process.

A step in this direction was the formulation of the IDEA League. This is a strategic alliance of four leading European universities, **I**mperial College, **D**elft University of Technology, **E**TH Zurich, and RWTH **A**achen. The alliance has: "…agreed to base their educational quality assurance system on a set of common principles and approaches that have emerged from a study carried out by the four universities…".[5] When the members of the IDEA League feel comfortable with the guidelines and procedures they have established, they will then invite other universities to join the alliance and participate in the developing quality assurance system.

Germany is amongst the leaders and one of the most aggressive in trying to change their system to accommodate the new educational paradigms sweeping Europe. In 1999, the German Association of Engineers founded the Accreditation Agency for Study Programs in Engineering and Informatics (ASII).[6] The formation of ASII is reactive in the sense that German engineering educators realized that they were increasingly being shut out of the market for international students. The formation of ASII is proactive in that they are now positioning themselves to again take full advantage of the international market, and the great value and heritage of a German engineering education.

Fuchs[6] states that the goals of the new directions in German engineering education include:

- "To internationalize and enhance the flexibility of education programs offered by German universities and universities of applied science.
- To improve employment opportunities for German graduates in the global market.
- (To) make studying at German universities more attractive for foreign students"

"Right now less than 10% of all students in Germany are of foreign origin in spite of the fact that Germany is among the few nations in the world which offer a cost-free education. The stated goal of the Government, the universities and all major scientific organizations is to double that figure."

It is hoped by Germany that these initiatives will help to re-establish Germany and their world-class engineering institutions as a destination of choice for engineering undergraduate and graduate students from around the world. China is one of the nations that Germany has targeted for increased numbers of students, and with the efforts now underway to facilitate international mobility, both China and Germany should benefit.

DEVELOPING NATIONS/DEVELOPING SYSTEMS

The situation is significantly different in the developing nations of the world. These nations are primarily importers of higher education services, and their goals and objectives with regard to higher education are different than the developed, higher education exporters of the world. Exportation of higher education is big business, with the three leading exporters being the United States, the United Kingdom , and Australia. The World Trade Organization (WTO) estimates that the global market for higher education and training was $27 billion in 1995.[12] With this magnitude of dollars involved, there is tremendous pressure on the providers to expand their services and their markets, and similar pressure being put on the recipients to open their markets to the foreign providers.

This huge international market has also attracted the attention of the WTO. It is expected that higher education services will be included in the next round of talks on WTO protocols and agreements and they will like become part of the WTO's General Agreement on Trade in Services (GATS).[12]

If done properly, these agreements may benefit all. Conversely, if done poorly, the damage to the educational systems of the developing countries could be substantial. These activities in higher education are paralleling similar activities in technical standards, such as those promulgated by ASTM. The following statement from Fabio Tobin, Executive Director of ICONTEC, the standards body of Columbia, is directly transferable to international accreditation of engineering programs:

"The increase in the activity of developing countries in the standardization {*engineering education accreditation*} world is a two-way responsibility. There has to be more willingness on the part of developing countries to participate for the benefits it will bring to their economies. On the other hand the international standards {*accreditation*} bodies have to be more proactive in establishing better and more "custom made" programs that fit the needs of developing countries."[13] (*emphasis added*)

The importation of higher education services may be even more culturally sensitive than the importation of technical standards relating to manufacturing or the providing of services. What happens to the unique cultural aspects of a country when they openly admit foreign providers of higher education services? Dr. Mala Singh, of the Council of Higher Education of South Africa, states:

"How can a national higher education system manage to hold on to its own stipulated values, principles and socially framed educational outcomes at a time when it also has to facilitate the development of knowledge and skills which will enable that country and its citizens to function effectively within a globalized environment?"[12]

Dr. Singh continues:

"The political and economic relations between those involved in international higher education exchange, especially between exporting and importing countries, and the capacity of developing countries to take a middle path between asserting their national priorities within higher education and quality assurance arrangements on the one hand and not becoming overly parochial and protectionist on the other."

"It is becoming painfully evident that the values often associated with globalisation ('privatisation,' 'deregulation,' 'liberalisation') are not necessarily compatible with specific national development agendas and do not bring equal benefits to developed and developing countries alike."[12]

This is a difficult tightrope that the developing nations are being asked to walk. Some countries are being very open with regard to inviting higher education providers into their countries. Some countries, such as Malaysia, are requiring the invited institutions to provide courses relevant to the culture of the host country. Malaysia requires "…foreign providers to provide compulsory courses in Malaysian language, Islamic Studies, Moral Studies and Malaysian Studies."[12]

However, even with this strict curriculum content requirement, there are still problems. Dr. Mahathir Mohamad, the Prime Minister of Malaysia, recently set the goal "…of teaching math and science in English from primary school level {through high school}…".[2] (emphasis added) In order for the Malaysian students to compete effectively against their counterparts from the west, Dr. Hahathir stated that "“…we have to master English, which is the current international and learning language". The one-time education minister continued, "If mother tongue is used for sciences and mathematics then those who do not speak the {English} language may not be able to go to some universities.”"[2] (The official language of Malaysia is Bahasa Melayu. 58% of the population is Malay and 27% are Chinese, and 8% are Indian)

The answer has to be based on a mutually beneficial cooperative arrangement. The Malaysian government is interested in obtaining the highest quality education for its citizens, and yet, they want to maintain their cultural uniqueness. When ABET visits a foreign engineering program, ABET requires that all of the documents to be reviewed by the visiting ABET team be in English. Is this culturally insensitive? Perhaps, but the reality is that increasingly, as the Prime Minister of Malaysia noted, English is the international language of technology and engineering. Therefore, in order to participate fully in the globalization of engineering, there will have to be concessions made.

CONCLUSIONS

The activity associated with the globalization of the accreditation of engineering programs is definitely on an upward trend, and the rate of increase appears to be increasing also. Some of the notable aspects of this international movement are:

- The increasing use of English as the official language of international technological communication,
- The emphasis on outcomes based assessment procedures rather than prescriptive criteria and procedures,
- The changing of the traditional European model of higher education to something more closely resembling the United States model,
- The increasing cultural sensitivity of the higher education exporters relative to the host or importing country,
- The change in attitude of the European universities from a passive provider of higher education to an aggressive provider with a targeted audience outside of Europe, especially Asia, and,
- An increasing awareness that international higher education services are big business with a potentially steep growth curve, and that regulatory rules and procedures are likely to be imposed by groups such as the WTO.

China is in an enviable position with regard to these trends. With over one billion citizens, China is a coveted market for the international higher education providers. However, China should institute controls that will ensure that the unique cultural aspects of China are maintained even as cooperative agreements with foreign educational providers are implemented. The on-going program between The University of Michigan and Shanghai Jiao Tong University in mechanical engineering is an excellent example of the benefits to be gained by both parties while ensuring the cultural uniqueness of the Chinese participant is maintained. The structure of this program could be emulated by other universities in China in their partnerships with other universities around the world.

Another area which China should explore further is the adoption of the outcomes based assessment model for accreditation. The inherent flexibility of this type of assessment model should dovetail nicely with the great diversity present in China's engineering colleges. The engineering programs in the universities in the great cities along China's east coast certainly have different missions and different constituencies than the universities in the western interior provinces, and the outcomes based assessment model is flexible enough to accommodate these differences.

It is very difficult for ABET to come to China and interact with a different accrediting agency for each engineering discipline. Likewise, it will be very inefficient for China to develop numerous accrediting agencies for the various engineering disciplines. From our perspective as foreign observers of the fledgling accreditation process in China, we believe there is a need for a non-governmental centralized engineering accreditation agency that can speak and act on behalf of all of the engineering disciplines. This will not only bring uniformity and efficiency to the process, but it will assist any foreign accreditation body that is providing advice or services to the Chinese engineering profession. The Chinese Academy of Engineering and/or the Chinese Association for Science and Technology appear to be well-positioned to lead this effort.

In conjunction with a centralized engineering accreditation agency, there should be a decision made as to whether the accreditation system is going to strictly serve the elite top 10% of the engineering schools, or is the system going to serve all of the engineering schools of China. At the present time, the accreditation system is being participated in by generally the elite schools. There is no compelling reason for the other 90% of the schools to participate. In the United States, professional licensure is one of the main drivers of the accreditation process. A similar motivator could be available in China if the appropriate Ministry of the Central Government decreed that all engineering programs in China must be accredited. This would not be a decision that should be taken lightly, however, in order for all of China to participate fully in the globalization of engineering, then a pronouncement of this type would be needed.

There will be many agencies knocking on China's doors offering mutual recognition agreements or similar arrangements that will ostensibly enhance the international mobility of your students, faculty, and your practicing engineers. You, as the leaders of China's engineering educational system, are encouraged to decide which elements of your engineering education culture are inviolate, and which elements can be compromised or changed to facilitate that international mobility and further assimilation into the global economy.

REFERENCES

1. Accreditation Board for Engineering and Technology (ABET) website for International Activities: http://www.ABET.org/international.html

2. Aglionby, John, "English in Schools Divides Malaysia". The Guardian, http://education.guardian.co.uk/print/0,3858,4508741,00.html, September 26, 2002.

3. "The Bologna Declaration on the European Space for Higher Education: An Explanation", Confederation of Rectors' Conferences and the Association of European Universities, Danish Rectors' Conference website: http://www.rks.dk/trends1.html

4. Eaton, J. S., "Taking a Look at Ourselves, Accreditation". Presentation to the CHEA Enhancing Usefulness Conference, Chicago, Illinois, June 28 and 29, 2001.

5. "Ensuring High Standards with the IDEA League", Press release from Delft University of Technology, November 2000.

6. Fuchs, Willi, "The German Accreditation System and the Specific Role of the Accreditation Agency for Study Programs in Engineering and Informatics – a Change of Paradigm in German Higher Education". 2001 ABET Annual Meeting Proceedings, The 2nd ABET International Congress on Education, Accreditation and Practice, Lake Tahoe, Nevada, 2001.

7. Haug, Guy, "Trends and Issues in Learning Structures in Higher Education in Europe". Project Report: Trends in Learning Structures in Higher Education in Europe: http://www.rks.dk/trends3.html

8. Hedberg, Torbjorn, "The Bologna Declaration and its Consequences for European Engineering Education". 2001 ABET Annual Meeting Proceedings, The 2nd ABET International Congress on Education, Accreditation and Practice, Lake Tahoe, Nevada, 2001.

9. "Joint Letter to Ministers of Education Meeting in Prague on May 17", Conference of European Schools for Advanced Engineering Education and Research (CESAER): http://www.cesaer.eu.org

10. Leung, T.P., "The Challenges Facing Engineering Education and Hong Kong's Endeavours". http://www.ems.uwa.edu.au/review/leungpaper.html

11. "SEFI's Position on Engineering Accreditation in Europe", Conference of European Schools for Advanced Engineering Education and Research (CESAER): http://www.cesaer.eu.org

12. Singh, Mala, "International Quality Assurance, Ethics and the Market: A View From a Developing Country". Presentation to the CHEA 2002 International Seminar; CHEA Occasional Paper, Council for Higher Education Accreditation, Washington D.C., August 2002.

13. Tobon, Fabio, "Developing Countries & International Standardization". ASTM Standardization News, ASTM International, West Conshohocken, PA, July, 2002.

14. Van Damme, Dirk, "Quality Assurance in an International Environment: National and International Interests and Tensions". Presentation to the CHEA 2002 International Seminar; CHEA Occasional Paper, Council for Higher Education Accreditation, Washington D.C., August 2002.

ENTREPRENEURSHIP EDUCATION FOR ENGINEERING STUDENTS

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China has a rich tradition of entrepreneurship, but currently little focus on entrepreneurship in its colleges and universities. I would like to provide an overview of some U.S. experiences in teaching entrepreneurship, providing students with the opportunity to participate in entrepreneurship programs. I will focus on programs offered in engineering schools.

Engineers, with their awareness of technological developments, are in an excellent position to initiate new, technology-based enterprises. But without motivation and education in the relevant topic areas, engineers will not be ready to take advantage of this capability.

Over 125 U.S. universities are now offering programs which prepare and motivate students to create new businesses. These programs have been enthusiastically received by students. It appears that offering students the opportunity to become entrepreneurs attracts and motivates them. Surveys in the U.S. indicate that two-thirds of U.S. high school students are interested in starting a business. Even those students who do not intend to begin new enterprises benefit from the exposure to marketing, finance, and related areas presented in entrepreneurship programs.

Participating in entrepreneurship education also offers new opportunities to engineering faculty. Faculty find that teaching highly motivated students is stimulating, and the opportunity to participate in start-ups developed jointly with students adds a new dimension to faculty activities.

Sponsoring entrepreneurship education provides visibility and potential revenue to the university for successful start-ups created under the program. For example, establishment of the University of Arizona's Berger Entrepreneurship Program increased the business school's corporate support by over one-third. Many entrepreneurship programs include an attached incubator program supported by the University, which increases the University's contact with companies.

The community benefits from the employment and revenue generated by the start-ups and the support activities they require. From a historical perspective, Silicon Valley in California and Route 128 around Boston are prime examples of major regions of corporate activity initiated by academic-initiated start-ups.

Additionally, successful entrepreneurship education has the potential to generate new industries with benefit to the entire world. Although tarnished by the "dot.com" bust, many aspects of the information technology and telecommunications industry rapid growth were triggered by spin-offs from university-generated activities. Improved preparation of students to take advantage of emerging technologies could both increase the role of engineers in the innovation process and speed the process in getting technology to the market.

There are concerns that attend entrepreneurship programs. Faculty participation in entrepreneurial activities could distract faculty from the traditionally important production of peer review research publications. Although including the instruction of students in the elements of entrepreneurship in the curriculum of engineering students would not be distracting activities, participating in the intense and time-consuming process of new venture creation could leave less time for the research and publication activities central to faculty life in research universities. Of course, in predominantly undergraduate institutions, this potential reduction in research output might be more acceptable.

Conflicts of interest are often created when start-up companies employ faculty or students--the issue of whether education or corporate profit should have higher priority is often difficult to resolve in such situations. Johns Hopkins University, among others, has put in place significant restrictions on students hiring faculty, and vice versa, because of several negative experiences that the University has had in this area. Conflicts of interest also occur when start-up companies fund faculty research or are funded by university capital. Such funding was very common in the early days of corporate start-ups from academic research. However, such issues as ownership of intellectual property and related issues have caused most universities to look very carefully at such transactions, and in some instances to ban them altogether.

What are some of the specific lessons would-be entrepreneurs gain from entrepreneurship programs?

<u>How to extract marketable product concepts from new technology.</u> Experience in start-ups indicates that to overcome the disadvantages of small size and limited financing, it is necessary that the proposed new product have dramatically improved value compared to existing products. This means that students must learn to identify consumer value.

<u>How to write a business plan.</u> Great technologies alone do not create great companies without a clear plan for how the product is going to be financed, positioned, and brought to market. There has been a dramatic drop in the availability of funds for new start-ups, so initiating a start-up today will probably depend on funding from sources including personal or family savings. Some start-ups have been funded through creative use of credit cards.

<u>How to market.</u> Even the greatest innovation will never succeed without a marketing campaign focusing on the value of the product to the consumers who would benefit from it. The skills involved in marketing are, in general, not analytic, which means that for most engineering students, effective instruction in marketing will be more difficult than most other topics in an entrepreneurship program. One approach to resolving this challenge, of course, is to assure that the team involved in developing a start-up includes at least one individual with strong marketing skills.

<u>An understanding of related legal issues.</u> An early legal issue which must be addressed is the vesting schedule of stock in the start-up, and related issues of control of the company and how decisions are made. The temptation to provide stock as "in-kind" payment for accounting, legal, and other consulting services can lead to loss of control by the founders. If the initial founders put different levels of effort in the start-up, for example, it is essential to reflect this in vesting stock appropriately. Another important topic is the area of contracts–specifically, the issue of what recourse is available to each party to a contract if one or more terms of the contract are not fulfilled. One truth perhaps not fully realized by most entrepreneurs is that litigation is very expensive, both in terms of

money and in the precious time of the entrepreneurs themselves. Serious litigation will often lead to the failure of the start-up regardless of who is in the right.

The importance of intellectual property. Since start-up companies have less money and less resources of all sorts, in the absence o f effective intellectual property protection, larger companies will be able to reproduce the innovative products produced by the startup. Students must understand the process and importance of intellectual product protection. It is very difficult to obtain funds from venture capitalists unless the central aspects of the start-up's innovations are effectively protected.

How to manage money, programs, and staff. Traditionally engineering education in the U.S. has been oriented towards students working by themselves. More recently, team activities have been integrated into engineering education in most schools. Effective entrepreneurs must know how to work with their colleagues and manage their staff. They must also know how to manage money and activities to assure success of their activities as projected by the business plan.

Ethics. In recent years in the United States, it appears that many corporate executives, especially in rapidly growing companies, have let their financial objectives outpace their sense of ethical values. Although the near-term, outcome of this approach was successful, the long-term impact has been seriously negative. It is, I believe, essential for engineering students to understand the basics and justification of ethical values.

There are number of other elements that can be part of an entrepreneurial education experience, including:

Interaction with successful entrepreneurs. Coffee-hours with successful alumni entrepreneurs is one activity that has been used by many programs.

Evaluation of potential start-ups by experienced businesspeople. Again, using successful alumni has proved to be an effective tool.

Developing an entrepreneurial mind-set in students. Case studies, presentations by people who have "been there" are useful.

Opportunities to interact with individuals with access to financial resources. Money today in the U.S. is much more difficult to obtain, but during the dot.com boom, academic-based new start-ups from institutions like Massachusetts Institute of Technology (MIT) and Stanford University were able to get venture capital funding for a wide range of projects, and even less well-known programs could get their start-ups funded. Now, it is more difficult.

Support of start-up "incubators". Incubators provide office and research space, and usually consulting for legal, accounting, and other professional services. Many academic incubators have charged less than actual cost initially, with equity interest in the venture that would ultimately make the incubator financially successful. The success in this approach has been highly variable, and the dot.com turndown has negatively affected many of them.

Successful examples of entrepreneurial activities can be found at a number of U.S. universities. Rice University recently received a grant for an Engineering Research Center in Biological and Environmental Nanotechnology. A part of this center will be a program in nanotechnology entrepreneurship. Steve Carl, the Director of the Rice Alliance for Technology and Entrepreneurship points out that the relatively small support for an entrepreneurship component for this Center holds the potential to rapidly bring identified innovations from the Center to the market.

The Massachusetts Institute of Technology (MIT) runs a well known competition for business plans, called the $50K. It attracts would-be entrepreneurs to compete for the top prize and a chance to impress venture capitalists who come to the MIT campus each spring. The student-run $50K competition is 12 years-old, and it has an impressive roster of alumni. More than 75 of the teams that have entered the competition over the years have started companies. Organizers estimate that those companies have created some 1,100 jobs and have had a market value of some $10 billion. Many of the most successful start-ups (Firefly, Lexicus, Flash Communications) have been acquired by companies such as Microsoft and Motorola. It is not unusual for the $50K competition to foreshadow a trend or spot a hot new field. Three years ago, the winner of the $50K was a bioinformatics company (marriage of biology with information technology), and it's a sign of the times that the past three winners have been in the biotech field. A recent winner was a start-up that developed a substance that can be placed inside a fractured bone to help it heal by allowing the bone to grow through it. Venture capitalists are already talking to the founders of the start-up.

At North Carolina State University, Michael Rappa, a technology management professor, offers an e-commerce course, "Managing the Digital Enterprise," for both engineers and management students, for free on the Internet at: http://digitalenterprise.org. He has formed corporate partnerships with companies with large e-business components like Cisco Systems, AT&T, IBM, and Eastman Kodak, who welcome the free course for their employees. The companies have, in turn, donated hundreds of thousands of dollars to North Carolina State for student projects and web-based education resources.

Stanford University has had its Technology Ventures Program for many years, and it has been one of the more successful U.S. programs. During the rage of dot.com start-ups in the 90's, both Yahoo and Goggle were started by Stanford students. Dr. Tina Seelig, the Executive Director of the program notes that the high tech bust and the resulting drop-off in attention has actually been beneficial. She says that although there has been a drop-off in funding for start-ups, the quality of the start-ups being funded has significantly increased.

The University of Maryland's Hinman Campus Entrepreneurship Opportunities (CEO) program is funded by Maryland engineering graduate Brian Hinman, who has made a successful career out of starting high-tech companies. The program gives budding entrepreneurs among the undergraduate population the opportunity to experience the excitement and stress of running a start-up company from a specially designed dormitory that features conference tables, wireless Internet connections, and a phone system that links cellular and home telephone systems to ring simultaneously. The program sprang from the imagination of William Destler, Maryland Provost and former Dean of Engineering, who would like to see the program foster a culture of entrepreneurship in Maryland similar to what exists in Silicon Valley or Massachusetts. Almost half the students in the program are majoring in engineering or computer science, and another nearly 40% are business majors. Hinman's CEO Program recently received substantial coverage recently in the Business Section of The Washington Post, and for the full story online, see following URL: http://www.washingtonpost.com/wp-dyn/articles/A37974-2002Oct29.html

In addition to the above, there are, as I mentioned earlier, numerous entrepreneurship programs being offered at universities. The Ewing Marian Kauffman Foundation, which is a major financial backer of entrepreneurial centers, lists 125 such programs across the country. The Kauffman Foundation has focused on entrepreneurial success at all levels – from elementary students to college students, from aspiring entrepreneurs to high-growth entrepreneurs. For a rich offering of information of interest to would-be entrepreneurs, the Kauffman Foundation's web site can be found at: http://entreworld.org.

At the American Society of Engineering Education, our newest division is the Entrepreneurship Division. The mission of the division is to foster and disseminate approaches to education and to stimulate faculty and students in entrepreneurship, including partnerships with business schools as well as the business and technology enterprise communities. This active division has its own web site, which I invite you to visit at: http://www.nciia.org/asee_ent/.

Thank you for the opportunity to speak to you today. I have enjoyed providing a brief introduction and overview of the success that U.S. schools have had in offering students the opportunity to study in entrepreneurship programs.

TO DEVELOP ENGINEERING QUALITY----
ENGINEERING PRACTICE OF UNDERGRADUATES

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Fifty years ago, China carried out a profound higher education reform, namely the reconstruction of universities and institutes, to meet the need of recovering and developing national economy. For example, eight institutes were founded in Beijing, including such diverse specialities as petroleum, geology, mining, metallurgy, agriculture mechanics, forestry, telecom, and aeronautics and astronautics. Beijing University of Aeronautics and Astronautics (BUAA) was founded in 1952, with the ambition of developing China's aeronautics and astronautics industry and training engineers in the field. For decades, groups of engineers had been fostered and distributed to various industries all over the country by these institutes, contributing greatly to the development of national economy. Under the planned economy, engineering institutes had fine specialities, which restrict undergraduates to very narrow area of science and technology. Graduates were assigned to posts according to the planned economy, and quite often would hold their job for a lifelong period. The higher engineering education under the planned economy was speciality education which was technically narrow. From1980s, the economy system transferred from plan-oriented to market –oriented. Personnel has become an important resource with mobility as one of its most important features. Market economy requires high international adaptability and competition capacity; market economy demands engineers to possess broad range of technologies, professional skills and free from language, and culture constraints and obstacles.

1. Reform in teaching from a narrow specialized education to all-round quality education

According to analysis of world economy, trend of science and technology development, and program of China economy development, consulting with renowned enterprises, universities and scholars of the world, the 21th century requires technological the professionals to

a. have a high sense of responsibility to society and the human race, the spirit to build a prosperous China, develop her national culture, and the determination to work hard and strive for best results in their work.

b. have a high level of professional ethics, a good style of learning and work, sound psychological quality and good health.

c. be aware of the relationship between science and technology on the one hand and social development on the other in the light of dialectical and historical materialism.

d. have a good command of the basics of mathematics, natural sciences and engineering sciences, and the ability to acquire information by means of modern information technology; have a wide scope of knowledge and the ability to employ the knowledge in engineering practice; have the ability to design and synthesize, to work competently in engineering projects and be innovative and creative in technological work.

e. display good teamwork of cooperation and the ability to organize, lead, communicate and negotiate with others, to take other people's advice as well as put forward constructive suggestions.

f. be aware of environmental protection and economics and the relevant laws and regulations of the State.

g. be culturally well-rounded and have the ability to express themselves both orally and in written form in one or more foreign languages as well as in Chinese.

It is quite difficult for the undergraduates to meet the above requirements in the relatively short four-year period of university life. The graduates are only "semi-finished" products. When making the teaching and training programs we must permeate the quality requirements through the whole process.

2. Reform the teaching schedule and decrease class hour to ensure the study initiative of undergraduates

There have been too many courses and too heavy a burden for engineering undergraduates for a long time. They do not possess enough time to do self-reflection, leading to poor ability of utilizing knowledge to get to practical work. The new teaching schedule has reduced the class hour to 2400 hours to guarantee the undergraduates enough time to study initiatively.

The Aeronautics and Astronautics Dept. of MIT provide an interesting description of how much a student can grasp given different teaching methods by citing some statistics.

Average Retention Rates of Teaching/Learning Methods

Teaching/Learning Method	Results of Mastering(%)
Lecturing	5%
Reading	10%
Audio-Visual	20%
Demonstration	30%
Discussion Group	50%
Practice by Doing	75%
Teaching Others/Immediate Use of Learning	90%

Source: National Training Laboratories, Bethel, Maine, USA

From the above statistics, we can see that the best ways of teaching are "practice by doing" and "teaching others/immediate use of learning". The teaching reform must change the class-centered situation, giving up the traditional way of confining both the teacher and the students to one textbook.

3. Undergraduates participate in engineering practice to cultivate qualities of engineers.

In contemporary undergraduate engineering education, there is a problem, which is seemingly difficult to deal with. This problem comes from two growing needs, which are in apparent conflict: educating students in an ever increasingly broad range of technical knowledge, while simultaneously developing students to possess a wide array of personal, interpersonal, and system building knowledge and skills that will allow them to function in real engineering world and to produce real engineering products. In order to resolve theses seemingly irreconcilable needs, we must develop a new vision and concept for undergraduate education.

BUAA has made its new undergraduate teaching plan items, among which the students are organized to participate in practical engineering projects. From 1990, BUAA has been holding science and technology activities, exhibitions and contests for sophomores and juniors. To memorize the forerunner of China′ s aeronautics, Feng Ru, and to encourage students to take him as a model, BUAA named the contest "Feng Ru Cup", holding it once a year in May. Every year there are about 600 pieces of work and 3000 students competing in "Feng Ru Cup", which means half of the undergraduates enter the competition in four years undergraduate program. To participate in the contest, a student should decide a topic, and the school or department arranges instructors for the students, or the student can find an instructor himself. University Academic Committee appointed professors to be members of the Expert Committee to judge the contest. The school or department that wins out gets the Feng Ru Cup, and the first three winners in the contest will be excused from the permission examination of postgraduate program (to get a master's degree). Outstanding winners are entitled the privilege of taking the doctoral program. The winning pieces of work will be recommended by BUAA to participate the National "Challenger" Contest, and BUAA is the only University that gets the winning prize for six successive years.

Years of experiences show that participating in science and technology practice does help students in studying initiatively, doing practical work, and cultivating engineering qualities.

1) Cultivating creative ability of the undergraduates. Engineering project contests stimulate students' desire to be creative and provide chances for young people to give the rein to their imagination. In year 2000 "Feng Ru Cup", Liang Hongjian, a junior from Mechanic School, designed a 0.8-meter long mechanic fish. It was quite hard to distinguish it from a real fish. Liang had been observing fishes in water and imagined if only ships and submarines could do that! He collected huge amount of material and studied hydromechanics by himself. He solved all kinds of problems concerning material, design, and power, and at last he succeeded and won the first prize in both "Feng Ru Cup" Contest and "Challenger" Contest. Now Liang is taking his postgraduate program and has got a million national funds to continue his bionic mechanic fish project.

2) Cultivate personal and professional skills of the undergraduates. Personal and professional skills are central to practice. Participating in engineering project contests demands the students to finish every step of the project from the idea, design, implementing the design and running it. All the designs in the contest can be performed.

3) Develop the interpersonal skills of teamwork and communications of the undergraduates. To participate in the contest, the students put forward a feasibility report and apply for fund from the school or department and the society, and thus improve their communication ability. Students participating in the contest often work in teams and cooperate with team members. With the rapid development of science and technology, teamwork is essential for any engineering project or product.

4) Foster the ability of tackling difficulties and forging ahead. Engineering practice appeals to the students and stimulates their interest in science and technology. Given the limited funds and lack of practical experiences, the students have done a great job in overcoming all the difficulties, tackling problems, cooperating with team members, and getting their goal.

Conclusion

Engineering education is a far-reaching, pressing and difficult historical task, which demands intensive research and long-term repeated practice. We do not expect an accurate answer as to what is the right way. We must explore actively through relentless effort according to our own situations. Here, I can confirm one point, that is, we have reached a common recognition as to the quality requirements of the engineers in the future. The quality requirements set the goal and direction for our coming engineering education reform.

References

① 《工业创新和高等工程教育》，路甬祥，王沛民。高等教育出版, 1996年7月。

② 《冶金及材料工程教育的改革》，柯俊。高等教育出版, 1996年7月。

③ 《MIT CDIO Report #1，The CDIO Syllabus, A Statement of Goals for Undergraduate Engineering Education》 Edward F. Crawley, Dept.of Aero. and Astro., MIT, Jan. 2001

RESEARCH ISSUES IN DISTANCE EDUCATION AND LIFELONG LEARNING: OPPORTUNITIES FOR CHINA-US COLLABORATION

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Lifelong Learning as a Policy and Research Focus

Lifelong Learning (LLL), and especially workplace learning, has become an increasingly prominent policy and research focus internationally over the past decade. Improving and maintaining the productivity of the workforce through longer worklife cycles and through a succession of structural changes in various professions are critical to global competitiveness and comprise at least part of the fundamental logic behind the increased attention and resources by national governments (Park, 2002; Fuwa, 2001; Griffin, 1999; Wilson, 2001). Additionally, a major conclusion reverberating through research and policy circles internationally is the need for a more elastic view of postsecondary education, with undergraduates developing stronger expectations and skills for continued learning (Cornford, 2002). A significant theme during the October, 2002 Bilateral Seminar on Engineering Education, Distance Learning and The Global Economy (the "Bilateral Seminar") was that college-level engineering education, for example, required significant revamping and strengthening, with greater time and attention devoted to project-based activities and opportunities for collaboration, along with upgraded core courses (Xie, 2002; Gaofeng, 2002; Shilie, 2002). There simply is not enough time in the traditional undergraduate structure alone to keep up with the learning and collaboration opportunities deemed essential to prepare a well-rounded professional, let alone keep a professional abreast of rapid changes in his or her field. The workplace and continuing education were continually cited as the natural and logical venues for these learning experiences. The sequential "learn, then earn" model is obsolete.

Information and Communication Technology and Elearning

Information and communication technology (ICT) has assumed an increasingly ascendant role in the policy and research discourse on lifelong learning (e.g. PITAC, 2001). For both formal degree training and continuing education in the workplace, ICT-enabled distance education, often called elearning, (mediated, for example, through combinations of the internet or intranets, satellite, cable or broadcast video feeds, and/or single station platforms) provides opportunities for flexible delivery of content and an approximation of "anytime, anyplace" learning. As in the past (e.g., with ICT in traditional classroom settings), hype and promise surrounding ICT in elearning threaten to outpace performance (Selwyn, Gorard & Wilson, 2001), at least absent coordinated research and evaluation. A significant body of evaluative literature compares learner performance in online settings with those in traditional settings, and generally finds neutral to modestly positive effects for elearning alternatives. Jack Wilson (2002) reporting on some of the most comprehensive single-institution comparisons involving online distance-education (Renssalear Polytechnic Institute).

Initial Questions

But what about the design of next-generation distance education systems? What are the most strategic pedagogical and design issues that must be faced to realize the promise of online learning, in both the university and the workplace? What are the opportunities for productive China-US collaborative research on elearning? Is such collaboration timely?

Timeliness of China-US Collaboration

To begin with the last question first, there are already some areas of existing China-US elearning collaboration, especially, as demonstrated in the Seminar, in engineering education (Director, 2002; Kalonji, 2002) and in the development of Chinese language software platforms (Huang, 2002). It may be especially timely, however, for the national funding agencies to support more coordinated elearning research and evaluation. Additionally, in domains such as engineering education, where harmonizing curriculum topics across international borders and building international project teams is of increasing value, the rationale for education research and evaluation collaboration is reinforced.

As of the beginning of 2002, distance education in China involved approximately 45 authorized universities, including the China Central Radio and TV University (solely distance learning) and 44 other conventional universities with distance course offerings, reaching nearly a half-million students (Zhang et al, 2002). According to Bilateral Seminar, the large majority of distance education in China takes place through synchronous, satellite-based lecture transmissions. In general, this mode multiplies the availability of lecturers to more students, but otherwise simply duplicates a transmissionist mode of instruction and has not proven more effective than traditional face-to-face lectures (Zhang, 2002). There have been significant developments, though, in creating a market and products for more comprehensive, Chinese-based distance learning systems that take advantage of multimedia, interactive and asynchronous communication features (Huang, 2002).

In the US, development in distance learning, especially as it is mediated through the Internet, has been rapid and haphazard. Traditional universities now offer at least a small fraction of courses online, and several dozen universities have started that are exclusively or nearly exclusively online. The supply of commercial tools to mediate elearning is much larger in English than in Chinese. While some positive effects have been found in elearning settings, there has been only limited credible documentation of the added value to universities (Saba, 2001) and to workplaces for the investment required to structure elearning opportunities, and many of the efforts to build distance education infrastructures in the US have been scaled back or abandoned.

In broad terms, China has a significant current investment in some forms of elearning, but it is still small relative to its overall population and the country is poised for a much more pronounced and larger elearning profile in the university and workplace. In similarly broad terms, US organizations have made sizable forays into elearning with mixed success. The following sections review developments in research on learning in online settings and learning through the aging process, and developments in the technology of online systems. These developments, along with the expected increased investments in elearning in the coming decade in both countries, suggest an especially compelling timeliness for China-US research collaboration.

Strategic Pedagogical and Design Issues

Three interacting metavariables in improving elearning systems should contribute to the frame of reference for any collaborative research program.

1. **Content**. What is the content of elearning, especially in the context or workplace and continuing education? Is passing on disciplinary knowledge sufficient, or is there more that we want to accomplish?
2. **Learner**. What do we know about the elearner? What have we learned about learning in online and workplace settings?
3. **Mediating Technology**. How is the technology that mediates elearning changing and how can it be used to greatest advantage in light of growing knowledge about learner characteristics and the goals for elearning?

While this paper does not answer these questions comprehensively, it argues that each affects the others, and that they must all be referenced implicitly or explicitly in theoretical frameworks for elearning research. Developments in each fundamentally alter research and development in the others.

What do we want to accomplish in elearning in the workplace and university?

The international literature in lifelong learning often contrasts an instrumental or economic frame of reference (improving worker productivity and staving off obsolescence by retraining workers to produce the greatest and fastest net profit gain) with a broader frame of reference that considers the learner in a more holistic perspective (e.g. Gustavsson, 2002; Gouthro, 2002) and not only attends to immediate productivity issues but is also "socially and culturally nourishing" (Grace, 2001). The Director of the US Business-Higher Education Forum, Jeremiah Murphy, argues that the goal of lifelong learning should be to "integrate a person's emotional, intellectual, and spiritual inclinations and interests. Lifelong learning should be about the wholeness of people," (Mullane, 2001). Murphy gives the example of workplace learning opportunities that lets employees go far afield of technical skill sets and immerse themselves in other cultures (using the specific example of how such flexibility could strengthen business relations of a company with China). This is consistent with many of the Bilateral Seminar presentations on goals for improving university engineering education. Dr. Tsun Ko argued movingly, for example, that engineering education must take a holistic approach to the learner, stressing an education that integrates the intellectual with the "cardinal virtues and moral conducts," with focus on collaboration and efforts to train learners in real-life engineering problems. These remarks were complemented by others who affirmed the goal of nurturing creativity and talent in the college (Xie, 2002; Huband, 2002) and workplace (Qihua, 2002; Tung, 2002; Zhewei, 2002). In similar spirit Edward Parrish argued in his Seminar paper (2002) that there is a growing international consensus that engineering education should result not only in a solid grounding in disciplinary fundamentals, but also in well-rounded individual (possessing deep appreciation for literary arts, leadership, communication skills, an understanding of technology in society) and a capacity and expectation for lifelong learning.

The examples of China-US engineering program collaborations (by Kalonji, 2002 and Director, 2002) suggest a synergy to these points. That is, in attending to project-based and real-life international engineering and design problems, students developed greater cultural awareness and social appreciation while building core engineering skills. Acquisition and use of rigorous engineering design and problem-solving skills are not inconsistent with more broadly defined values of productive teamwork and creativity.

The values and goals that are promoted through elearning are not necessarily researchable questions, but any program of collaborative research and evaluation should identify the values and goals of the programs that are the subject of collaboration.

What we know about the learner

Such research should also draw and incorporate the growing research based both on learning in online settings and on learning through the aging process. Smith (in press, 2003) surveys and analyzes research on workplace learning, expanding on earlier distinctions between procedural learning - developing skill sets to use new tools or manufacturing or design methods, and strategic learning, including understandings of how and when to apply new knowledge. This review constitutes an important synthesis of cognitive competencies that elearning delivery systems are increasingly able to address in the workplace. The field of cognitive science has opened new insights and findings on the memory, metacognitive, affective, and motivational characteristics of learners. Cognitive neuroscience is shedding promising light in one area of great importance - the potential for maintaining cognitive vitality throughout the aging process (OECD, 2002; Taylor, 2001). A fundamental premise of workforce education is the trainability of the adult; demonstrations of neural plasticity in adults suggests that beyond trainability, adult learners may be much more capable of agile learning and adjustment, with corresponding changes in brain structure (Maguire et al, 2000). The capacity to learn and absorb continues throughout the life cycle in greater measure than has been traditionally thought. How to create the conditions for rapid knowledge gains in the workplace learner is a relatively unexplored research domain (De La Harpe & Radloff, 2000).

Additionally, while the research literature identifies different types of learning in workplace education, the field of knowledge generation through online communities is relatively new. That is, the workplace education and elearning literature focuses on progressively sophisticated forms of learning (from procedural to strategic), but little attention has been directed to knowledge generation as an aim of formal workforce education systems, nor has it extensively built a theory of distributed knowledge systems.

In the Seminar, Jack Wilson contrasted Moore's Law (that the size of a computer chip halves and its speed doubles every 18 months) with Metcalf's Law, a simple extension of the mathematics of networks. In any group of n individuals, n^2-n dyads or one-to-one relationships are possible. Elearning creates geometrically increasing social contexts; it also creates expanded opportunities for knowledge production.

Knowledge production in ICT-mediated contexts that benefit from this geometric increase, where communication patterns have such different dynamics, benefits from social situations is the subject of a major priority program of the German DFG ("Net-based Knowledge Communication;" see Buder & Hesse, 2001). The US National Science Foundation supports a Lifelong Learning Center organized around research on online social networks that nurture creativity and innovation (Fischer, 2001).

Extending conditions for rapid conceptual gains in the adult learner, capitalizing on net-based communication, and amplifying learning and creativity through net-based communication are significant topics that should be incorporated into a collaborative research agenda.

Changes in the technology that mediates learning

ICT-mediated learning requires a technical infrastructure that is changing rapidly and creating increasing opportunities to attain the goals of elearning and to take advantage of the increasing knowledge about how to tailor learning opportunities to the characteristics of the individual or organizational learner. The technology "metavariables" can roughly be broken down into increases in **computational** infrastructure and in **networking** infrastructure for online delivery.

Computational infrastructure refers to patterns of increasing memory and processing capacity, often illustrated by the earlier reference to Moore's Law. Increasing capacity enables, for example, complex simulations of design or experimental processes, visualization software that can depict structural features of dynamic processes, and virtual reality scenarios. It enables more flexible structuring of content delivery to accommodate learner cognitive and affective attributes, preferences, motivations and decision paths.

Increased network infrastructure refers to bandwidth increases and development of grid technologies that create a greater real-time look and feel to communication technology.

These developments are more than simply stepwise increases in capacity. They do more than improve throughput for online learning systems, they alter the fundamental delivery and course authoring models that are possible. Higher computational capacity creates more dynamic and richer interaction with an engaged learner or group of learners to participate in simulations, manipulate visual models, or respond to intelligent tutoring systems. It creates greater opportunity for blending video with online assessments, and for blending different computational forms (sensors, video systems, PDAs, intelligent tutors). The advances in technology will create opportunities for sophisticated customization of workplace education organized around the needs of the individual learner (Hinrichs, 2002).

Higher networking capacity creates opportunities to re-examine the asynchronous-synchronous models of online instruction. Synchronous instruction removes half of the "anytime-anyplace" flexibility of online learning by constraining activities to a fixed time. Most online courses provide threaded and asynchronous discussions. Network infrastructure changes, however, create opportunities for a different kind of synchronous engagement, and can propel learning community development. For example, participatory simulations currently take place over low bandwidth handheld devices but demonstrate potential for synchronous learning activity (Colella, 2000). Real-time engagement of the groups of learners is becoming more prevalent in corporate training software (e.g., by vendors such as Webex, PlaceWare, or Centra), in which learners interact with each other. Increased computational capacity enables real-time interaction between a learner and richer content; increased network capacity enables real-time interaction between learner**s** and content. Each of these capacities creates new questions of the design of online environment to spur learning and learning communities, and they create conditions for research that can only modestly rely on knowledge bases built on the premise of lower-capacity and lower-speed pedagogies.

Suggestions for China-US Collaboration on Elearning Research and Evaluation

The convergence of new insights in learning through the aging process and in knowledge building and creativity in online communities, coupled with advancing computational and networking infrastructures, generates fresh and critical areas for research and evaluation. A broad area for potential collaboration is thus in **setting research and evaluation agendas for next-generation elearning systems, especially in engineering education**.

In terms of developing a collaborative *research* agenda, one specific step involves a joint effort by the NSF and the US Office of Naval Research, who are co-sponsoring a February 2003 workshop designed to identify the most critical questions in distance learning and to help the agencies determine the most strategic approaches to investing in elearning research. As a result of the Bilateral Seminar, we have invited NSF-C participation in this. The workshop, organized by Kenneth Lane of California State University at San Bernardino (2003), explicitly focuses on the pedagogy of next-generation distance learning systems. Chinese participation will be an important forerunner to any collaborative elearning research program; it will help identify issues specific to workplace and university engineering education that the NSF-C and NSF could embed in any long-term collaborative framework.

In the related area of an *evaluation* agenda: How can the effectiveness of elearning models be accurately assessed relative to each other or relative to traditional systems? Yantong Zhang (2002) argued that some distance learning modes offered no comparative benefit over face-to-face instruction, but that as the elearning mode become more interactive, the benefits increased. Jack Wilson (2002) presented compelling evidence of the value-added of the Renssalear distance-learning program. A collaborative program could organize **evaluative benchmarks for learning and return on investment used in future studies such as these**. Such a program could develop and seek to standardize formative evaluation frameworks in anticipation of the many ICT-mediated engineering programs that exist now or that will come online in coming years.

The October 2002 agreement by both governments to promote foreign language acquisition through elearning at the precollege level (U.S. Department of Education, 2002) was, coincidentally, signed during the same week as Bilateral Seminar. The timing of the agreement reinforced the interest on both sides in structuring win-win opportunities for the two countries; indeed, the Seminar stoked a great deal of interest in continued collaboration in project-based college exchange programs, such as the University of Washington - Sichuan University program (Kalonji) or the Shanghai Jiao Tong University – University of Michigan program (Director). A related area of potential collaboration is to **survey programs of this nature and to survey the current means by which their effectiveness is measured.** Such a survey should also include an analysis of the potential of workplace programs, which feature international product design projects, such as those presented by Hewlett-Packard (Yang, 2002), Baosteel (Qihua, 2002), and General Motors (Tung, 2002) to contribute or participate in these exchange programs. The survey could provide a critical baseline and database for universities, corporations, and national agencies as they develop or fund exchange programs of the future.

REFERENCES

Colella, V. (2000). Participatory simulations: building collaborative understanding through immersive dynamic modeling. *Journal of the Learning Sciences, 9(4)*, 471-500.

Cornford, I.R. 2002. Learning-to-learn strategies as a basis for effective lifelong learning. *International Journal of Lifelong Education* 21(4), pp. 357-368.

De La Harpe, B. & Radloff, A. 2000. *Informed Teachers and Learners: the importance of assessing the characteristics needed for lifelong learning*. Studies in Continuing Education 22(2), pp. 169-182.

Director, S.W. 2002. *Globalization and Engineering Education*. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 1-3.

Fischer, G., H. Eden, E. Arias, and M. Eisenberg (2001). ROLE: Social Creativity and Meta-Design in Learning Communities. NSF Grant 0106976.

Fuwa, Kazuhiko. 2001. Lifelong education in Japan, a highly school-centered society: educational opportunities and practical educational activities for adults. *International Journal of Lifelong Education* 20(1), pp. 127-136

Gaofeng, Z. 2002. New Century Reform and Development of Engineering Education in China. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 67-84.

Gouthro, P.A. 2002. Education for sale: at what cost? Lifelong learning and the marketplace. *International Journal of Lifelong Education* 21(4), pp. 20-35

Grace, A.P. 2002. Lifelong Learning: International Perspectives on Policy and Practice. 21 Annual Conference (May 30 to June 1, 2002) Canadian Association for the Study of Adult Education (CASAE) Proceedings, pp. 128-133.

Gustavsson, B. 2002. What do we mean by lifelong learning and knowledge? *International Journal of Lifelong Education* 21(1), pp. 13-23.

Huang, J. 2002. Elearning and software engineering education. *Proceedings of China-US Bilateral Seminar on Engineering Education*.

Huband, F.L. 2002. Preparing Engineers for Creativity. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 132-135.

Kalonji, G. 2002. Multinational Project-Based Approaches to Integrating Engineering Education and Research. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 177-180.

Lane, K. (2003). Technology Assessment of Distance Learning Workshop. NSF Grant 0307027.

Maguire, E.A., Gadian, D.S., Johnsrude, I.S., Good, C.D., Ashburner, J., Frackowiak, R.S. & Frith, C.D. (2000). Navigation related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences (USA*) 97(8): 4398-403.

Mullane, L. 2001. *Innovations:* Educating the Whole: An Interview with Jeremiah Murphy, Director of the Business-Higher Education Forum. *CenterPoint*. [On line]. Available: http://www.acenet.edu/calec/centerpoint/index.cfm?articleID=47

Park, S. 2002. The change of South Korean adult education in globalization. *International Journal of Lifelong Education* 21(3), pp. 285-294.

Parrish, E. 2002. Issues in Engineering Education. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 228-232.

PITAC (President's Information Technology Advisory Committee) (2001). *Using Information Technology to Transform the Way We Learn.* Washington DC: Office of Science and Technology Policy, Executive Office of the President.

Qihua, X. 2002. Continuing Engineering Education Facilitates Enterprise's Technological Innovation. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 41-53.

Ratchford, J.T. 2002. Globalizing Engineering Education: Public Policy Impacts. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 142-166.

Saba, F., (2002). Connecting the dots: Cost of education, reduced resources and distance education. *Distance-Educator.com*. Retrieved January 2003 from http://www.distance-educator.com/dnews.php4?action=detail&id=6082.

Selwyn, N., Gorard, S. & Williams, S. 2001. The role of the 'technical fix' in UK lifelong education policy. *International Journal of Lifelong Education* 20(4), pp. 255-271.

Shilie, W. 2002. The Concept of Talents and the Concept of Education. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 54-66.

Smith, P. (2003, in press). Flexible Delivery and Workplace Learning. *Review of Education Research* 73(1).

Street, G. 2000. An overview of the development of biochemical engineering education. *European Journal of Engineering Education* 25(3), pp. 181-187.

Taylor, E.W. 2001. Transformative learning theory: a neurobiological perspective of the role of emotions and unconscious ways of knowing. *International Journal of Lifelong Education* 20(3), pp. 218-236.

Tung, K.H. 2002. General Motors China Engineering Education. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 216-218.

U.S. Department of Education (2002). U.S. Calls for Strengthening E-Learning Efforts in APEC Region. Available at http://www.ed.gov/PressReleases/11-2002/11062002.html.

Wilson, J. 2002. eLearning in Engineering: The Interplay of Technology and Pedagogy. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 97-100.

Wilson, J.D. 2001. Lifelong learning in Japan – a lifeline for a 'maturing' society*? International Journal of Lifelong Education* 20(4), pp. 297-313.

Xie, Y. 2002. How to Educate Students with the Ability of Innovation and Creation. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 181-190.

Yang, E. 2002. Reinventing the Partnership with Higher Educational Institutes in the Globalization Age. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 39-40.

Zhang, Weiyuan , Niu, Jian & Jiang, Guozhen (2002). Web-Based Education at Conventional Universities in China: A Case Study. *International Review of Research in Open and Distance Learning:* 2, 2.
http://www.irrodl.org/content/v2.2/zhang.html#b19

Zhang, Y. Promoting Student-Centered Learning. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 255-258.

Zhewei, Z. 2002. Innovation and Creation in Engineering Education. *Proceedings of China-US Bilateral Seminar on Engineering Education*, pp. 126-128.

DISTANCE LEARNING AND THE NATIONAL DIGITAL LIBRARY

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digital library: "A managed environment of multimedia materials in digital form, designed for the benefit of its user population, structured to facilitate access to its contents, and equipped with aids to navigate the global network ... with users and holdings totally distributed, but managed as a coherent whole."
--Mel Collier, *International Symposium on Research, Development, and Practice in Digital Libraries 1997*

With the global availability, the speed and the continuing rapid growth of the Internet, the world becomes smaller and more connected; information can be shared anywhere in almost real-time. This brings us to an entirely new model for education. The Internet makes it possible for more individuals to access information, to use it and to learn from it in many new and different ways. It forces us to look at learning in a very different way.

No longer do we need to bring students to the learning; we need to be thinking about how to bring learning to the students. The mode of presentation and even the class structure can be very different than the traditional classroom model we have used since the beginning of mass education. And with the explosion of information, we cannot expect the teacher to know all, to develop materials that are always cutting-edge, and to understand and implement the latest teaching technique. We need a way to share the educational materials that are being developed by various people. Unlike a conventional library where multiple people can enjoy one book but only one at a time, the Internet allows us to make the latest [engineering] educational materials available to all. And, it can be used by all at the same time! We need to re-think the traditional model and location of mass education.

The National Science, Technology, Engineering and Mathematics Education Digital Library was conceived and is being developed to support excellence in science, technology, engineering and mathematics education in the United States. Building on research supported under the multi-agency Digital Libraries Initiative, this program is creating a national digital library that will constitute an online network of learning environments and resources for science, technology, engineering, and mathematics (STEM) education at all levels – preK-12, undergraduate, graduate, and life-long learning. The resulting virtual institution is expected to catalyze and support continual improvements in the quality of science, technology, engineering, and mathematics (STEM) education in both formal and informal settings.

Currently there are over 60 NSF NSDL projects with some 40+ to be announced by early October. Several include topics that would be of interest to engineering educators around the world. For example, one project is the creation of a digital library of micostructures for functional ceramics with emphasis on materials used for structural, electronic and thermal applications. This database and software is currently being beta tested and will soon be available. Another example is a collection of high-quality numerical software for science and engineering education that supports a rich, highly interactive and inquiry-based learning environment needed to enable learners at various levels to master the use of numerical methods and software libraries.

With the Internet, anyone can post anything for all to see. The flood of information could easily make the useful educational materials hard to find and hard to identify as being useful. We need some method to organize, to share and to search for the materials and ideas. How will high-quality materials that have been thoroughly classroom-tested be distinguished from the untested "works in progress"? How will the information be updated? Is a logical step in the development of the NSDL the inclusion of international projects?

In the past two years we have had visitors from Asia, South America, Europe, etc who expressed great interest in the NSDL. There are currently several international collaborations underway. Recently a JISC (UK)/NSF review panel evaluated joint proposals where one of the proposing institutions was in the UK and the other in the US. There are currently joint proposal solicitations with NSF/DFG (Germany) and NSF/EU (European Union) (www.dli2.nsf.gov/intl.html). The multinational " Million Book Project" funded under the NSF ITR initiative (www.itr.nsf.gov) is investigating the creation of a digital online archive of at least one million books and manuscripts that will then available to anyone at anytime. Several Chinese universities are involved with distance education programs with partner schools in the US. Where will these nascent efforts lead?

An international extension of the NSDL is a natural question to pursue. Many questions arise from international collaborations and contributions to an International Digital Library. Can the NSDL become the infrastructure to enable a globalization of educational information? How can the idea of a digital library help build collaborations and enable the globalization of engineering education? How will this impact engineering education with respect to the distance education model? Can we create and build an educational environment that provides high quality engineering education to people around the world?

WEB-BASED “LEARNING BY DOING” INQUIRY LEARNING

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The world is witnessing a revolutionary change driven by a succession of significant technological innovations ranging from transportation to communication, from the burgeoning IT industry to the foreseeable biological technological revolution. Thus the world in which we live and work is becoming more dynamic, mobile, and interdependent. Both human society and the natural environment on which we depend are increasingly fragile and uncertain, which is reflected not only in quantity but also in the depth and breadth of the influence they make.

Education should adapt to this irreversible trend and nurture talents for it. When we are facing reality and looking forward to the future, we should ask ourselves such questions as: what is most valuable for our life in our schooling? How do we define scholars and knowledge? What influences students’ future most? Could the following qualities, instead of the book knowledge, be singled out as the answer to the last question: adaptability, communicative competence, the ability of life-long learning and the ability to meet challenges and cope with pressure, etc. The once prevalent opinion in China that a good knowledge of mathematics, physics and chemistry could help overcome whatever difficulties under the sun has long been out of date.

Another noteworthy change is that science and technology are no longer a career exclusive to those scientists in ivory towers but is present in every aspect of social life. Take students majoring in mechanics as an example, they are required to learn not only mechanical engineering, mechanical layout and technology but also electronic engineering, computer science and material science ranging from metal to non-metal materials, nanomaterials and biological materials. No one knows what kinds of materials will come into being and be applied in the future. And the disciplines and technology concerning these materials also make a great difference. Besides the knowledge of natural science and technology which is closely related to their major, these students should also learn economics, management, marketing as well as the language, history and culture of their motherland and other countries. Moreover, they should be expected to know how to obtain a thorough understanding of the subjects they have learned, to study for sake of application, and to be able to predict and manage the future risks, etc. Therefore, more and more subjects will be offered and required. Within limited class hours, however, there will be a conflict between the range and depth of the subjects offered. It will become more and more difficult to design courses focusing on only one single discipline, at least, during the stage of specialized course learning.

With an increasing proportion of students receiving higher education and the popularization of higher education, the prospective careers for students are no longer confined to academic research and engineering technology. The diversification of employment poses new challenges for higher education.

Inspirations from science education reform in kindergartens and primary schools—"Learning by doing"

Science education reform in kindergartens and primary schools, namely, "Learning by Doing" is a joint action initiated by some scientists at the turn of the new century. The rise of the reform is of remarkable significance to meet the requirement today.

About 15 years ago, Dr. Leon Lederman, a Nobel Prize Winner in Physics from the U.S.A., put forward the "Hands On" learning mode. He stated that, in doing so, they were preparing the qualified US citizens for the future 20 years. I was greatly impressed by his view when I visited the science education in Chicago. Five years ago, Dr. Georges Charpak, a Nobel Prize winner in physics from France introduced this learning mode to France and named it "La Main a La Pate", literally translated as "kneading the dough", meaning "Learning By Doing". Dr. Charpak noted that this innovation in science education changed not only children's way of learning but also their way of living. Owing to the generally recognized success of the reforms, it has been adapted by many countries as an important part of their education reforms. In November, 2000, in a meeting hosted by the ISCU, scientists, educators, NGOs and teachers from more than 20 countries gathered in Beijing to discuss science and mathematics education in primary schools. Dr. Leon Lederman personally drafted the Beijing Conference Statement to propose a new action network to co-ordinate the efforts to archieve the common goal of worldwide advance of science knowledge and science thinking as a vital component of the education of young girls and boys.

After careful consideration and full preparation, a teacher training plan and similar science education plans have been jointly initiated by the Chinese Ministry of Education and the Chinese Science Association last year. We call it "Learning by Doing". Though this reform has been under way for only a short period of time and in a few schools, it has achieved noticeable results in at least the following three aspects:

1, It has changed efficiently the long-established teacher-centered methodology and aroused students' initiative learning

2, Students have developed the ability to learn and apply the knowledge to different situations.

3, In the process of scientific education with experiments, students have learned how to cooperate with each other, respect each other and value facts, etc.

"Comprehensive quality oriented Education" has been talked about for years in China and it is said that the definitions of it have amounted to hundreds. There are many articles focusing on macro-problems while seldom have we found those on specific problems. Judging from the results it has achieved in the world and in China, "Learning by doing" is indeed a feasible solution, though it might not be the only one, even not so much as the best one. Another inspiration I got from this experiment is that it is very vital to research into our way of teaching. Nothing can be achieved without proper teaching or learning methods. The reform in methods is much more important than that in the teaching content according my personal view.

Some suggestions of using the conception of "Learning by Doing" in Colleges

We think the conception of "Learning by Doing" inquiry learning can be applied to higher education as well. It advocates a close cooperation and dynamic interaction between teachers and students, the combination of basic knowledge and typical cases, and the integration and coordination of various disciplines, etc., all of which are needed by the ongoing high education reform. We believe, by adapting some ideas of "learning by doing" to the engineering education reform in some universities and by making some expanding of them, we will surely be able to find another way for the ongoing reform in colleges and universities. We are thinking of implementing the following expansions that are not include now in the reform of science education in the kindergartens and primary schools:

1, Using of Internet connection and information technology links with different resources from different webs to promote an worldwide knowledge acquiring and interactive learning.

2, the integration of scientific practice with rational thought in line with the cognitive characteristics of college students; practice would no longer be considered a way to verify theories but rather an important learning process

3, the introducing the social science contents into the learning process of engineering education is necessary.

We envisage that we can implement the learning of basic knowledge required by centering upon academic disciplines in the first one or two years of the undergraduate study and can implement professional education, using the "learning by doing" inquiry learning centering on problem-solving, in the later stage of college education. In the process of carrying out "Learning by Doing", various courses and learning plans should be designed to accommodate various students' interest and inclination to their prospective careers. For example, teaching material and learning plans of academic value or those stressing technological process, technological application and establishment of enterprises, etc.

We are fully aware that a large amount of exploration work, such as teacher training, problem-based courses design and classroom coordination, is needed to be done if we decided to put our blueprint into reality. "La Main a La Pate" in France set ten principles during its implementation. In the process of practicing "Learning by Doing", we put forward nine principles in correspondence with Chinese characteristics in a hope to ensure its quality. Certain principles should be determined if the reform is going to be implemented in universities. Though it sounds difficult, it is promising. We hope that some of excellent professors in the field of Chinese higher education will actively undertake this task.