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The Computer is Critical for Globalisation of Engineering Education*

Billy L. Crynes
College of Engineering, School of Chemical Engineering, University of Oklahoma, 100 E. Boyd, Sec T335, Norman, Oklahoma 73019, United States of America

Technology today is a global commodity and business must find technology and engineers anywhere in the world and put them to work. A far greater number of students and faculty desire to study, teach, and research abroad than can ever possibly afford to do so. Connectivity by the Internet and World Wide Web is an excellent alternative. The barriers preventing engineering education globalisation, like lack of standards and costs, will eventually fall. With globalisation of engineering education, especially driven by information technology like the computer and Internet, worldwide pervasiveness will, it is hoped, take decades to achieve, not centuries. The world map of engineering education with no boundaries or borders is our goal.

COMMERCE DRIVEN

Worldwide commerce, globalisation of business and marketing, acts like NAFTA, and greatly increased media, entertainment, sports and cultural exchange are driving globalisation of education. Engineering education is not exempt. For years we have had healthy and significant international exchanges of students and faculty. The flow of engineering students from one nation to another has varied over the years, as political, cultural and economic conditions change within sending and receiving countries. An example of globalisation of engineering is Boeing's design of the 777 aircraft, which was a paperless design, drawing on engineers worldwide, 24 hours a day. Corporate mergers at the billion dollar level over the past few years are clear signals of growing global commerce (eg British Petroleum-Amoco - US$48 billion, DaimlerChrysler - US$43.5 billion, and in the chemistry sectors: US$33.2 billion for Hoechst-Clariant, Unileaver-ICI and Mitsu-Toatsu-Mitsu Petroleum). A team of engineers and scientists at Battelle Institute rated global business competition as one of the United States top ten concerns [1]. Technology today is a global commodity and business must find technology and engineers anywhere in the world and put them to work any where in the world. There is no doubt that international teaming is on the rise with the growth of international engineering projects and the global market place [2]. Globalisation of engineering education must, logically, follow and support this global technology.

An excellent sign of educational globalisation is the proliferation of international meetings. Just in the last couple of years there have been the *Global Congress on Engineering Education*, Cracow, Poland; *ICEE '98*, Brazil; *IGIP*, Moscow; *XII Congreso Chileno de Education en lngenieria*, Chile; *Technology Standards for Global Learning*, Salt Lake City, USA; *The Global Digital Library*, London, UK, 1997; *International Conference on Engineering Education: An Asian Perspective*, Madras, India, 1998; *IASTED International Conference: Computer Systems and Applications*, Jordan, 1998; and all of the excellent meetings organised by UICEE in 1998 in Kenya, Mexico, Australia, Germany, and other countries.

EXCHANGES NOW

The primary method of interactivity now is student and faculty exchanges and at national/international

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Table 1: Student sources to United States.

Asia	57.2%
Europe	14.8%
Latin America	10.4%
Mid East	6.7%
North America	5.2%
Africa	4.6%
Oceania	0.9%

Table 2: Trends of student sources to United States.

1995/96		1982/83	
Japan	10.0%	Iran	7.9%
China	8.7%	Taiwan	6.2%
Korea	8.0%	Nigeria	6.1%
Taiwan	7.2%	Venezuela	4.6%
India	7.2%	Malaysia	4.1%
		Canada	4.2%
1972/73		**1962/63**	
India	7.3%	Canada	10.8%
Hong Kong	7.0%	India	9.5%
Canada	6.6%	Taiwan	8.5%
Taiwan	6.6%	Japan	4.5%
Iran	5.4%	Iran	4.5%

Table 3: Origin and purpose of scholars.

Asia	43.0%
Europe	37.3%
Latin America	6.2%
North America	4.4%
Mid East	3.4%
Oceania	1.8%
Purpose	
Research	83%
Teaching	12%
Other	5%

Table 4: University of Oklahoma.

Formal agreements with foreign universities	95
Number of foreign students enrolled	1,800
Our total enrolment	25,000
Number of foreign students in engineering	572
Our total engineering enrolment	2,900
Number of our students who studied abroad last year	32
Number of our faculty who travelled abroad last year	41

meetings. More than one million students worldwide studied outside their country in 1995. A large proportion of these chose, about equally, business and engineering fields. The United States, for example, received about 481,000 international students in 1997-98 to study at 3,700 higher education institutions. Of these, about 57% were from Asian countries. Only 85,000 US students went abroad. Tables 1 and 2 show more detail about US exchanges. Faculty exchange is also significant, but, much lower. In 1997-98, over 65,500 visiting scholars studied in the United States, with probably less than 5,000 US scholars studying abroad [3]. Table 3 shows the countries and purposes of these scholars [4]. A recent survey of 20,000 persons revealed that engineering faculty are more likely to work with colleagues in other countries, but not more likely to travel abroad to teach and study [5].

There is one problem that concerns, in particular, the sending countries. This is the failure of the visiting student or faculty to return home and, thereby, contribute to their country's further economic, technical, scientific and educational development. For example, a recent study reports that 63% of foreign-born students who earned US PhDs between 1988 and 1996 plan to stay in the US [4].

In the US's 320 engineering programmes last year, there were 71,000 students from other nations; only about 2,000 US engineering students studied abroad [6]. Engineering had 7,500 foreign faculty and probably less than 500 US faculty served on sabbatical, postdoctoral assignments, or some other form of visitation. About 58% of the doctoral degrees and 15% of the BS degrees given in engineering in the United States were to non-US students. There was a significantly fewer number of US students studying abroad. Some of their reluctance is caused by attractive employment opportunities during summer months when United States class offerings are greatly reduced.

The University of Oklahoma operates as a typical United States institution. Table 4 lists the University's import and export of students and faculty; students and faculty from around the world contribute significantly to the institution, especially in engineering.

There is always a significant cost to students or faculty who travel to another country, even if some form of scholarship or support is provided. Airfare and room plus board can be considerable, even if the receiving institution waives the tuition and fees. For example, the University of Oklahoma is a relatively inexpensive institution in the southwestern part of the United States. Even so, airfare from Europe and back, plus 12 months minimum room and board accommodation would be approximately US$18,000 for a student, and this would be living in adequate but sparse university student dormitory accommodation. Of course, fee waivers, scholarships and assistantships are available. Of those foreign students who studied in the United States, 68% of their funds came from personal or family resources, 18% from US universities or colleges, and 5.9% from their home government or university. The point is that a far greater number of students and faculty desire to study, teach and research abroad than can ever possibly afford to do so. Connectivity by the Internet and World Wide Web is an excellent alternative.

The growth of connectivity in the US can be seen by the increasing number of higher educational institutions involved in distance learning via the Internet. This year more than half of all of the US's 3,700 institutions offered distance education courses. In 1994-95, over 750,000 students were enrolled in distance education courses and about 3,400 received degrees exclusively this way [7]. Also, the National Technological University in Fort Collins, Colorado, USA, plans to offer a global Master's degree in Information Technology Management only via the Internet in 1999 [8].

TECHNOLOGY INCENTIVE

The greatest recent initiatives to enhance engineering education globally have been the Internet and World Wide Web (WWW). Of course, being in a particular country for study and fully immersed in the culture is always best. However, electronic connection is an order of magnitude over the other forms of stay at home connection, such as television, printed media and telephones.

Consider all that it is now possible to do in global engineering education using the computer or other forms of information technology such as the Internet and WWW:

- Words, sounds and pictures (still or animated) can be exchanged from any place in the world.
- A group of students in Cracow, Poland, can connect with another group of students at the University of Oklahoma to work on joint engineering design projects.
- This collaborating team of students may connect, real time, with the engineers in a major corporation, for example, in Bombay, India.
- A professor at the University of Oklahoma in the study of rock mechanics, with his petroleum and engineering students, may simultaneously teach a group of students in Caracas, Venezuela.
- Or, that same professor's course might be available asynchronously over the WWW for all petroleum and geological engineering students at any time, anywhere, in the world.
- List serves and chat rooms now provide a format for continuous, lively exchange of ideas between students, faculty and others.
- Students and faculty now have access to data over the Internet that is so extensive as to be nearly unmanageable. The problem has shifted from access to information mining for knowledge gold.
- Theories, discoveries, ideas and concepts can be almost instantaneously available worldwide. An international debate might rage the moment a controversial discovery is published over the Internet. The merits can be quickly established by debate, replication or legislation.

All of the above are now possible and are being achieved, but they are not yet pervasive or worldwide, nor without many faults and barriers. Consider some of these barriers.

BARRIERS

Until there are hardware and software standards, portable across all country boundaries, globalisation of engineering education will continue to be restricted [9]. Just the simple issue of power supply from country to country is an aggravation.

Startup and operating costs are a problem to all nations, industrialised or developing. Of course, the former would be further along in application of information technologies for engineering education than the latter. Nevertheless, the cost issue confronts all. Reality of this cost barrier is seen in a country like Romania where the cost of even a used computer is currently 10 to 15 times the guaranteed minimum salary [10].

No matter what country, no matter what university, there exists a majority of the faculty who greatly resist change and challenge to the old, proven and comfortable ways of teaching and learning. They are not yet convinced that compelling evidence exists that shows that new learning technologies are an improvement and, hence, worth the human and financial costs associated with change.

In the longer perspective, global engineering education will converge on a set of standards, both hardware and software, that will balance the necessity for individual and cultural flexibility, yet overcome the hassles of international mobility. There must be room for some choice, yet limited enough for exchange. As for the costs, in all areas these continue to fall, and sometimes quite rapidly. What usually happens, however, is that desire for faster and better and for network/systems expansion pushes total costs upward, faster than unit costs of hardware/software can fall. For the sake of globalising engineering education, we might consider fixing on a reasonable standard technology and then pursue global growth rather than the next generation of technology. Also, from a greater vista, the resistant and reluctant faculty will be gone and new generations will eagerly embrace the information technology.

What seems so exciting to us now, what offers so much promise for better learning technologies worldwide, will seem so ordinary to the next generation of teachers. Using the WWW for many is becoming as commonplace as using the telephone, and has the same expectations and attention associated with it, ie it must always be available and it must always work immediately, and failure to be or do so has already become, for some, a great inconvenience. The following is one definition of a pervasive technology: it is so common, so reliable, that it is unnoticed except by its highly infrequent failure. But until recently, attitudes to the use of the Internet reflected how slow and marginally reliable it was, tempered, nonetheless, by awe with even its sporadic and feeble performance. It is rather remarkable that in such a short time the technology has become so accepted and ordinary that it tends to become unnoticed by the user.

PACE OF CHANGE

On a worldwide basis we will need patience and great diligence to realise a pervasiveness of globalised engineering education. The computer and the Internet are the vehicle by which we can accelerate globalisation. But consider for a moment how long a familiar technology, the automobile, has taken to become globalised.

The *automated mobile* was conceived as far back as the 15th century by Leonardo DaVinci. Practical, demonstrable models began to appear around 1678, even though they were steam powered. Then the electrical vehicle, and finally the internal combustion engine were developed in 1884 and 1885 respectively. In 1916 only about 1.5 million automobiles were produced in the United States; however, note that in 1990, 50 million cars were made worldwide. Today, there is one vehicle per 12 persons in the world and in the United States, remarkably, there is one per two persons, counting autos, buses and trucks.

So, with the automobile from concept to world pervasive use, centuries passed. However, with globalisation of engineering education and especially driven by information technology like the computer, worldwide pervasiveness will, we all hope, take only decades to achieve, not centuries.

CONCLUSION

Commercial and business markets are significantly driving the globalisation of engineering education. There is a convergence, a slow one, toward global accreditation standards. *Most developing countries do not have the infrastructure to take part as equal partners in the worldwide enterprise of knowledge production and dissemination* [11]. We should work to ... *commit the organisations of the United Nations system to assist developing countries in redressing the present alarming trends* [12]. *Faced with issues of self-sustainability, while creating quality of life ... will only be achieved by first class educational opportunities for all mankind* [8]. The recently graduated engineer, the product of our world education institutions, could become a worldwide commodity. As long as three years ago, an Intel vice president made this forecast about our students.

Figure 1 shows a typical United States College of Engineering student input/output diagram. All engineering graduates must be prepared to work anywhere in the world. A key element, indeed the primary asset to globalisation of engineering education, is the use of information technology: the computer/Internet/World Wide Web. There is no greater technical element that offers such significant promise as this. We must develop strategies and focus resources to drive engineering education globalisation with these technologies. At the same time, opportunities to exchange faculty, researchers and students must be expanded because no matter how electronically pervasive we become, no virtual exchange can substitute for actually being there. Beyond any measure of comparison, to live, to learn in another country, will provide the greatest individual and, eventually, national growth for both sending and receiving nations. The information technologies must always be complimentary, compatible and supportable, not competitive to these greater exchanges. The world map of engineering education that shows no boundaries or borders is our goal.

REFERENCES

1. Top 10 technical challenges. *ASEE PRISM*, 11 (1997).
2. Siegel, D., International teaming on the rise. *Engineering Times*, 20-1 (1998).

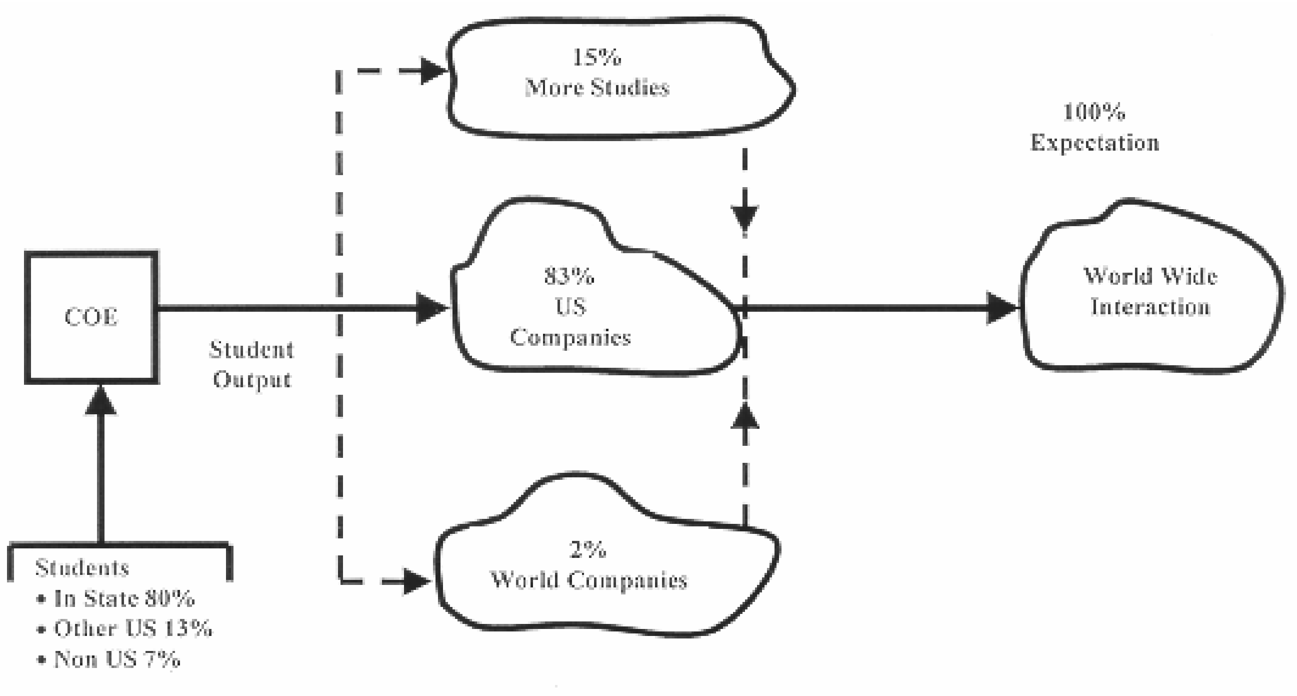
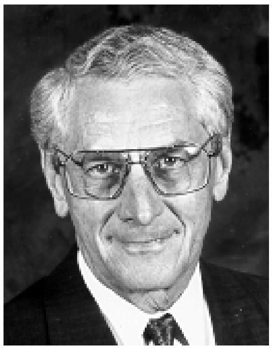


Figure 1: Flow through of engineering students.

3. Open Doors, 1996/97 Report on International Educational Exchange. Institute of International Education, New York (1997).
4. Statistical Profiles of Foreign Doctoral Recipients in Science and Engineering: Plans to Stay in the United States. NSF (1998).
5. Altbach, P.G. and Lewis, L.S., Internationalism and insularity: American faculty and the world. *Change*, 54 (1998).
6. Gerhardt, L.A., Internationalising education. *ASEE PRISM*, 12 (1998).
7. Distance Education in Higher Education Institutions. National Center for Educational Statistics, US Department of Education, www.nces.edu.gov.
8. Johnson, G.G., Creating virtual universities. *Proc. Global Cong. on Engng. Educ.*, 23-26, Cracow, Poland (1998).
9. Crynes, B.L., Engineering education in the 21st century requires student universal access to computers. *1st Latin American and Caribbean Forum on Engineering and Technological Education* (Reprints), Puebla, Mexico (1998).
10. Ilinca, M. and Stoica, M., The role of the regional teaching centre in computer science in the formation of engineering. *Proc. Global Cong. on Engng. Educ.*, Cracow, Poland, 112-114 (1998).
11. Arunachaiam, S., *The Technology Source.* http:/horizon.unc.edu.
12. World Telecommunication Report (1998).

BIOGRAPHY



Billy L. Crynes served as Dean, College of Engineering, for 11 years, and is currently Professor, School of Chemical Engineering and Materials Science, at the University of Oklahoma. He graduated from the Rose Hulman Institute of Technology with a BS in Chemical Engineering. Following employment with EI DuPont de Nemours, Inc, he returned to graduate school and achieved his MS and PhD from Purdue University. For 20 years he served in engineering education as an associate and full professor and Director of the School of Chemical Engineering at Oklahoma State University.

His areas of technical expertise include kinetics, catalysis, pyrolsis, and reaction engineering. In the last five years he has emphasised computer and other forms of information technology applied to engineering education. He moved the College of Engineering at the University of Oklahoma into a position to require student computer ownership beginning in the Fall of 1998 in order better to enhance their education and greatly to change the course material delivery format in that college.

ALLTED - A Computer-Aided Engineering System for Electronic Circuit Design

by A.I. Petrenko, V.V.Ladogubets, V.V. Tchkalov and Z.J. Pudlowski

ALLTED is the fourth publication in the *Monash Engineering Education Series*. The series was established by the UICEE in 1995 in its on-going mission to undertake research and development, and to act as a clearinghouse on information on engineering education. The publication of this book is a joint effort of the UICEE and the CAD Department of the National Technical University (NTU) (Kiev Polytechnical Institute), Ukraine.

ALLTED (**All Te**chnology **D**esigner) is a Computer-Aided Engineering (CAE) system developed in the former Soviet Union at a time when computer hardware lagged behind that available in the West. The designers overcame this problem by developing the software around original algorithms with the result that ALLTED, the designers believe, surpasses the abilities of SPICE, the industry standard, and yet can operate on a system with as little as a 386 processor.

ALLTED is an educational tool which has been developed for the simulation, analysis and design of such diverse devices as drives, control systems and dynamic systems composed of electronic, hydraulic, pneumatic, mechanical, electrical, electromagnetic, and other physical phenomena elements. This can be done by considering each technology individually or in combination. Complex drives and systems of this type are widely used in modern aerospace, robotics, NC machine tools, test equipment, highway engineering, agricultural and other applications. This book deals with the design of electronic circuits using ALLTED.

Both the UICEE and the CAD Department of the NTU distribute the ALLTED code and will be able to deliver one or two-week long seminars for training in optimal design for electronics and mechatronics. Such seminars can be organised in Kiev, Ukraine, or Clayton, Australia, or at any university or company worldwide which can provide suitable conditions.

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