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Green Chemistry for Chemical Engineers in the Third World: Interplay between the Environment, the Digital Divide and Democratisation

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Abstract

In developing countries, engineering education can be as effective as it is in the First World, but striking differences can be identified. In the Third World, it is elitist, highly selective, male dominated, comparatively expensive and gives relatively little cognizance to environmental standards. The challenge for educators, particularly engineering educators, in overcoming and addressing these problems, necessitates the introduction of cheaper ways of delivering education and attracting disfranchised groups to academic programs.

This paper describes attempts by the authors to address the problem through distance education, home-practical kits with green methods, the Internet and special efforts directed at women.

Elitist Education

Education in the West is far more democratic and inclusive than in the rest of the World. This is recognized in Table 1 which gives the enrolment in higher education, as given by UNESCO in its World Education Report[1], for the critical 18-22 age group for a sampling of countries. The table shows the disparities and improvements from 1985 to 1995. The World Bank's education experts believe that for a country to have some chance of reaching Newly Industrialized Country status, the percentage from this critical age group enrolled in tertiary education ought to be at least 8%.

While shortcomings still exist in the areas of women and other minorities, good progress has been made through special programs in the past two decades. In Sri Lanka we now have 46% and 47% enrolment of females in programs leading to first degrees and postgraduate degrees, respectively. However, Sri Lanka is yet to address the problems of diminished female enrolment in the professions and the hard sciences[2].

Although the proportion of female participation is broadly satisfactory (at least in Sri Lanka as indicated in relation to that of males), the larger problem of very low male and female participation in and access to higher education as a percentage of the total population is a critical problem to be addressed if those countries aspiring to Newly Industrialized Country status are to

have their dreams realized. The key figure of 8% of the 18-22 age group participating in higher education must be achieved.

Table 1: *Enrolment in Higher Education for some Countries*

Country/Region	Percentage of 18-22 age group in tertiary education: 1985	Percentage of 18-22 age group in tertiary education: 1995	Percentage of 18-22 age group in programs leading to a first degree: 1995
Sri Lanka	3.7	5.1	2.22
Malaysia	5.9	10.6	-
India	6.0	6.4	-
People's Republic of China	2.9	5.7	2.0
Japan	27.8	40.3	25.4
United Kingdom	21.7	48.3	24.15
United States	60.2	81.1	38.1
Australia	27.7	71.7	33.7
South Africa	-	15.9	7.3
Nigeria	3.3	4.1	4.1
Brazil	10.3	11.3	11.3
Ecuador	11.3	17.2	12.73

As seen in Table 1, unlike in the West, higher education remains elitist in many poor Third World countries. In Sri Lanka for example, a country of some 18 million people, the university population is only about 18000[3]. The reason is cost, unemployment and scarcity of academics qualified to teach. University graduation is limited to about 2% of the population (as opposed to the 2.2% enrolled in degree programs). Governments have in the past tended to estimate how many can be employed or "brain-drained" and determine admissions figures. In areas such as computer science where strong needs have been felt and the government wants to graduate more specialists, there is an inability to increase output because there is practically no staff. Education therefore is elitist at least in the sense that the few with degrees are marked out for leadership of some sort in society.

Special Place for Computer Science and the Digital Divide

While traditionally catching up with the West in technology has been considered difficult because of the necessary phases of industrialization a country has to go through, the information revolution provides new opportunities[4]. Essentially, a PC for each student and 6 years of training after the GCE O. Level can produce a graduate as good as any in the West and it would be easy to generate quickly the personnel for a viable software industry. With this in mind the Sri Lankan Government has declared IT a priority area for development. On the advice of a Presidential Taskforce, duty on all computers and computer related items has been removed[4]. Internet access is available throughout the country through so-called cafés.

Nonetheless, growth in the output of high quality Computer Science personnel has been elusive mainly because of staff shortages. Probationary staff sent abroad at great cost to the state, have not returned because of lucrative employment opportunities in the West and the few who have returned have moved to the private corporate sector where pay is 4 times what state universities

can pay. As a result, state universities have inadequate staff while private universities tend to teach degree courses using programmers who often do not have a university degree and a smattering of foreign consultants who need to be paid heavily. Private education is therefore extremely costly, although it is cheaper than going abroad for a degree. Concomitantly, private universities tend to produce richer, less academically talented (in terms of G.C.E. A. Level performance) and better trained graduates than do state universities which provide free education to the best of the high school crop.

The important cause of the failure of state universities in Sri Lanka is that their students, however clever, come from poorer homes and are less effective in communication and less socially confident so that the burgeoning private sector prefers to employ private sector products who, studying in English, are suave communicators in the language of international commerce. Indeed, as Professor Lakshman Jayatilleke who recently as Chairman of the National Education Commission informed the liaison meeting between Sri Lanka's Institution of Engineers and the Department Heads of National Engineering Faculties at the University of Ruhuna in the presence of one of these authors, based on hearings he held: "Ninety percent of Sri Lanka's national university graduates are unemployable!"

Thus we have a situation, as in many poor countries, where the best students are in state universities, but the less talented richer students in private universities get the best jobs. It creates a political crisis. The growing need to expand the production of graduates cannot be met by government, but there is political opposition to getting private sector help.

Because there is political pressure against privatization through student strikes, any private education provider has been permitted registration only under the Companies Act rather than the Universities Act. As such academics in private universities need to retire at 55 (rather than at 65 as under the Universities Act) and can be fired with 3 months' notice (while the Universities Act gives virtual tenure). Senior academics used to a life-style of leisure and academic freedom under the state, have therefore not taken up positions in private universities except on visiting assignments. Nonetheless, private education is attractive to many good students who, left out of the state system (which provides free education) because of intensely high admission standards, can pay and get into private universities. Another reason why private institutions are attractive is the greater discipline in that sector (with no student or staff strikes as in the state sector and the attendant unpredictability of graduation dates). Yet another factor, as stated, is that private universities successfully impart skills highly valued in the world of commerce, especially communications skills in English, and impart a multicultural outlook that enhances employability in these days of globalization. Equally, the need for the state to cater to all disciplines, has made the private educational sector focus better on market oriented disciplines like computer science, management and accountancy.

Thus we have a situation where the state sector's drive to expand computer science is sputtering for lack of staff, while the private sector's opportunities are confined to the rich who can pay. The digital divide therefore is strongly to be seen between the rich and the poor and, for the reasons given in the next section, between men and women.

Women's Lot

The typical jobs-driven educational choices in Sri Lanka with its high unemployment rates, has resulted in the best going for the sciences after the G.C.E. O. levels while the weakest go for the Arts[5]. However, within the sciences stream at the G.C.E. A. Levels, women tend to go for the biosciences with entry to the medical colleges in mind while more men go for the physical sciences with entry to the engineering faculties in mind. In Sri Lanka, unlike in the West, women do well in the professions; but for the reasons given, they predominate in the biosciences (numbering 61%) and the Arts (62%), and do well in medicine (44%) while doing poorly in engineering (15%) and the mathematical sciences (28%).

Not only do women lose out in the lucrative professions of engineering, but as a result of the burgeoning area of computer science, in the Sri Lankan context, being an off-shoot of the mathematical sciences for purposes of university admissions, avenues to this area are also virtually shut. A new IT Faculty by the government has just begun to admit students from the bio-sciences stream at the G.C.E. A. Levels where women are strongly represented, but it remains to be seen how successful that bold faculty will be in light of its having been able to attract only non-computer science staff so far.

Attractions of the Big City

Colombo, the financial capital of Sri Lanka, is attractive for many reasons, particularly the fact that there are jobs. The first university in Sri Lanka, founded initially as a college of the University of London, namely University College, was at independence deliberately and with a grand vision moved to Peradeniya, a hundred kilometers from Colombo, so as to promote a residential Oxbridge atmosphere, with high tables in the halls of residence and academics coming in their gowns for their meals. But the pull of the big city has vitiated the University of Peradeniya's premier position, and Colombo and its suburbs have seen the establishment of several state universities including the Open University.

At the same time, regional universities have been unable to attract staff – the attractions of better schools and consulting opportunities (as well as employment opportunities for spouses) in Colombo being too much to resist. Students too, (particularly students whose families live in Colombo after fleeing the war in their homelands) tend to prefer the Colombo universities because of the presence of family, greater safety and access to their own culture, and additional educational opportunities through private institutions teaching IT and accounting (which they pursue in parallel with their university education so as to enhance their employability).

Colombo therefore is excessively strained as it struggles to meet transport, water, power and housing needs. Government's efforts at establishing regional universities have practically failed (with the exception of the University of Peradeniya which survives with quality only because of its early history, residential facilities and traditions as the legal successor to University College.

The Distance Education Experiment and its Problems

The government has been most mindful of the elitist nature of the education it provides and the lack of access to private education that poorer segments of society must grapple with. Equally a problem was the centralization in the financial capital which increased the digital divide in the regions and strained the environment.

Distance Education has been traditionally and historically the means to empowering the weak through education. Historically, the Pauline Epistles of the New Testament may be one of the earliest experiments to teach remote pupils. However, the University of London's bold experiment in opening its doors to non-Anglicans through its External Degrees Programme, brought about revolutionary access to political minorities and women. Asynchronous learning (that is, studying at a different time from that at which the teacher is teaching) has also opened previously shut doors to learning to working persons, housewives and late starters. By and large, with the arrival on the scene of mega-universities like the Open University of the United Kingdom (and the OU in Sri Lanka) that, unlike London, also provide the teaching materials for their students in addition to examination and certification, distance education has become a true alternative to conventional education, particularly for those who did not make it into conventional universities. A measure of the success of the distance experiment is that there are as many students enrolled at the Open University of Sri Lanka as in all the Sri Lankan conventional universities put together.

However, the distance option still suffers from problems. There is a high failure rate because of diminished peer interaction, lack of full time commitment and other reasons. But the problem is most severe in engineering and (to a lesser extent) in the physical sciences where sometimes there are more academic staff members than there are graduates in a year. Naturally therefore, the distance method fails to yield dividends in the most neglected areas of conventional education. That is, it is fails as an alternative in engineering and the physical sciences where women are under-represented and therefore is vitiated as a solution to their problems.

One of the reasons for the non-fruition of the promises offered by distance education, is that in the area of laboratory work, distance education is typically neither asynchronous nor distant. Laboratory work is not done at home. Presently all students need to come to the central campus for an intense period of laboratory work, sometimes for as long as a month in an academic year. As a result, housewives and working persons cannot reap the full benefits of distance education. In addition, coming to the central campus in Colombo means students need to rent accommodation which is usually not possible for a short period unless one goes to an expensive hotel. Besides, the insurgency in Sri Lanka means that Tamils students will not be easily offered accommodation by land-lords frightened of getting dragged into possible anti-terrorism cases and being detained under the Prevention of Terrorism Act as an accessory.

Similarly, the need to come often to the central campus to sit examinations, quizzes and continuous assessment tests also makes a mockery of the term "distance". So also with the necessary student-teacher conferences. Indeed, many working persons drop out because they are unable to fit these laboratory sessions and meetings into their schedules.

These short periods of stay in Colombo for these multifarious purposes also place a strain on the transport needs of the city and add to the city's pollution and congestion.

The Problem in Summary, and Solutions

The multi-faceted problem as can be seen, is that the solution offered to mitigate the elitist nature of government education through distance education, is vitiated, particularly for women and the poor and more particularly in the physical sciences where women do especially badly, by the necessary laboratory, quiz and examination components that cannot be offered in distance mode.

The solution we have come up with is as follows:

1. Use web-based teaching[6] so that students, communicating over the Internet, do not have to come to meet their teachers. Further, the attendant peer-interaction over the network will diminish the prospects of failure.
2. Redesign traditional experiments so that they can be done at home through home-kits[7] and thereby obviate the need to come to a central campus for laboratory sessions.
3. Use the opportunity of using the web to make women computer literate[2].

Web-teaching

When the web is used as the medium for delivery, the advantages may be summarized as follows[6]:

1. The use of colour, animation and sound makes the pages and their layout much more user-friendly and attractive than the usual black and white pages of a textbook.
2. The use of email and bulletin boards enhances communication between the teacher and students and even students and students. The absence of such repetitive and unscheduled communication (as possible in a conventional system) is one of the principal reasons for the high failure rate in external degree studies.
3. The use of the Internet for communication obviates the necessity of students having to come to the central campus for consultations and laboratory work, thereby easing the burden on the city and the university and their services.
4. The ability to correct mistakes in the text quickly whereas paper-based teaching material is very difficult and costly to update and must usually await the next edition.
5. Students receive enhanced writing experience since interactions through speech are replaced by email.
6. Since one CD can fit at least 10 textbooks, CD-based distribution of course material is much cheaper than the distribution of paper-based material (in terms of both cost of material and cost of postage). The incremental cost of the increased use of the Internet is negligible because universities provide e-services now and the main cost is in the capital outlay.
7. Paper-based material is difficult to get across because of postal delays and the war on in Sri Lanka. Internet-based delivery is immediate and more reliable.

An on-line examination system has also been developed so that many of the examinations may be conducted without students having to come to the centre[8]. The same on-line system has also the facility to be used by students for purposes of self-assessment.

We have taken one course in the curriculum, Analytical Chemistry, which is of use to most science and chemical engineering students and converted it for web-delivery. Chemistry is considered to be the most environmentally polluting subject. It has been run at the Open University in parallel with the textbook-oriented traditional version of the same course, using only students who volunteered to try web delivery. All those who tried it, based on surveys, were extremely pleased with their experience.

The web-based courses Applied Chemistry for Chemical Engineers and Food Chemistry, neither yet offered by the regular means of delivery, are nearing completion of development.

Green Chemistry and Practical Home-kits

The purpose of practical home-kits is to allow traditional laboratory experiments to be done at home. The experiments are re-designed with safety and environmental consciousness in mind so that the experiments may be done at home in safety using easily available materials and equipment.

To enhance an environmental consciousness and give access to remote students, green practicals are developed that can be performed within the home but demonstrating the same principles as with conventional laboratories.

The home-kit consists of those materials and chemicals not available at home[7]. For example, phenolphthalein which is used as an acid-base indicator is replaced by flower extracts of *gloriosa superba* (morning glory) or *rosa sinensis* (shoe flower) either of which is easily available and can be used as an acid-base indicator. Potassium iodide which has no easy replacement is given in small measured quantities with the kit. Likewise, test-tubes, filter paper, etc. are supplied.

To describe briefly an experiment from engineering, a continually stirred tank reactor is traditionally used for calculating the percentage conversion of a process. But in the home-kit to study urea hydrolysis at various temperatures, the same thing is done with a toy motor after which the ammonia produced is taken up in battery acid and titrated with caustic soda. Similarly, a model with a manually rotated coconut scraper is used to emulate a centrifugal pump.

Now in a traditional lab, instructors are present to help the student. To give suitable directions for the home experiments, they are done, photographed and/or filmed with a digital camera and placed on the web (or, alternatively, on a CD) with suitable voice and text directions step by step. Color changes and such other things as may require noting, are highlighted and pointed out to the students.

Women and Rural Folk: Bridging the Digital Divide

The web-based course was used to give access to computers to women and rural folk. Working with the Director for the Regional Educational Centres of the Open University, computer clusters were made available at some 20 regional and study centers spread country-wide. Where there was no Internet access, CDs were used with web-pages.

The Central Campus also had a LAN network built by raising funds for the joint purposes of web-teaching and EMIS implementation. In Sri Lanka where not every Lecturer has a desk-top computer, the Vice Chancellor promised a machine to every one who would go for web-delivery. Computer clusters were used to give students access to the Local Area Network though which faster LAN access to the web-pages on the authors' PCs was possible.

Those who used the web-pages enjoyed it immensely. There was a clear personal enhancement of self-image as those who used the web felt modern and had things to chat about. Enrolling for web-based courses was also an excuse for gaining access to computers.

After moving from the Open University to the University of Peradeniya where one of the authors established a new program in computer sciences, gender equity was pushed more vigorously using NECUSE guidelines[9]. To increase access to machines, computer laboratories were kept open to midnight (whereas all laboratories traditionally shut down at 4 PM). Women were given priority bookings at terminals so that they would not need to come at night. All staff were instructed to follow the NECUSE guidelines in teaching – such as looking out for women with questions at the terminal but shy to ask the male instructor, giving a minute after asking a question in class before accepting answers so that women would have a chance to orgnanise their answers in their minds and so on. For the first time, final year projects were introduced and, as expected, the female students who are comfortable in informal sessions, participate comfortably and interact with their teachers better as suggested by NECUSE.

As a result, from the first computer sciences batch of 20 with no female, we have now gone to the third batch of 30 with 4 women.

Conclusions

A combination of web-based teaching, practical home-kits for redesigned experiments and on-line examiners can be effectively used to push distance education as an effective alternative to conventional education with diminished dependence on the capital cities and an easing of the environmental burden (including transport, water and other services at such cities). The process is very rewarding as the poor, the working, and housewives and women benefit immensely as the playing field is leveled. The home kits can be pushed to promote green-chemistry and stress environmental safety standards which tend to be neglected in the poorer countries.

Much of the software and data-banks of questions is made available at the Distance Education Project under the web-site of the Computer Sciences Department, Faculty of Engineering, University of Peradeniya (www.cs.pdn.ac.lk).

References

1. UNESCO, *World Education Report: Teachers and Teaching in a Changing World*, Paris: UNESCO, 1998.

2. Dushyanthi Hoole and S. Ratnajeevan H. Hoole, "Women Engineers in Sri Lanka", *Society of Women Engineers*, Volume 47, No. 6, pp. 51-57, Oct./Nov. 2001.

3. UGC, Annual Reports, Colombo: University Grants Commission, Ministry of Higher Education, Govt. of Sri Lanka, 1984-1994.

4. P. Rajapakse, Lal Jayawardene, Gaya Cumaranatunge and S.R.H. Hoole, Information Technology and what it can do for Sri Lanka, C11, Proc. Annual Conference of the Sri Lanka Assoc. for the Advancement of Science, SLAAS, Paper No. C11, 1997. See also: P. Rajapakse, Lal Jayawardene, Gaya Cumaranatunge and S.R.H. Hoole, "The Report of the Presidential Taskforce on making Sri Lanka a Communications Hub," National Development Council, Colombo, 1997.

5. Ministry of Education, *Statistical Handbook*, Colombo: Ministry of Education, Govt. of Sri Lanka, 1999.

6. Dushyanthi Hoole and S.R.H. Hoole, "Web-based Teaching: Infrastructure Issues in the Third World", in A.K. Aggarwal (ed.), *Web-Based Learning and Teaching Technologies: Opportunities and Challenges*, Chapter III, pp. 33-41, Hershey, USA and London: Idea Group, Jan. 2000.

7. Dushyanthi Hoole and M. Sithamparesan, Chemistry Practical Home-kits with CD-based Instructions for Distance Undergraduates, *J. of Chemical Education*. Accepted subject to revision.

8. Dushyanthi Hoole, N. Yogendran, S. Thavachandran, P. Pryatharshan and S. Ratnajeevan H. Hoole, "A Bank of Chemistry Questions on an On-line Server," *Journal of Science Education and Technology*. Vol. 11, No. 1, pp. 9-13, 2002.

9. NECUSE, 1996, The New England Consortium for Undergraduate Science Education, "Achieving Gender Equity in Science Classrooms" A Guide for Faculty," Rhode Island: Office of the Dean of the College, Brown University.

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