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Creating Virtual Universities*

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Distance learning and the term *virtual university* have become commonplace during the last few years, primarily due to the rapid advances in, and the convergence of, computing and telecommunications technologies. Text-based correspondence programmes and open universities have been around for many decades, leading to the adage *learning, any time, any place*. However, most of these programmes have played a minor part in the higher education system, especially in science and engineering education. Now computers, CD-ROMs, DVDs and the Internet promise to change higher education dramatically and forever. Numerous groups are either talking about or have already begun implementation of virtual university programmes. Before undertaking such a development many questions need to be addressed. This paper introduces a set of these questions and provides the answers for one particular model that is described in some detail: the National Technological University, a satellite television network-based educational system. The questions are then addressed for other possible models for different audiences, using different technologies, etc. In addition, contrasts are made between private and state funded (subsidised) institutions.

INTRODUCTION

Education is increasingly coming under pressure to be more accessible, more flexible, and less expensive. This is true for primary, secondary and even higher education. Increased accessibility has led to numerous *open universities*. Examples include the British Open University, the Dutch Open University, the University of the Air in Japan, and many others. Most of these have been developed to meet the needs of one country. However, now we are beginning to hear discussions of regional open universities, such as the Arab Open University. It needs to be seen whether or not education can be made significantly less expensive. Education, at least to this time, has been people intensive and the costs are directly proportional to the cost of professional teaching labour. Flexibility has been attacked in a number of ways: non-traditional hours, such as weekend or evening classes, the increased use of technology, such as videotape, satellite television broadcasting, teleconferencing, and now the Internet and World Wide Web. In many ways, the increased usage of technology may aid both flexibility and accessibility through its use in supporting distance education.

Distance learning and the term *virtual university* have become commonplace in the last few years, primarily due to the rapid advances and the convergence of computing and telecommunications technologies. Correspondence programmes and open universities have been around for many decades, leading to the adage *learning, any time, any place*. However, most of these programmes have been a minor part of the higher education system, especially in science and engineering. Now computers, CD-ROMs, DVDs, the Internet and the World Wide Web promise to change higher education dramatically and forever. Before beginning the discussion of the creation of virtual universities, a brief history will be provided.

The history of university-based distance education in the United States is very interesting. Technology has always been an active element of this distance education process, ranging from the use of the traditional postal system to the Internet and the World Wide Web. In fact, one of the most significant problems has been the over emphasis on technology and the under emphasis on basic educational processes, except perhaps for correspondence courses using the postal system. Many times technology has been a solution in

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search of a problem rather than the natural consequence of a prescribed educational model.

Text-based or reading correspondence courses have been popular additions to many college programmes. However, most of these courses are not professionally oriented. Rather they support leisure learning or meet general educational requirements allowing students to obtain college credits for independent study. In this case, the traditional postal system is the technology used (some might argue that the postal system is not a technology), although equivalent courses are now appearing on the Internet, that is, pure text-based courses where either the major readings or supplemental readings are posted on the World Wide Web. A first step up from these text-based courses is courses based on the use of software packages, such as mathematics courses using Mathematica, Maple, or other software systems.

With the advent of television, a few visionary educators hailed the beginnings of a new era for education. Many universities experimented in the 1950s and 1960s with the use of television, especially for teaching large classes on campus. Universities constructed local cable television networks for cable television delivery to individual classrooms all across the campus. Master teachers prepared material for viewing by on-campus students in classes led by graduate teaching assistants. The results from these efforts were mixed. Usually the efforts were driven by university administrators in the hope of saving money, not by faculty, and certainly not by the students. Most universities had abandoned these efforts by the 1970s. Engineering schools did not experiment with this application of television because very large classes did not exist within engineering programmes. On-campus television was useful, however, because the measurements of learning outcomes showed convincingly that television education was effective even if not liked by the students. It should be pointed out that many of the same funding discussions are resurfacing again with arguments in favour of using the Internet and the World Wide Web for course delivery.

In the late 1960s, US high technology firms pressured engineering colleges to provide practising engineers with access to postgraduate education. These businesses wanted this education because they realised that the future of the organisation relied on the technical expertise of its employees. They also wanted the education delivered to the engineer at the work site because the costs due to time away from the job of the working engineer to attend a local institution were too high and in some cases there were no local institutions even available. Large corporations were willing to commit resources to establish distance learning programmes and to reimburse the practising engineers for their educational costs. A number of colleges responded to this need, and to this day, distance learning for engineering education continues to lead the development of the use of educational technology in the US.

By the 1970s, Instructional Television (ITV) using microwave delivery systems or videotape delivery had become widespread because it was simply based on televising the traditional on-campus lecture classes. This format allowed instructors to continue using their basic teaching/lecturing methods. Instructors did not have to learn how to create new and different learning material in new formats - an extremely important but often overlooked issue, particularly for faculty who are engaged in significant scholarly research, it turns out.

In the early 1980s, the next step was ready to be taken using a live satellite television network to reach a national and even international audience. No single university seemed ready to accept the challenge, so a new university model emerged.

NATIONAL TECHNOLOGICAL UNIVERSITY

The National Technological University consists of three parts: product suppliers, customers, and an advanced technology satellite television network. The product suppliers are mainly established, traditional universities; the customers are sponsoring government, industry and university organisations.

The National Technological University (NTU) is a private, non-profit institution established in January 1984 to serve the advanced educational needs of working technical professionals and technical managers. NTU is licensed by the Colorado Commission on Higher Education and accredited by the Commission on Institutions of Higher Education of the North Central Association of Colleges and Schools, and may award degrees in the United States, Canada, Mexico, Asia, Australia, and the Pacific Islands. Accreditation was granted with NTU's first graduate in October 1986.

NTU is not a traditional university; it delivers Master's degree academic courses and non-credit short courses directly to the working professional's place of employment. The academic courses are simulcast, or telecast in taped delay format, from any of NTU's 51 participating universities. The participating universities are Arizona State University, Boston University, Clemson University, Colorado State University, Columbia University, Florida Gulf Coast University, The George Washington University, Georgia Institute of Technology, Kettering University, Illinois Institute of Technology, Iowa State University, Kansas State Uni-

versity, Lehigh University, Massachusetts Institute of Technology, Michigan State University, Michigan Technological University, New Jersey Institute of Technology, New Mexico State University, North Carolina State University, Northeastern University, Oklahoma State University, Old Dominion University, Purdue University, Rensselaer Polytechnic Institute, Southern Methodist University, The University of Alabama, University of Alaska at Fairbanks, The University of Arizona, University of California at Berkeley, University of California at Davis, University of Colorado at Boulder, University of Delaware, University of Florida, University of Idaho, University of Illinois at Urbana-Champaign, University of Kentucky, The University of Maryland at College Park, University of Massachusetts at Amherst, The University of Michigan, University of Minnesota, University of Missouri-Rolla, University of Nebraska-Lincoln, The University of New Mexico, University of Notre Dame, University of South Carolina, University of Southern California, The University of Tennessee-Knoxville, University of Washington, the University of Wisconsin-Madison and Vanderbilt University. The universities are both private and public, large and small. Non-credit courses originate from universities, professional societies, and for-profit companies.

NTU draws upon its 51 participating universities for more than 1400 graduate courses, enabling NTU students to pursue programmes of study leading to thirteen MS degrees: chemical engineering, computer engineering, computer science, electrical engineering, engineering management, environmental systems management, health physics, management of technology, manufacturing systems engineering, materials science and engineering, software engineering, transportation systems engineering, and a unique special majors programme that allows students to tailor the NTU course offerings to meet specific needs such as aerospace engineering, mechanical engineering, optical sciences, telecommunications management, etc. In addition, NTU offers a unique International MBA degree. Note that three of these degree programmes are management related: engineering management, management of technology, environmental systems management; and one is a business degree, the International Master's in Business Administration.

NTU's vision simply stated is *to enable technical professionals and managers to share premier educational resources globally via telecommunications*. Annually, NTU offers nearly 500 academic courses for a total of 23,000 video broadcast hours.

Today, the delivery system is based on compressed digital video technology and provides up to twelve simultaneous television channels on GE 3 over North America and one channel to the Asia Pacific region using PanAmSat 2. NTU is the largest and most advanced engineering education delivery network for distance learning in the US. But, NTU is not an open university, nor does it support *any time learning*.

NTU is accessible to working technical professionals and managers employed by those organisations committed to staff professional and career development. Those employers pay a one-time fee to have access to the educational resources available over the NTU Network, install the necessary equipment to receive the satellite signal, and provide administrative support for the participants.

Among those organisations that have subscribed to NTU on a corporate-wide or agency-wide basis are Alcoa, AT&T, Eastman Kodak Company, EI du Pont de Nemours & Company, Exxon Corporation, General Electric Company, Hewlett-Packard Company, Honeywell Inc, IBM, Intel Corporation, Lockheed-Martin Corporation, Motorola Inc, NASA, Pacific Bell, Polaroid Corporation, Tektronix Consolidated, Texas Instruments, Raytheon, Federal Highway Administration, and the US Departments of Defense and Energy.

Perhaps the most surprising aspect about NTU is its size. NTU employs only nine full-time staff in Fort Collins, Colorado. The staff is divided into administration, which includes the president's office, admissions and records, and the finance office. NTU has been described as the *walkman* of the world's universities, just big enough to get the job done. The operations are highly automated, with more computers than personnel. NTU has been actively engaged in creating an electronic image as more and more of its information and procedures are made available through the Internet. NTU's universal resource locator is http://www.ntu.edu

NTU's participating universities are equipped with instructional television classrooms and compressed digital video uplinks by which they transmit on-campus classes to the NTU Ku-band transponder (Transponder 10) on the GE 3 satellite. GE 3 is located at 87 degrees West Longitude, 22,600 miles above the Earth's equator. The transponder supports up to twelve simultaneous compressed digital video channels. It is estimated that the university investment is about US$10 million. More than 240 corporations and government agencies receive NTU courses at more than 700 individual work locations. Half of these locations are capable of receiving the classes direct by satellite and the other half are served by interconnected video networks. For example, the Illinois Satellite Network interconnects the University of Illinois at Urbana–Champaign with thirty two community colleges within the State of Illinois. As another example, NTU's non-

credit continuing education courses are rebroadcast on the Stanford Instructional Television Network through its microwave distribution system in the Bay area of California.

QUESTIONS TO CONSIDER

When NTU was founded the following set of questions was asked. In hindsight, these or a similar set of questions should be asked anytime that a new distance education or *virtual university* is contemplated. The questions are:

- Who are the target learners?
- What are their needs?
- Who will be the education providers?
- Who will be the stakeholders?
- How will the instructional material be handled?
- What is the appropriate delivery technology?
- How will this be financed?
- What will be the support mechanisms?
- How will the endeavour be evaluated?

One of the important items to notice in the list above is that the *what is the appropriate delivery technology?* is far down the list and is only one small part of the process. Many groups seem to start with the technology and then build the rest of the organisation around the selected technology, rather than addressing the educational goals first and then choosing an appropriate technology.

Who were NTU's target learners?

From the very beginning, NTU's targeted learners were full-time, working technical professionals and managers employed in industrial, government and university locations. Because these people are both busy and highly mobile, conventional campus-based continuing education does not work for them. In reality, they may be the organisations' most valuable employees and providing continuing education must fit within their often hectic work and travel schedules. Any continuing educational opportunity must be extremely *flexible* to meet their needs.

What are the targeted learners needs?

These adult, technical professionals need both technical and managerial education and training. In order to have career security and growth opportunities, these adults continually need to refresh and update their skills. Both for-credit and non-credit courses may fulfil these needs. It is important to note that the targeted learners are working technical professionals and, therefore, already have achieved at least the entry-level degree necessary for their employment. In the United States this means a Bachelor's degree as a minimum, although many NTU students have received more advanced degrees, such as a Master's or even doctoral degrees, and have found that their careers have taken an unforeseen path now requiring new information and knowledge. An example might be a physicist now supervising a software development group.

NTU's plan was to offer MS degrees in technical fields in engineering and computer science for the young BS graduate. As the graduate progressed through his or her career, the next educational opportunity is for a technical management degree, perhaps, in engineering management or the management of technology. Following this step, NTU now offers a pure business MBA degree for those managers who move into general administrative business areas, such as CIO, CFO, COO and CEO positions. In a recent National Science Foundation report it was found that engineers with both an advanced degree in engineering and an advanced degree in business were twice as likely to become senior managers than engineers with just an advanced engineering degree [1].

Who are the product providers?

In the case of for-credit, academic course offerings, engineering colleges and institutes were chosen as the primary providers for engineering courses, and business schools were chosen as the primary providers for management and business courses. The decision was made not to go into competition with the traditional universities for academic courses, but to leverage their investment in video production and experience and to use their facilities, such as *candid* video classrooms, broadcasting studios, etc. Universities would join the NTU network and use NTU to distribute their courses to the full-time, working technical professions. For non-credit short course offerings, colleges of engineering; professional societies such as the American Society for Mechanical Engineers (ASME), the Institute for Electrical and Electronics Engineers (IEEE), and others; corporations; consulting companies; government laboratories; and NTU itself, are all providers.

Who are the stakeholders? Who has to *buy-in* for success?

In order to provide the product, deans, faculty, and customer executives must become stakeholders. In this case, top-down support was absolutely necessary

for success. The idea was to use traditional faculty at participating universities for all course offerings; that is, NTU would out-source education. The primary reason for this decision was the short shelf life for postgraduate courses. Postgraduate courses change so rapidly that the cost of developing stand-alone material was thought to be prohibitive. No up-front investment for faculty work would be required. The participating university would bear the cost of continually updating the courses and paying the faculty for teaching the course to on-campus students. Thus, the offerings would remain fresh. This decision would establish NTU as the world's first *virtual university*.

Who will integrate instructional material?

Again, NTU's decision was to have faculty have the control over any programmes offered. NTU established a traditional faculty committee governance structure; however, the faculty are decentralised, representing all the institutions involved. The academic organisation is headed by an Academic Executive Committee made up of the chairpersons of thirteen Graduate Faculties (the Special Majors programme is chaired by the NTU Academic Vice President). A Graduate Faculty is organised for each discipline in which a degree is offered. The Graduate Faculty for each discipline is organised to provide the major academic functions usually carried out by departments and faculty in traditional institutions. Normally each of the Graduate Faculties has organised a Curriculum Committee which develops the programmes of study, reviews and approves or disapproves all courses submitted by participating institutions, and recommends course additions, deletions and curriculum changes at meetings held each year. The Graduate Faculty provides organisation, continuity, and quality control to each academic discipline. Graduate Faculty members are selected, in accordance with criteria set by NTU, by the relevant dean of the participating institution and recommended to the Academic Vice President of NTU who makes the appointment. They are chosen from senior faculty well respected by their colleagues. Teaching faculty are usually chosen from the participating universities' faculties and have considerable experience teaching remote students using television technology.

What is the appropriate delivery technology?

Television was the technology of choice. The decision was to use satellite television broadcasts directly from the originating university, that is, to simulcast the class as it was happening on the campus. Hence, the NTU students are simply remote students in a regularly scheduled on-campus class. The students at the remote sites use their video receiver environment as a *virtual classroom*. The major problem with the decision to use satellite television in 1984 was its high cost. To lower the operational fixed cost, NTU pioneered split transponder technology in 1985; that is, NTU was the first organisation in the world to broadcast two analog television channels on one transponder, thereby halving the cost of each broadcast hour. This early pioneering of technology carried over into 1991 when NTU became the first user of compressed digital video technology and today delivers twelve simultaneous channels on one satellite transponder, a six-fold increase over the use of split transponder technology used in 1985. Thus, NTU continues to lower the cost of satellite broadcasting.

Another question related to the delivery technology concerned whether to design, build or contract for the delivery system. NTU decided to build its network and contracted for satellite transponder time for the lifetime of the satellite to lower costs. NTU is currently operating on its fourth satellite. It began broadcasting on GSTAR 1, but that satellite's life ended in 1992. NTU then signed a lifetime contact on AT&T's Telstar 401. In January 1997, Telstar 401 failed catastrophically in what was the world's first total communications satellite failure. NTU quickly negotiated a short interim contract with SBS 5 and operated on this satellite from February to October 1997 when GE 3 became operational. NTU now has a for-the-life of the satellite contact for one transponder (Transponder 10) on GE 3.

Unlike commercial broadcasting systems, the NTU network is fully decentralised with uplinks at each participating university and downlinks at every customer site. Network control is operated from NTU's headquarters in Fort Collins, Colorado, with backup at the University of Arizona in Tucson. In December 1993 NTU contracted with PanAmSat to broadcast one compressed digital video channel into the Asia Pacific region twenty-four hours each day, throughout the year. The extension into Asia allows NTU to broadcast two non-credit short courses five days a week and as many as twenty academic for-credit courses each of three terms per year. MS degrees may now be earned in electrical engineering, computer science, and engineering management, and an international MBA degree is also offered. The international MBA degree programme was initiated in January 1998 and is the first NTU degree programme with participating universities from outside the United States.

In 1990 NTU joined the Internet. For the first

three years the primary activity was electronic mail, but in 1995 the explosive growth of the World Wide Web greatly facilitated NTU's distribution of on-line information, admissions and registration. The Internet enhances both student-to-student interactions and student-to-faculty interactions. The Internet flexibly supports asynchronous interactivity, nearly eliminating telephone interaction or fax transmissions. Again, for the working professional this mode of interaction is the way they now conduct business in a highly interconnected world operating over twenty-four time zones daily. It is not uncommon to find engineering design groups with components on three continents communicating via the Internet and the World Wide Web.

How was the system to be financed?

Because the decision was made to make NTU a private, non-profit institution, state and federal funds were not available for start-up costs. This meant that other forms of financing would be necessary. One-time access fees were invented to provide the necessary start-up funds and continue to provide operating funds not covered by the pay-per-view income. The existing know-how in the local and regional ITV systems at the participating universities was also available, resulting in little training costs necessary to broadcast nationally and even internationally. In other words, the instructional television history and experience that the participating universities brought with them was used to keep start-up costs of NTU very low. Each participating university had previously used ITV to reach their local and regional businesses and government agencies.

NTU joint ventures with universities and other producers by sharing revenue. Copyright remains with the originating producer. NTU markets and administers the courses. Typically, NTU passes about 55 percent of the revenue to the producer. The universities pay for their support staff of television engineers and their local operating costs from their revenue. In other words, the producers are required to cover all costs to get the signal up to the satellite. NTU then covers the costs for administration, marketing, billing and the satellite. The customer pays for local site support and local site administration. All maintenance is handled by each site whether producer or customer, although NTU will do this on an individual contract basis.

In a move to provide additional resources to pursue advanced technology for telecasting its courses and for improved customer services and marketing, NTU created, on 1 July 1998, an affiliated for-profit company, NTU Corp. One of the new company's goals is to provide for a replacement technology for the original compressed digital video system in use from 1991 through 1999. Advances in consumer electronics now permit very inexpensive television receive installations, such as those used by the Direct Broadcasting Services industries like Primestar, Hughes DirecTV, Echostar, etc. In 1985, when NTU began satellite broadcasting, a receive site cost $25-30,000. Today, using the new technologies, a receive site can be purchased for $5-800. However, changing to this new technology requires an investment of more than $4 million.

Marketing has also been seen as a limitation to NTU's effectiveness. As a traditional university, NTU spent in the order of 3-5% of its revenue on marketing and customer support. In today's world this is inadequate. In order to raise the needed funds to pursue new technologies and better and more effective marketing, NTU sold a minority position in NTU Corp to Olympus Partners, Stamford, CT.

As a part of this restructuring, NTU also signed a services agreement with NTU Corp to be an outsource for managing and operating the satellite network, customer services and marketing, finance, data processing support, and the non-credit short course offerings. The role of the university has returned to academic oversight and control of the academic administrative processes associated with the accredited university. Approximately thirty-five employees were transferred to NTU Corp.

What are the support mechanisms?

When an organisation joins the network, they are required to name a local education site co-ordinator. This person acts on behalf of NTU at the site but they are normally paid by the sponsoring organisation. The education site co-ordinator is responsible for approving student registrations and for interacting on behalf of the university for course assessment by proctoring examinations, when required. Arrangements were also made with a company to be NTU's bookstore to facilitate students getting appropriate textbooks and published notes in a timely fashion. At NTU's headquarters, central administration and satellite network control were established. NTU maintains the students transcripts (grade records), awards credits and grants degrees. Nearly all of NTU's students are on a full tuition reimbursement programme, that is, the employer pays for the student's education and is considered a benefit. This is true of academic students only. Non-credit training courses are usually budgeted for by the student's management team or centrally within the organisation.

How will the endeavour be evaluated?

NTU has instituted ways of gathering information on an on-going basis so that problems can be addressed in a timely fashion. One procedure of this kind is the use of a *squawk card,* which NTU instituted in fall 1986. Until 1994, double postcards were sent to all enrolled students to elicit information about video and audio quality and about instructor's visuals and handouts. In 1994 the mailed *squawk cards* were replaced with an electronic mail version called the Student Early Warning system, which permits much more rapid response to student inputs. For example, the email message is sent in seconds, the response returned in seconds, and problems can be immediately routed electronically to the appropriate and responsible organisation or individual. This use of the Internet has taken days off problem resolution and response results, and is an example of NTU's continuous quality improvement of the delivery process.

NTU contracts with F&W Psychometric Consulting Group, in West Lafayette, Indiana, to conduct an evaluation of all academic courses offered each year. This evaluation programme began with the first enrolments in fall 1984. The most recent report covers the 1997-98 school year. Survey instruments are sent to all students, site education co-ordinators and course instructors. A spin-off from the F&W findings and recommendations is the *Instructional Systems Assessment Report* on which Outstanding Instructor Awards, identification of poor instructors, and identification of weak sites are based.

NTU has always made it a practice to act on evaluations. For example, instructors ranked in the bottom 20th percentile are quietly dropped from the network. This mechanism provides openings for new instructors and even new participating universities. NTU currently has one of the world's largest databases of faculty evaluations and annually awards up to twenty outstanding teacher awards to those so selected by the students.

In addition, NTU accumulates the grades of the on-campus students in each of the courses offered. This permits NTU to compare the grades received by the NTU students with the grades received by the on-campus students in the same class. Over NTU's history, NTU's students have consistently outperformed their on-campus peers by 0.3 grade point average or higher. Why is this? Maturity and motivation are certainly key factors, but it does prove that televised learning for engineering education for working adults is effective and distance learning for these students is efficient, flexible and meets their academic needs. Anecdotally, nearly all 1271 NTU graduates, to date, express themselves by stating that except for NTU they would not be obtaining a Master's degree. This indicates that NTU attracts students who otherwise would not be continuing their education. Direct delivery to their place of employment is the key idea that enables them to continue to learn while maintaining a full-time job with all its inherent responsibilities.

The next obvious extension of this model is direct delivery to the home or small office. Low cost, small antennae coupled with personal computers offer the possibility to take compressed digital video to the home. NTU is currently working on an MPEG 2/DVB broadcasting system, featuring 90 centimetre dishes and commercially available set-top boxes for decoding. The total installation price should be in the order of US$600. This should be compared to the original television receive station cost of US$25000 in 1984 when NTU was founded.

In many ways, NTU is a model for non-traditional education. NTU draws on existing infrastructure, and leverages faculty productivity in an era when these are important considerations. Because of the high cost of postgraduate engineering education, we may see traditional universities de-emphasise MS education on campuses, preferring to concentrate on the Bachelors and Doctoral programmes. This, in fact, may already be happening at a few progressive universities by increased sharing of graduate courses. It will be interesting to see if other postgraduate programmes, such as teacher training, law, medicine, journalism, etc, follow in the footsteps of engineering.

OTHER MODELS

In re-examining the nine questions posed during NTU's formation, other responses were possible. For example, the target audience need not be full-time working technical professionals. Choosing a different audience could affect nearly all the responses. Non-working adults might be the audience. Undergraduate students could be another possibility. Distance education has been shown to be effective for nearly any age, but the more maturity the students have, the better the acceptance. And, of course, engineering does not have to be the target discipline. Virtual universities offering teacher training, public health, law, or many other disciplines can easily be conceived. However, beware of thinking of distance education as a panacea for education's many ills, such as high and expanding costs, lack of trained teachers, or building and operating budgets.

NTU chose to use existing faculty in traditional participating universities. A different model results if faculty are hired as consultants to develop courses that the delivering organisation then owns or pays royal-

ties for. Be careful of course shelf-life. Even undergraduate engineering and computer science courses may have only a few years of useability without major redevelopment, resulting in a different cost model.

Delivery technology is another important consideration. Many organisations are caught up in the Internet and World Wide Web frenzy. It is an exciting technology, but again it has limitations and is not the ultimate technology answer. High quality streaming video demands at least 500,000 bits/second of bandwidth and the quality is much improved at speeds approaching 1,500,000 bits/second. Streaming audio and static graphics, so-called *talking tablet* technology, works successfully through current telephone lines and modems. Pure text courses may also utilise this technology. We may see a number of such initiatives in the coming year. NTU plans to offer a global Master's degree in Information Technology Management only via the Internet beginning in August 1999. Courses will be unbundled with instruction, tutoring and assessment individually priced. Students will be able to begin the programme at any time, but they will have time constraints on finishing a course, probably a maximum of four to six months. Course development will be contracted by NTU to individual faculty, but the university will also share in the revenue in order to support keeping these courses fresh.

Financing is a major issue. NTU is a private, non-profit institution and suffers from the lack of capital for investment. In hindsight, NTU should probably have been created as a for-profit entity, but this would have been unfavourably received at the time. Universities were either private, non-profit, or state supported in the United States. The picture has altered today. Education, just like health care, is undergoing a revolution in the US. For-profit institutions are expanding at a great rate and old ideas about profit and non-profit are being challenged. Today, the fastest growing university in the US is a for-profit organisation, the University of Phoenix.

State or federal support of distance education means that education is once again subsidised. Such programmes may or may not be better off. If a plan is not built that successfully continues the operation and growth of a virtual university, when funding declines or disappears, viability may be jeopardised. Clearly, successful and continued funding is a key criterion for operation.

SUMMARY

What lessons can be learned from the NTU experience that other virtual universities can draw upon? A few may be briefly summarised here. Set the objectives and design the system to them. Flexibility and response times are key success factors. Decentralisation keeps central administration small. NTU has only nine full-time employees and NTU Corp has 44 full-time employees, yet these two small organisations contain all the features of a traditional university; plus NTU Corp operates a very sophisticated satellite television network. Do not underestimate the human and organisational issues: NTU expends a great deal of energy and resources working directly with its providers and customers to be as responsive as possible, yet it could devote even more if resources were available. However, when dealing with 51 participating universities, over 90 non-credit producers, and 250 sponsoring organisations with over 1200 receive sites, it is easy to be overwhelmed. Do not be intimidated by the technical and organisational challenges. In NTU's case, the customer provides sponsor site management and the user is the learner. The good news is that distance education fits the way adults live and work much better than traditional education/training models, but the design must offer flexibility for the adult learner and their work interactions. And finally, continuously adjust to changing conditions by focusing on job skills and needs which are changing at a phenomenal rate. New careers come into existence daily, it seems.

As more alternatives to education are explored over the coming years, distance education will increasingly play a larger role. However, distance education is not the answer to all of education's ills. Distance education must be closely matched to the needs of the students it serves. In the case of NTU, the continuing education of mature, technical professionals falls easily within the realm of distance education. These people are busy and highly mobile and they are mature enough to deal with the issues and complexities of distance education.

The future of education in the world seems to be under attack in ways that ultimately will affect the overall quality of life for everyone on this planet. Nations must recognise that their human resources are their most valuable resource. Creativity and the ability to turn ideas into reality are the hallmarks of engineering. This group of individuals has created much of the world's wealth. Faced with issues of self-sustainability while creating an increased quality of life for all will require unparalleled and unmatched innovation and creativity. Such goals will only be achieved by *first class* educational opportunities for all mankind. Nothing else will suffice.

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BIOGRAPHY

Dr Gearold R. Johnson is the Academic Vice-President of the National Technological University (NTU) in Fort Collins, Colorado. He holds a BS in aeronautical engineering, an MS in engineering, and a PhD in mechanical engineering from Purdue University. He joined NTU in July 1994. Dr Johnson spent 23 years on the faculty at Colorado State University (CSU) before joining NTU. In the ten years before his retirement from CSU in 1994, he held the George T. Abell Endowed Chair in Engineering, Colorado State University's first endowed chair. He was a NATO postdoctoral fellow at the von Karman Institute for Fluid Dynamics in Rhode-Saint-Genese, Belgium. He has been a visiting professor at the University of Kent in Canterbury, England, and the California Institute of Technology in Pasadena, California. Dr Johnson also spent a year as a visiting researcher at Shape Data Ltd in Cambridge, England.

Dr Johnson is Co-Editor of *Computing: Archives for Computing Science,* published by Springer-Verlag, and Assistant Editor of the *International Journal of Computing and Software Engineering,* published by Ablex Publishing. Dr Johnson is a member of the International Committee on Engineering Education (ICEE) that advises Dr Federico Mayor, Director- General of UNESCO, Paris, France. His research interests over the years have focused on computing environments to assist engineering analysis and design, technology in support of engineering education and embedded control systems.