## COMMITTEE 1 REPORTS: COMMENTS BY CHARLES SHEFFIELD

**OVERVIEW.**

Taken together, the individual papers of this committee lead to a general conclusion regarding the next generation of information technology, research, and teaching.

The general trend, as has been several times remarked, is away from supply-driven and toward demand-driven programs and services. The infotec of the next century will thus largely be provided in response to market forces. However, that implies that the biggest markets will dictate the main direction of technology development. Small users (small market segments, or geographical areas low in population or resources) will be as badly off as they are today, since they will in practice remain as supply-driven segments. The infotec available to them will be that which best matches not their own needs, but the needs of the largest demand customers.

Can we already see examples of this, in today's infotec? I will suggest one. Users with text-based or mathematical applications often gain little from icon-based displays and graphic interfaces. Such interfaces also have a high cost in terms of required machine speed and storage. However, the ubiquitous WINDOWS is assumed by much of today's PC software. The text-based or mathematical user, like it or not, must live with the software manufacturers' response to the larger number of icon-based users.

The counter to this is that, without a large number of users, software development costs would be prohibitively high. It cannot be denied that the key to low software prices is large numbers of users (I can remember when a payroll program, available now for $100 on a PC, cost $50,000 for a main-frame implementation). At the same time, software tuned to the needs of small market segments or geographical regions may never be developed in the demand-driven infotec economy directed to serve the largest users.

I now offer my thoughts on the committee papers. I do not have significant comments on all of them, partly because several papers often seem to call for the same comment. Also, if my remarks become shorter as I proceed, it is because I do wish to be repetitive.

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### THE UNIVERSITY IN THE TWENTY-FIRST CENTURY
### by Richard L. Rubenstein.

I found this paper totally persuasive. It suggested to me the following thoughts and questions: In the past, universities could be regarded as "supply-driven" institutions, in that they offered a limited selection of course options and students took those or they took nothing. However, if most universities, other than the oldest and most elite ones, in the future become increasingly "demand-driven" by student and corporate needs and desires, they are also likely to become more specialized. How then can the quality of graduates be compared?

Fifty years ago, it was meaningful to provide a ranking of universities and to accept some fair correlation of graduates with the schools from which they came. That may no longer be true, today or in the next century. I'm not sure that a degree in MacDonald can be compared with a degree in Disney or even Burger King, or that any such degree tells a new prospective employer much about the graduate. At the same time, the increasing global coupling of information and society calls for more, rather than less, bases for the comparison of different institutions. Will it be, in the future, that the only universities whose degrees carry international acceptance will be the old elite ones?

I have no answer to these questions, and I would welcome Professor Rubinstein's comments.

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## INFORMATION TECHNOLOGY, HIGHER EDUCATION, AND RESEARCH
**by Marcelo Alonso**

It would be a brave or a foolish man who tried to answer the difficult and important questions raised on Pages 6 and 7 of this paper. I am not particularly brave, but I will admit to folly. Here then, are my suggested answers.

Q.1. Is the location independence of infotec based communications making the physical situation of a higher education institution or research center irrelevant?

A.1. In a sense, the physical situation of a place matters little, and has always mattered little. What is important is information about <u>what can be found there</u>. Students will go anywhere to seek out what they need, as Bach walked 200 miles to hear Buxtehude, Halley sought out Newton in Cambridge, or the world's leading quantum theorists were drawn to Bohr at Copenhagen. Princeton and MIT, Oxford and Cambridge, Tokyo and Gottingen, are important not for where they are, but for what they are presumed to contain in superior human resources.

Q.2. Will the widespread use of infotec result in a decline in person-to-person contact (not just student-teacher but also teacher-teacher and student-student) which is very important for education as well as for research.

A.2. The most difficult part of research is often defined as asking the right question (see Itamar Procaccia's paper of this conference, Page 4). In the same way, the most difficult problem faced by the average student is <u>knowing what is worth knowing</u>. The vast available resources of a world wide information system make this problem harder, not easier. The student, facing a nearly infinite choice, is likely to drown in the information flood. The direct interaction with and advice of older and more seasoned people will be <u>more</u> necessary, not less, in the next century. And the best way to obtain that interaction is with the mixture of formal and informal meetings and discussions which characterize the best research and educational institutions. Once there is personal student-teacher interaction, the other components (student-student and teacher-teacher) naturally follow.

Direct interaction has benefits beyond the immediate. To place this in a personal contact, my own supervisor in mathematics was the astronomer Fred Hoyle. Although he was supposed to, and did, advise on subjects directly relevant to the Mathematical Tripos, what I remember today are his digressive ruminations on such matters as the difference between Newton's and Einstein's approach to frames of reference and forces. I can see no way such tangential yet important benefits could ever be achieved using the Internet.

Q.3. Do these new means of communication improve the efficiency and reduce the cost of education and research?

A.3. They help in two ways. First, when a specific question is to be answered, access to global data bases can provide an answer very easily and inexpensively. Second, browsing - random wandering around the Web - is like browsing in library stacks. It is hard to place a value on it, but few would deny the existence of value. I suspect that the overall cost reduction of the new data base access is negligible, at least with today's level of infotec. It seems to take me far longer to get an answer on the web than it does by looking something up in a book - provided that I have the book.

Q.4. Does infotec open new opportunities for learning by providing access to a worldwide pool of electronically linked scholars?

A.4. Certainly. One of the things we often find, even with today's primitive world-wide links, is who else is interested in what most interests us. There are electronic interest groups on everything from beer to the works of P.G. Wodehouse. One can debate whether or not these are true scholarship, but there are also linked groups who study quantum theory, chess, ancient languages, and particular diseases. The problem is often one of selection. A friend of mine was diagnosed as suffering from Parkinson's disease. I went onto the web to search for information, and was offered 320,000 references.

Q.5. Does the above mean that instead of jet-set visiting scholars what is needed is access to a virtual community of electronically linked scholars?

A.5. I don't think it is either/or. I think we will have both. The sustained interaction needed for collaboration is often best provided in person, but few people who travel a lot have anything to say in favor of airports or airlines. With ninety percent of the interaction done electronically, the remaining ten percent should be far more pleasant.

Q.6. Is infotec an effective instrument for meeting the diversification of higher education required by modern societies?

A.6. Drawing from Professor Rubinstein's paper in this conference, I will say, yes, provided that some form of the traditional instruments (such as the old and elite universities) is preserved. Not every education need will be served by demand-driven curricula; on the other hand, I would rather have the person who cooked my hamburger know proper food preparation procedures, rather than be knowledgeable about the poetry of Wordsworth or the philosophy of Hegel.

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## INFORMATION TECHNOLOGY AND THE UNITED KINGDOM HIGHER EDUCATION SYSTEM

**by Alistair Chalmers**

This summarizes what is going on today in the institutes of higher education within the United Kingdom. What I found to be missing is a picture of what the future seems likely to hold. For example, I sympathize completely with the statement (Section 7.1): "The cost of the end-user systems remains high, partly because ever more powerful desk-top boxes are required in order to run (over-configured) new versions of software." This problem applies world-wide. However, I would like to hear suggestions as to what can be done about this. It does not appear in the interests of either hardware of software manufacturers to rein in their enthusiasm for ever more memory and ever more memory needs. The pressure for freezing hardware needs must come from users, by refusing to buy software that calls for more and more memory. At the moment I see no sign of such refusal.

The question of copyrights for electronic publication, addressed briefly in Section 7.3, will surely become more and more important. Again, however, I would like to see positive suggestions as to how to handle the problem.

The personal remarks of Section 9 were to me the most interesting part of this paper. In particular, the observation that distance learning alone will not be the salvation of existing universities seems exactly right. To quote: "The new technology is more about doing new things than about doing old things in new ways." Distance learning does not call for *less* thought in teaching and research, it calls for more.

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## THE IMPACT OF INFORMATION TECHNOLOGIES IN EASTERN EUROPEAN UNIVERSITIES
**by Tamas Kozma**

This presents a case where change was so abrupt during 1989-90 that information technology seems to have appeared in a region almost overnight. A nearly instantaneous change took place, from supply-driven higher education and infotec, to the demand-driven system evolving in the western Europe United States. As the author remarks, this happened at the time when the whole economy of the region was seen as moving from planned to market-driven.

One fascinating element of this paper is the speed with which change has proceeded. It seems that, in less than a decade, a relatively pre-computer society went to widespread use of PC's (even if some are older models), E-mail use, and the world-wide-web. The rate at which eastern Europe comes to resemble western Europe in the use of computers will be decided, not by technology or politics, but by economics. In all this change, industry rather than the academic community has been the principal agent for change.

This paper makes a point that deserves to be brought forward and emphasized: "Commonsense says that the use of modern information technology contributes to the equality in (higher) education. Against this commonsense the introduction of information technologies widens the gap among institutions of Eastern Europe."

And not, surely, in Eastern Europe alone. If we accept that knowledge is power, those with wealth enough to gain superior access to knowledge are in a position to further widen the gap between themselves and those less affluent. The democratic spread of infotec is not guaranteed. If we desire it, we will have to work for it.

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## INFORMATION TECHNOLOGY AND INTER-INSTITUTIONAL COLLABORATION: THE CASE OF THE NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO
**by Victor Guerra**

This paper was available to me only in the form of viewgraphs, and the presentation may answer some of my questions.

I would like to see addressed:

1) The extent to which the USA "drives" Mexican infotec development.
2) Whether any such driving is good (Mexico benefits from US efforts) or bad

(Mexican independent development is stifled).

3) What are the advantages and disadvantages of preserving a distinct national identity in infotec?

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## INFORMATION TECHNOLOGIES AND INTER-INSTITUTIONAL COLLABORATION: THE CASE OF THE UNIVERSITY OF THE WEST INDIES

**by Christine Marrett**

Rather than repeat comments I have made concerning other regional infotec development, let me note the outstanding points or questions suggested by this paper.

1) Changes in information technology fail if they try to base themselves on changing the culture of a society. This leads to an important question: What level of infotec is right for a society? The answer may not be, as most promoters of infotec would say, as much as possible and as fast as possible.

2) "...the threat is that those parts of the globe not participating in the instantaneous communication with those on-line will become remote." What is the price of such remoteness? Can it be quantified? Are there hidden benefits (e.g. preservation of national character)?

3) What can the Internet really offer a region with only one telephone line per thousand people?

The answer, I suspect, may be a good deal; but specific analysis of this type needs to be made.

4) Where resources are available, it is not at all obvious that they will go to the right places. "Every desk in the bursary has a computer," yet the culture department has none.

5) The object lesson that we can draw from the West Indies cricket team is a valuable one: dedication and cooperation can make up for small population numbers and limited financial resources.

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## INFOMEDICINE: THE NEW PARADIGM

**by Jose Felix Patino**

I would like to see additional explanation of the comment made on Page 3, that the world of atoms will be replaced by a world of bits, in "a change that is both irrevocable and irreparable." Surely, the two elements will co-exist, and both will be essential for infotec development. I have trouble imagining software that does not rely on hardware for its implementation, and indeed, the storage and speed requirements of modern software often make it impossible to operate it on older hardware.

Like the author (and many others) I am deeply suspicious of the direction of modern medical practice, which demotes the roles of both the physician and the patient. Am I reading too much out of this paper, if I look ahead to a time when medicine, with computer assistance, becomes a science? In weather forecasting, it used to be that the only method for estimating weather was by analogy to past weather - the so called "statistical" meteorological approach. Today, we are developing computation models based on established physics. If today's physician still also operates largely statistically - "Where have I seen a condition like this before?" - can we look to a time when, as the paper suggests, the patient is modeled as a unique biopsychological system?

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## FUTURE DEVELOPMENTS IN MICROELECTRONICS AND THEIR IMPLICATIONS FOR COMPUTING.

**by Richard Turton**

The main lesson I draw from this paper, with its description of the prodigal potential of new computer hardware devices, is that the second half-century of computing is likely to be as surprising as the first. In 1946, when ENIAC was built, no one had the slightest idea of what was to come. In the same way, the papers presented at this conference, although they take for granted the existence of the world-wide web and ready access to data banks of all kinds, are almost certainly far too conservative.

Let me take a simple example. Suppose that the quantum computer described in this paper can be built, with the spin of individual electrons as the basic computing units. Suppose also that, using quantum indeterminacy, calculations corresponding to every possible system state can be done in parallel. Then, extending the paper's example, an assembly of a million electrons - a tiny number, in macroscopic terms - would allow $2^{1,000,000}$, or about $10^{300,000}$, different cases to be run simultaneously. A serial machine with a switching time of one nanosecond would not be able to run anything like this number of cases, even if it ran until our sun reached red giant stage.

If the quantum computer and the DNA computer sound ridiculous and impossible, recall the 1940s view of many scientists, that a reliable computer could never be built, because it would require tens of thousands of electronic components (vacuum tubes, at that time) to function correctly at the same time.

The moral of this paper is thus, think boldly; and even then, expect that your projected future of infotec in the next two generations will prove far too conservative.

There is one other lesson to be drawn from the same information, and it is something that occurs again and again in different forms in the papers of this committee. As component sizes dwindle to the sub-microscopic and speeds increase beyond the gigaflop mark, it will become increasingly difficult for nations lacking a high-level technological infrastructure to get into the business. They will, inevitably, be buyers rather than makers. Again, we find that the technology supplied for one user will be dictated by the needs of others.

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## PROSPECTS FOR INTELLIGENT SYSTEMS

**by Edward J. Finn**

This fascinating paper mentions Roger Penrose in the Bibliography, but not in the text. Since Penrose's ideas on the way that the brain functions would, if true, have enormous effects on Artificial Intelligence, I reproduce here my own brief discussion of those ideas, drawn from another source:

**Minds and machines**. In **Chapter 9**, we described the extraordinary advance of digital computers. The first ones, in the 1940's, were used for straightforward calculations, of tables and payrolls and scientific functions. Since then the applications have spread far beyond those original uses. Computers today perform complex algebra, play chess and checkers better than any human, control power generating plants, keep track of everything from taxes to library loans to airplane reservations, check our spelling and the accuracy of our typing, and even accept vocal inputs that may soon make typing unnecessary.

Given a suitable program, no human effort of calculation and record-keeping seems to be beyond computer duplication. This raises natural questions: Is every function of the human mind really some form of computer program? And at some time in the future, will computers be able to "think" as well as humans?

To most of the scientists represented in **Chapter 9**, the answer to these questions is an unequivocal Yes. Our thought processes operate with just the same sort of logic as computers. Our brains are, as Marvin Minsky said, "computers made of meat." The field of Artificial Intelligence, usually abbreviated as AI, seeks to extend the range of those functions, once thought to be uniquely powers of the human mind, that computing machines are able to perform. The ultimate goal is a thinking and "self-conscious" computer, aware of its own existence exactly as we are aware of ours.

That ultimate goal seems far off, but not unattainable -- unless a distinguished mathematician, Roger Penrose, is right. In 1989, he offered a radically different proposal. This is the same Penrose that we met in **Chapter 2**. He is the Rouse-Ball Professor of Mathematics at Oxford University, and a man with a reputation for profound originality. Over the past thirty years he has made major contributions to general relativity theory, to numerical analysis, to the global geometry of space-time, and to the problem of tiling the plane with simple shapes. His work is highly diverse, and it is characterized by ingenuity and great geometrical insight. More important, many of his results are surprising, solving problems that no one else had suspected might exist, and stimulating the production of much work by other investigators. Even his harshest critics admit that Roger Penrose is one of the world's great problem solvers. He cannot be dismissed outright as a crank, or as an intellectual lightweight.

What then, does he propose?

In a book that was a surprising best-seller, *THE EMPEROR'S NEW MIND* (Penrose, 1989), he claimed that some functions of the human brain will never be duplicated by computers that develop along today's lines. The brain, he asserts, is "non-algorithmic," which means that it performs some functions for which no computer program can be written.

This idea seems like perfect scientific heresy, and it was received with skepticism and even outrage by many workers in the field of AI and computer science. For one thing, prior to this book, Penrose was very much one of their own kind. Now he seemed like a traitor. Marvin Minsky even called Penrose a "coward," which is a perplexing term since it takes a lot of nerve to propose something so far out of the scientific mainstream.

What does Penrose say that is so upsetting to so many? In *THE EMPEROR'S NEW MIND*, he argues that human thought employs physics and procedures quite outside the purview of today's AI and machine operations. The necessary physics is drawn from the world of quantum theory. In Penrose's words, "Might a quantum world be *required* so that thinking, perceiving creatures, such as ourselves, can be constructed from its substance?" (Penrose, 1989).

His answer to that question is, yes, such a quantum world is required. To see the direction of his argument, it is necessary to revisit what was said in **Chapter 2** about quantum theory.

In the quantum world, a particle does not necessarily have a well-defined spin, speed, or position. Rather, it has a number of different possible positions or speeds or spins, and until we make an observation of it, all we can know are the probabilities associated with each possible spin, speed, and position. Only when an observation is made does the particle occupy a well-defined state, in which the measured variable is precisely known. This change, from undefined to well-defined status, is called the "collapse of the quantum mechanical wave function." This is a well-known, if not well-understood, element of standard quantum theory.

What Penrose suggests is that the human brain is a kind of quantum device. In particular, the same processes that collapse the quantum mechanical wave function in sub-atomic particles are at work in the brain. When humans are considering many different possibilities, Penrose argues that we are operating in a highly parallel, quantum mechanical mode. Our thinking resolves and "collapses to a thought" at some point when the wave function collapses, and at that time the many millions or billions of possibilities become a single definite idea.

This is certainly a peculiar notion. However, when quantum theory was introduced in the 1920's, most of its ideas seemed no less strange. Now they are accepted by almost all physicists. Who is to say that in another half-century, Penrose will not be equally accepted when he asserts, "there is an essential *non*-algorithmic ingredient to (conscious) thought processes" and "I believe that (conscious) minds are *not* algorithmic entities."?

Meanwhile, almost everyone in the AI community (who, it might be argued, are hardly disinterested parties) listens to what Penrose has to say, then dismisses it as just plain wrong. Part of the problem is Penrose's suggestion as to the mechanism employed within the brain, which seems bizarre indeed.

As he points out in a second book, *SHADOWS OF THE MIND* (Penrose, 1994), he is not the first to suggest that quantum effects are important to human thought. Herbert Fröhlich, in 1968, noted that there was a high-frequency microwave activity in the brain, produced, he said, by a biological quantum resonance. In 1992, John Eccles proposed a brain structure called the *presynaptic vesicular grid*, which is a kind of crystalline lattice in the brain's pyramidal cells, as a suitable site for quantum activity.

Penrose himself favors a different location and mechanism. He suggests, though not dogmatically, that the quantum world is evoked in elements of a neuron known as microtubules. A microtubule is a tiny tube, with an outer diameter of about 25 nanometers and an inner diameter of 14 nanometers. The tube is made up peanut-shaped objects called *tubulin dimers*. Each dimer has about ten thousand atoms in it. Penrose proposes that each dimer is a basic computational unit, operating using quantum effects. If he is right, the computing power of the brain is grossly underestimated if neurons are considered as the basic computing element. There are about ten million dimers per neuron, and because of their tiny size each one ought to operate about a million times as fast as a neuron can fire. Only with such a mechanism, Penrose argues, can the rather complex behavior of a single-celled animal such as a paramecium (which totally lacks a nervous system) be explained.

Penrose's critics point out that microtubules are also found elsewhere in the body, in everything from livers to lungs. Does this mean that your spleen, big toe, and kidneys are to be credited with intelligence?

My own feeling is that Penrose's ideas sounded a lot better before he suggested a mechanism. The microtubule idea feels weak and unpersuasive. Like the Wizard of Oz, the theory was more impressive when it was hidden away behind the curtain.

My views, however, are not the issue. Is Penrose wrong, destined to be remembered as a scientific heretic? Or is he right, and a true prophet?

It is too soon to say. But if he proves to be right, his ideas will produce a huge change in our conceptions of physics and its relation to consciousness. More than that, the long-term future of computer design will become incredibly difficult.

With the latter point in mind, we might paraphrase Bertrand Russell. He said of Wittgenstein's theories, as we can say of Penrose's: "Whether they are true or not, I do not know; I devoutly hope that they are not, as they make mathematics and logic almost incredibly difficult."

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## COMPUTER SIMULATIONS AS THE SCIENCE OF FALSE REALITY
**by Itamar Procaccia**

I read this paper rather like a traveler on a long rail journey, admiring the scenery all along the way but increasingly curious for a glimpse of my final destination. How, I wondered, was the author going to tie his discussion in with the general conference theme of 21st century infotec and higher research?

In the version of the paper that I received, the Conclusions are absent. Therefore I never saw the author's destination. However, I will offer as a straw man for discussion my own ideas as to where this paper takes us.

Simulation is touted more and more as an alternative to experiment. The case for simulation sounds good: situations can be explored which could never be realized in practice; computer simulations are usually fast and cheap; larger numbers of simulated trials can be run, yielding a distribution of results rather than a single data point; and simulations call only for computer power, not specially-built equipment. We hear of simulations of everything from automobile air-bag testing to full-scale nuclear explosions (the latter proposed as an alternative to real nuclear testing).

As the author points out, with great clarity, not only is a simulation not reality, it is removed from reality by several steps. From reality we derive an iconic representation, with whatever assumptions we choose to make on important versus unimportant variables. Our iconic representation is then employed to set up a mathematical model; finally, that model is embodied in particular computer code and simulations are run.

The link between reality and simulation can unwittingly be broken at any step. The simulation may explore parameter regimes for which the iconic representation was never intended. The model may make compromises on numbers of variables, or adopt doubtful techniques of solution; and even if everything else goes right, a simulation usually has its own internal parameters, such as time step, whose wrong choice can lead to excessive truncation error on the one hand, or build-up of round-off error on the other.

Unfortunately, simulations are used more and more, and with little caution. In the past week I have seen the results of simulations of the growth of El Nino and of the catastrophic end of TWA Flight 800, and I have heard of increased use of simulations in automobile ergonomics. Nowhere did I see a caveat, pointing out what assumptions were made in setting up the simulations.

Will this problem become worse in the next century? Almost certainly, it will, so long as the results of simulations are presented to the public as if they are no different from real-world experiments. Go to the river when it is raining hard, and measure the flow of water? No. Much drier and cheaper to sit in the lab and run your computer program, and just as safe - until the real flood comes.

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## THE ACADEMY IN A WIRED WORLD
**by Tom Abeles**

This is a dark, Gibsonian, cyberpunk-inspired vision of the future of universities. "In their rush to be at the edge, academia embraced technology and made its pact with Faust" (Page 12). I will go along part of the way with this, but I would like to add some more optimistic notes.

If you wanted to do quantum theory in the mid-1920's, you pretty much had to be in Copenhagen, Göttingen, or Cambridge. The subject was being developed so fast that near-daily contact was necessary. Either you were an insider, or you didn't get to play. Oddly enough, that situation applies today but without geographic proximity. If there is a significant development in certain fields (significant can mean anything from a major award to a death), anywhere in the world, I now hear about it the same day in my E-mail. In these few fields, I am an insider, the equivalent of our 1920's Copenhagen group member. Naturally, in a thousand other fields I am a complete outsider, and rely on general news media for information. But within a field, electronic preprints replace published articles, E-mail comment (Hey, you really ought to read this!) replaces peer review. Not all recommendations are equal. Seniority, measured not by age or position but by past track record, determines how much weight an individual's opinion will be given.

This sounds like the death knell of the traditional university, but I don't believe it is. I agree with Richard Rubenstein's assessment (in his paper at this conference) that the next century will draw distinct lines between two types of university: the career-oriented, demand-driven schools, and the traditional and elitist "ivory towers." I expect that the divergence of these two types will become more and more pronounced, just as the teachers to be found at each will differ more and more. The teacher/publicist/entrepreneur may thrive in the on-line, real-time academies, but there will still be places for a Wittgenstein, brooding for years or decades over age-old questions and immune to daily infusions of information over the Internet. The fact that the latter institutions may be small, apparently old-fashioned, and weakly coupled to industry and state support, is not a weakness but an advantage. In the wild sea of 21st century higher education, we will need sheet anchors.

(As a final note, responding to a comment on Page 10 of this paper: Lovelock himself shudders when he sees it suggested that the Gaia theory implies some level of collective unconscious by the biosphere. His own early writings are partially to blame, but now he spends a lot of time showing how Gaia is consistent with Darwinian evolution and requires no component of conscious intent.)

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## THE EXPERIENCE OF THE OPEN UNIVERSITY: POINTERS TOWARDS A GLOBAL NETWORK FOR EDUCATION AND RESEARCH

**by Gary Alexander**

It's my impression that Britain's Open University has been ahead of its time in almost all aspects of infotec and education. For that reason, their experiences and advice demand special attention.

I want to agree with, and quote directly from, certain comments concerning on-line learning given on Page 11: "Perhaps the most important lesson to be learned from the various projects described in this paper, is that the most important use of computer networks is to link people for discussion and collaborative work."

And, again from Page 11, "Crucial to this new framework is an on-line environment with associated organisational support designed to foster a sense of community."

In other words, although on-line learning might make a student feel remote, cut-off, and an "outsider," programs can be designed to reverse this. In fact, by putting people in touch with others of like interest, a very positive sense of identity can be created. To quote again, this time from Page 3, "They find, perhaps for the first time in their lives, that they are intelligent people, and are respected and accepted as such by their peers."

This paper, based on real experience rather than theoretical fears, is the best possible answer to the dystopian fears of many writers regarding the future effects of global infotec.

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## INFORMATION TECHNOLOGIES FOR INNOVATION IN THE ANDEAN COMMUNITY: EXPERIENCES AND POTENTIALS

**by Carlos Aguirre**

See remarks made above regarding the papers by Chalmers, Kozma, Guerra, and Marrett.

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## SCIENCE EDUCATION IN THE OPEN UNIVERSITY: A NEW CHALLENGE FOR DEVELOPING COUNTRIES

**by M. Shamsher Ali**

Bangladesh may be one of the world's poorest nations, but the points made in this paper apply to everyone - even if the wealthier nations do not recognize the fact.

1) Good education depends on good teachers. Infotec can help the education process, but teachers are still the central pivot. Distance learning must be built around teachers, not offered as an alternative to them.

2) Teachers today are low in pay (relatively worse in the wealthy nations than the poorer ones), and, much worse, teachers are held in low esteem within society. If the teaching of our children is not important, then what is?

3) Science is not just talking, science is doing. "Teaching science without the students performing laboratory experiments is unthinkable." Unfortunately, the very motion of distance learning seems in conflict with laboratory work. The answer: "Open Universities need not set up their own laboratory facilities; they could enter into collaborative agreements with conventional universities to the effect that students of an Open University could use the laboratory facilities of the conventional ones during the long holidays of the latter." This is certainly not a panacea; it is, however, a rational start to a difficult problem.

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