Science, Technology, Education and Learning

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Introduction

It is a pleasure to be back in Sri Lanka and to address you on World Science Day. My title is *Science, Technology, Education and Learning.*

I shall begin with some background about my own studies and career because we all have our personal trajectories of involvement with science and technology.

Then I shall ask, what is science? Why do governments attach such importance to science while people like yourselves are not always convinced that you need to study it?

Governments like science because it is the basis for technology – and technology is what makes us richer. So I shall explain technology, show how it relates to science and why it makes us more prosperous.

Today's event has a focus on climate change. Thanks to the careful work of thousands of scientists around the world we now realize that we are in a particularly rapid period of climate change. Much of the change is due to the pressure that humankind is putting on the planet.

We often hear that new technology will help us combat climate change and I shall argue that technology can have its greatest effect through its use in scaling up education. I shall look with you at the role of technology in education. Technology is all around us: motor vehicles, televisions, computers, aircraft, and telephones. But you probably see the least amount of technology around you when you go to school. Why is this?

I shall explain why technology has been little used in education. That must now change. Sri Lanka has some good examples of the use of technology to expand and improve education and you should take more advantage of them.

My concluding words will be about learning. Education is what most of you are going through now. When you finish school or university I hope that you will be able to say that you had a 'good education'. Your education will then be in the past, but learning will be your future. You will continue learning all your lives. In these fast-changing times, what you learn after you finish your education may well be more

important to your lives and your livelihoods than what you learned during your formal education. I shall give examples from the work of my own organization, the Commonwealth of Learning about how the lives and prosperity of people in Sri Lanka are being improved by lifelong learning.

Personal notes

So I begin with some recollections about the role of science and technology in my own life. When I went to secondary school in England 50 years ago you were expected to choose a subject for specialisation very early, at age 14. I enjoyed both languages and science and had opted to specialise in modern languages until and my mother and uncle persuaded me to change to science – a change I've never regretted. Later I made up for not specializing in languages by studying for my doctorate in France and learning French as I did so.

After concentrating on Mathematics, Physics and Chemistry in school – I had to decide what to study at university, where you had to specialise even more. At school I was fascinated by solids and crystals, so I opted to study Metallurgy – the science of metals – at Oxford University. Four years later I went to the University of Paris to research for a doctorate.

The aim of my research was to find out how crystals of uranium behave when you put them in tension or compression at different temperatures. This work was supported by the French Atomic Energy Authority because France had made a big commitment to develop nuclear energy. My research was pure science rather than nuclear technology. You might describe it as putting another brick in the wall of scientific knowledge on which technology can be built. Nuclear reactors are an example of technology. But like most technology, in order to make it work you need to know the science involved. Nuclear reactors contain uranium, which is a difficult metal to work with, not just because it is radioactive but also because when you heat a uranium crystal it expands on some dimensions and contracts on others, which is unusual.

From the University of Paris I became an assistant professor at the University of Montreal in Canada, teaching metallurgical engineering in French and continuing to do research on metal crystals and molten salts. Because I had become a university teacher I felt that I ought to learn something about Education. So I enrolled as a part-time student in a Masters programme in Educational Technology.

This part-time learning had a profound effect on my intellectual and professional life. It was my first close contact with the social sciences, which I found very different from the physical sciences. But the really life-changing experience was the programme internship, which I spent at the Open University in the UK. Although the Open University had only just opened, it already had 40,000 students and was the most audacious use of technology in education ever attempted.

It was enormously exciting. This was the future of higher education and I wanted to be part of it. On returning to Canada I reoriented my career and since then I have spent much of my life in open universities in Canada and the UK. Today I head a Commonwealth organisation, the Commonwealth of Learning, which helps Commonwealth countries like Sri Lanka use technology to expand and improve education.

I draw three lessons for you from that personal history. First, I am glad that I studied science at school and university, even if my later work had more to do with education and the social sciences. It's a lot easier to study science first and social science later than the other way around.

Second, the continuing education that I embarked on once I was working has had a profound impact on my career. I urge you to become lifelong learners – you never know what opportunities it will create for you.

Third, if you find some new development interesting, whether it's a new technology, a new institution, or an inspiring speaker, take time to find out more and go to the sources if you can. Without my part-time studies of educational technology and my internship at the Open University my later life would have been much less interesting and rewarding.

Science

This is World Science Day. You don't need me to define science so I will focus on distinguishing science from technology.

Science builds and organises knowledge in the form of testable explanations about the natural world. The key to science is the testing of explanations. Science is not a matter of opinion but of observation. If all the tests indicate that a theory or hypothesis is true – and none indicate that it is false – then it acquires the status of a law, or rule. But laws and rules are always subject to revision. If there is an exception to any rule and that exception can be proved by observation, then the rule is no longer a rule.

Some scientific theories, like Einstein's principle of relativity, are conceived first through mathematical thinking and only later confirmed by physical observation. Others, like Darwin's theory of evolution by natural selection, were developed by reasoning based on massive numbers of observations. These principles of relativity and evolution now have the status of rules. Many people do not like the rule of evolution by natural selection, but so far no exception to it has been proved by observation, so this rule is as solidly established as something like Boyle's Law or Hooke's Law, that you may have studied.

Basic scientific research is always searching for deeper knowledge from either calculation or experimentation. Recently, for example, the famous physicist Stephen Hawking has hypothesised that the laws of physics may not be the same throughout the universe. This is a revolutionary idea which physicists and astronomers will now design experiments to test.

Technology

I now turn to technology. Research is a link between science and technology. Basic research is the search for knowledge, while applied research is the search for solutions to real problems.

The UK Open University's Foundation Course in Technology defines technology as the application of scientific and other organised knowledge to practical tasks by organisations consisting of people and machines. Technology draws on scientific knowledge, such as that emerging from applied research, but also draws knowledge from other sources: tacit knowledge, business processes and common sense. Note also that technology is about people and machines. Technology, much more than science, involves people and their social systems.

Why is technology so important? Why does technology make us more prosperous? Over 200 years ago the economist Adam Smith wrote a book,*The Wealth of Nations,* which explained the how technology creates wealth. He compared the process of making pins individually by hand and making them in a factory and identified four important differences – four principles of technology.

The first is division of labour. Previously one person had to carry out all the different operations involved in making a pin, but in the factory these operations are divided between different workers. That leads to the second principle, specialisation. Each worker specialises in a particular operation and becomes more skilled at it. The third principle is the use of machines to draw out the wire, cut the pins and put heads on them.

All this leads to the fourth principle, which is the powerful result of technology: economies of scale. Technology allows us to produce many more items at a lower cost for each one. The worker making pins individually could produce only a few every day, whereas the pin factory can churn out thousands. Because of that the pins cost much less. Finally, technological processes give more consistent quality. Since quality is consistent, and since technology operates at scale, it is worth investing to make sure that the quality is good.

I have been describing the technology of the industrial revolution. As a result of that revolution ordinary people now have access to a range of quality goods at relatively much lower prices that they did a hundred years ago or even fifty years ago, because technology keeps getting better as it incorporates new insights from science and management.

Industrial revolution and communications revolution

I now make a simple distinction between the industrial revolution of the 18th century and the communications revolution of our own times. The distinction was well expressed by Lord Geoffrey Crowther forty years ago. He was presiding over the inauguration of the first great application of the communications revolution to education, which was Britain's Open University. He said:

"The world is caught in a communications revolution, the effects of which will go beyond those of the industrial revolution of two centuries ago. Then the great advance was the invention of machines to multiply the potency of men's muscles. Now the great new advance is the invention of machines to multiply the potency of men's minds. As the steam engine was to the first revolution, so the computer is to the second... At the Open University in the communications revolution... every new form of human communication will be examined to see how it can be used to raise and broaden the level of human understanding."

But why were the UK Open University – and the many other open universities like the Open University of Sri Lanka that followed its example – so revolutionary? After all, the technologies of both the industrial revolution and the communications revolution have been applied in all areas of human life for many years. Why was it so unusual to see them used in education?

I explain this in terms of what I call the iron triangle. What we want to have in education – as in other areas of life – is wide access to quality education at low cost. Let's put these three vectors, access, quality and cost together in a triangle. What we seek to do is to stretch the triangle in the way that technology has done for the making of cars, bicycles, radios and computers: create more access at higher quality and lower cost.

But you can't stretch classroom education like this! Try extending access by packing more students into each classroom and you will be accused of damaging quality. Try improving quality with better learning resources and the cost will go up. Try cutting costs and you will endanger both access and quality.

This iron triangle has hindered the expansion of education throughout history. It has created in the public mind – and probably in your own thinking – a link between quality and exclusivity that need not exist. This mistaken link still drives the admission policies of many universities, which define their quality by the people they exclude. It explains why you have such a desperate shortage of university places in Sri Lanka and why even the Open University of Sri Lanka serves far fewer people than it should or could.

But today we don't have to put up with limited access and poor quality. Technology can transform the iron triangle into a flexible triangle. By using technology you can achieve wider access, higher quality and lower cost *all at the same time.* This is a revolution – it has never happened before.

The most successful example of this revolution in education is what we call open and distance learning, or ODL. ODL combines the technologies of the industrial revolution and the communications revolution.

From the industrial revolution it uses the principles of division of labour, specialisation and economies of scale to produce high quality learning materials, such as print, audio, video, and computer software, in large quantities at low cost. These allow people to study independently where and when they want. But most people can't succeed by independent study alone – they need help from other people: teachers or fellow students. That's where communications technology comes in.

Using telephones, e-mail and the Internet allows those involved in a course to communicate quickly and easily, giving help when needed and providing timely feedback on assignments. In distance education we use the word synchronous when people are communicating at the same time, as in a phone conversation; and the term asynchronous when they communicate at different times, as in e-mail. The challenge in designing an effective – and cost-effective – teaching and learning system is to combine these elements well.

First avoid the extremes. For example, you might imagine a system where video links are used to teach people synchronously in many places at once. But this has two big problems: it is inflexible, since learners have to be in a particular place at a set time; and it is very expensive – the initial equipment, the bandwidth to communicate, the maintenance and supervision are all costly.

At the other extreme you might imagine a system where people study printed learning materials and DVDs independently at home. The cost will be low, but it may not be cost-effective if many people give up on their studies because of lack of human support.

Between these two extremes are an infinite number of combinations of independent study materials (print, audio, video, software) backed up by interaction with teachers and other students, synchronous or asynchronous, through the Internet by e-mail or social media. The cost-effectiveness of each of the different combinations for learning is only loosely related to its cost.

For example, it is easy to add in more interaction with teachers, which is costly, without giving the students a more successful experience. Research shows that the key factor in improving student performance is to get the student to interact with the content, and there are many ways of automating that – like websites with answers to frequently asked questions, or computer-marked quizzes that take students through the reasoning that gets them to the correct and incorrect answers.

Opportunities for Sri Lanka

Before I conclude let me make three observations about education in Sri Lanka, which I offer in a constructive spirit.

The first is that education in Sri Lanka has a very unusual profile compared to other countries. Primary education is essentially universal and gives you a high literacy rate. That is admirable.

You also have pretty good access to secondary education with a gross enrolment rate of 88%, which is also commendable. Climate change is one of your themes today, so let me say here that the most effective action that the world could take against climate change would be to bring all countries up to Sri Lanka's level of participation in secondary education.

The most powerful driver of climate change is population growth, so slowing population growth will act against climate change. In Sri Lanka population growth is already very small, so you are not creating climate change problem, although you will suffer from it.

I simply ask you to note that worldwide, on average, women with secondary education have 1.5 fewer children than those who do not have secondary education. A difference of one child per woman means 3 billion more or fewer people on the planet by 2050. That is what will determine the gravity of climate change for you in Sri Lanka. Secondary education for girls everywhere in the world *must* be a priority.

Your secondary education is fine in world terms – but your tertiary education is a disaster. Your tertiary enrolment rate is a dismal 6% which places you at 112th place in the world – between Swaziland and Cameroon. Yet Sri Lanka is much more developed than either of those countries – so why is access to higher education so limited? The key reason is that you have persisted in maintaining a few free universities for the elite rather than creating universities for the whole population and charging students fees to pay for them. Until you bite that bullet you won't progress. Encouraging private and foreign universities to set up here may help – but one day you will have to tackle the main problem.

My second comment has to do with the Open University of Sri Lanka – and I speak as a proud honorary graduate of that university. OUSL should be doing far more to help solve the access crisis. In my view it should have a student enrolment at least three times greater than it does now. The reason it doesn't is that it persists with an expensive model of distance learning that relies far too much on interaction between students and the full-time academic staff. In my view it would be more efficient, and the students would get better support, if OUSL trained large numbers of part-time tutors to interact with the students.

Third, and you will tell me if I am out of date on this, I believe that you are seriously under-utilising the National Online Distance Education Service that was set up under the Distance Education Modernisation Project that started in 2003. I have visited some of the NODES centres in various parts of the country and they are superb. They also seem to be mostly empty of people, at least when I have visited them. This seems to me a woeful waste in a country that has such desperately low access to tertiary education.

Learning for Livelihoods

I've talked about education, but what really counts is learning. Our best way of coping with an uncertain and changing world is to keep learning throughout life. That is especially important here in Sri Lanka

where so few people get the chance to go to university. Maybe the demands that you make as lifelong learners will help the country recoup its investment in the National Online Distance Education Service and in the Open University of Sri Lanka.

Let me end by mentioning two programmes where the Commonwealth of Learning is helping to advance lifelong learning in Sri Lanka. We are deeply indebted to Professor Uma Coomaraswamy, a great Sri Lankan, for her intense engagement with both initiatives.

Lifelong Learning for Farmers

The first is called Lifelong Learning for Farmers. It helps farmers become more prosperous by increasing their income from farming through partnerships between rural communities and universities. I have visited three of these partnerships.

In Hambantota the University of Colombo is helping local farmers switch part of their rice paddy to sour bananas, the cultures for which are grown locally by young women trained in the technology.

In Batticaloa, farmers are growing vegetables that have higher value added than the crops they were growing before.

Finally, the University of Ruhuna is helping farmers gain additional income by growing oyster mushrooms. In all cases the farmers have improved their livelihoods substantially and the learning necessary to achieve the change has contributed to community development.

In each case the university involved is putting its expertise in science and technology at the service of the community. Then, in turn, community needs are inspiring the universities to pursue research and refine the technology to improve livelihoods further.

Learning for bankers

COL is also helping the Central Bank of Sri Lanka and the Open University of Sri Lanka with a learning programme in microfinance intended for bank staff all over the country. This is related to the farming projects, which depend on having the banks make small loans to rural people, something that the banks have not done well in the past. The course is taught using interactive multi-media technology and contact sessions. 250 bank staff began the programme in July and I gave completion certificates to the graduates yesterday. The plan is now to expand the programme all over the country.

These are just two examples of the way in which learning throughout life can contribute to better livelihoods and help us adapt to change. The Commonwealth of Learning is proud to assist with these endeavours.

I have enjoyed talking to you on World Science Day. I hope that my reflections on my own career, my comments on science and technology, and my analysis of the role of technology in education have made you think. And if you are thinking, then you are becoming lifelong learners!