Thank you for your welcome and thanks to NICTA for the opportunity to take part in the Big Picture Seminar Series.

I note that the series has been billed as an effort to communicate the exciting and rapidly evolving vision of ICT around the globe, and to raise issues for discussion by the technologically literate.

Let me just say that tonight I have taken up a license to vary the theme. The reason is obvious. I doubt that I could persuade many of you that I had any big ideas about ICT that were remotely as big as those many of you already have.

I do agree with the idea that we need to communicate our vision for our science, or our ICT. We do; and many advocates have been trying to do that for quite a long while now. But there is slight evidence that it has worked well. Polls of the community reveal a variety of attitudes – some positive and some not so positive. Whereas once the sciences seemed to deliver some sense of assurance to the public, it seems to be more than ever vulnerable to criticism, both when the criticisms justified and when it is designed simply to achieve the purpose of the critic.

I also agree that important issues can only be dealt with fully and effectively by a process of regular discussion. Often that will be amongst the technologically literate. It is through the sharing of that knowledge and expertise, indeed the challenging of ideas by those with the expertise to mount the challenge that we advance. But we also need to talk to those who might not be classified as technologically literate - the majority. In the end, if the majority don't care for what we do, don't believe in what we do, or don't instinctively want what we do, it won't happen.

The standing of science in our community has been challenged. That challenge must surely make us wonder whether we do our communicating the right way - or the best way. It seems to me that we must even ask whether the way the dialogue with the wider public is conducted through the media really assists, or whether the messages get lost in white noise.

I will revisit the question of what we should be doing to engage in that wider forum a little later.

My topic tonight, *Australia's Future in Science and Technology* is timely for a number of reasons; a lot of our future will depend on the quality (and quantity) of the science and technology we can mobilize to address some of the big issues between us and a prosperous future.

So it is with an eye to that future that I want to talk about the present state of science and technology – and what we might do about it - in both an Australian and a global context.

It is idiomatic that there's no time like the present; I say idiomatic, because in life there is no pause button, we are forever working with the future in mind.

And the future of Australia, indeed the future of the world, will be shaped by mathematics, engineering and science. This is because they provide the enabling skills and knowledge that underpins many professions and trades and the capacities of a technologically based workforce.

The problems that Australia and indeed the world face – won’t be solved, moderated or even managed without science and technology.

Yet it is not clear to me that most people, or even many people, really understand the importance of science and technology to our future.

Mathematics, Engineering and Sciences help us to understand the natural world and provide us with the foundations to improve the lot of human kind by building a constructed world and a future that is socially, culturally and economically prosperous.

A well-rounded world is one that is safe and prosperous, one that balances the way it uses the talents of the people inhabiting it.

Scientists and technologists are a part of that, because science and technology will underpin the environment in which we work, regardless of what our work is.

So while not everyone needs to be a scientist or a technologist, we also need an understanding that science and technology is good for the common cause, and that it needs to thrive for the knowledge and understanding and benefits that it brings, for the sense of security it engenders among us all.

But it seems to me that science and technology and what it delivers to us is either taken for granted, or simply ignored.

I think the science that is embedded in everyday processes, for example the baking of a cake, should be a source of daily amazement.

How many smart-phone obsessed kids using plastic bank notes realise they wouldn’t have their flash toys without scientists, mathematicians and technologists?

But people tend to think that science is something that is done by someone else somewhere else.

But it isn't, and it shouldn't be. On the contrary, it should be of concern that in effect, our stock of scientific skills is being run down and that in Australia and in other countries around the world there is a measurable decline in the numbers of students wanting to study science, technology, education and mathematics, or STEM.

That is not universal, some countries are well ahead of us, even decades ahead.

Take the Korean language, which barely had the words to describe modern science and mathematics until work developing a modern education system in South Korea began in 1948. The words had to be invented before the text books could be written.

South Korea began to give serious and sustained special attention to scientific and technical education in 1973, when it established vocational schools to - I'm sorry I don't know the Korean for this - *'scientificize the whole people.'*

In Europe, Education Ministers identified the need to increase enrolments in the STEM disciplines in 2001 to foster a *'dynamic and innovative knowledge-based economy.'*

They took as their examples from what has been achieved in South Korea, Singapore, Hong Kong, China and elsewhere.

Concern at declining numbers of STEM degrees being taken in the United States starts at the top. In 2009, President Obama staked out the territory by saying: *American students will move from the middle to the top of the pack in science and math over the next decade. For* *we know that the nation that out-educates us today will outcompete us tomorrow.*

In February this year, the President's Council of Advisors on Science and Technology argued that the United States needed to produce one million additional graduates in STEM over the next 10 years simply to retain the US pre-eminence in science and technology.

The report - *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics* [i] - stresses that change is needed, that doing more of the same or tinkering will not generate the numbers needed.

Australia compares very poorly internationally. The international average for the ratio of STEM to non-STEM degrees was 26.4 per cent in 2002. In 2002, the Australian ratio was 16.1 per cent and in 2010, it was 16.2 per cent, if you blinked you'd barely notice the change. When IT is included, the figure is 22.2 in 2002 and 18.8 in 2010 the drop following the fall in university graduates in IT. But whether it is 16.2% or 18.8%, it is nothing to say we can stop pulling and start resting on the oars.

This should be of real concern to a nation where the national agenda is about transformation of traditional industries for a new global economy.

It should be of real concern to a nation that is proud to claim that, with only 0.3 per cent of the world's population, we generate around 3 per cent of the world's stock of knowledge.

It should be of real concern that under the program for international student assessment we have slipped from third place behind Korea and Japan to seventh behind China – Shanghai, Finland, China-Hong Kong, Singapore, Japan and Korea.

Investing in science and technology serves the nation's interests. It establishes a cohort of experts that will not only maintain our 3 per cent contribution to world knowledge but also has the expertise to adapt the other 97 per cent of knowledge to solutions for Australia.

Externally it builds Australia's standing in the world; internally, used properly, it increases scientific literacy in the community - empowering citizens to make better choices about life options.

Investing in mathematics, engineering and science is the key to unlocking the innovation that will unleash the productivity growth that will transform Australian industry. In turn, this ensures our economy remains internationally competitive and delivers higher living standards.

Just as the report Engage to Excel suggests a massive effort for the United States, in Australia we cannot afford to be left behind.

This would most likely mean we would become an importer of the knowledge and skills we need; that is if we can find somewhere to buy them in an environment where the premium on such things will be high and competition fierce.

Like China, India and the rapidly advancing economies, we need to produce adequate numbers of people skilled in the mathematics, engineering and sciences disciplines and in applying their knowledge.

It is pleasing that the Australian Government has uncapped the number of university undergraduate places.

This responds to a Skills Australia forecast that by 2025 a third of workers of all ages will require a minimum of a bachelor's degree qualification. Uncapping the numbers will help to meet that demand for highly skilled workers.

But we are still left with a lag because there has been little growth in enrolments in the enabling sciences for over 20 years, despite a massive expansion in the higher education sector.

Enrolments in university science programs at all course levels, by Australian **and** international students, grew by 20 209 between 2002 and 2010 to 88 710 (nearly 30% growth).

At the same time health enrolments grew by 66 727 places to 164 036 (nearly 70%) and management and commerce enrolments grew 99 405 enrolments **to** 340 401 (over 40% growth). Compared with an overall increase of 33 per cent in total university enrolments, and the even stronger growth in fields like Health and Management, science enrolments rose by only 30 per cent.

Unfortunately this growth in total enrolments hides the story of the enabling disciplines and what happened to them over the last 20 years. Work done for the Health of Australian Science (HAS) report shows that the mathematics, chemistry and physics being studied beyond first year by our domestic science undergraduates decreased by 20-25%, from peaks in the early 90s through to 2000. Since then they have pretty much flat-lined. This is in stark contrast to 20 years of expansion of the higher education system.

I imagine there is a preponderance of ICT people in the audience today, so I want to digress briefly to look at your sector in detail for a few moments.

Computer sciences enjoyed a steady, even burgeoning, growth throughout the 90s but ICT lost its gloss.

From a peak of higher education completions in ICT in 2002 it took what could almost be classed as a nosedive.

Obviously this coincided with the dotcom crash. Poor graduate employment outcomes at this time contributed to the decline for several years, particularly among domestic students. Since 2008 domestic ICT commencements have started to increase again, albeit slowly.

I think a contributing factor has been the domination of the ICT sector by males, with females accounting for just 23.3 per cent of all full-time ICT professionals in February 2010.[ii]

The view of the Australian Government's IT Industry Innovation Council is that a lack of grounding in the technical aspects of computing at a school level is a factor in whether students take up computer studies at the tertiary level.

To this end the Industry Innovation Council is contributing its thinking to a national schools technologies curriculum with the Australian Curriculum, Assessment and Reporting Authority.

The council believes that schools should teach rudimentary ICT design, development and implementation skills that give students a meaningful introduction to ICT tertiary studies and the ICT profession.

In *The Australian* on 31 January this year, Dr Nick Tate, the president of the Australian Computer Society, called for a greater focus on ICT in secondary and primary school. This would ensure the development of ICT skills: and this school level education would form the basis of entry into tertiary studies to educate and train ICT professionals.

A paper delivered to the 22nd Australasian Conference on Information Systems in December 2011, by Madeleine Roberts from the University of Wollongong, suggested that the transition from school to university was difficult for ICT students, particularly female students. The paper further suggested that more support should be provided during the early period when students are likely to change courses.

Finally it called for a better balance between application and theory in ICT courses with more emphasis placed on workplace application and case-based teaching, and developing alternative career pathways into the ICT profession.[iii]

I contend that some of the issues I mention in this digression are relevant right across the STEM spectrum.

I think it is obvious that we need to do what we do now, better.

And, if there are any teachers among you, let me reassure you, I am very cognisant of the issues arising from an already crowded curriculum.

I spoke earlier about transforming industry. I hope the Australian Government will take over responsibility for signaling, repeatedly, the importance of the STEM disciplines to the community and for ensuring the resourcing of teachers and students to gain, at the least, the scientific literacy to make a difference.

A part of this is ensuring the quality of education across Australia. To develop our nation's potential, all Australians need to develop theirs by having access to a quality education, one that is constantly tested, one that is challenging and one that fits a need.

We need to act now to address the serious challenges in Australia. And it gives no comfort to say they are not unlike those confronting many developed countries.

As a former scientist and educator, I am concerned that attitudes to science and the daily discoveries it yields vary widely.

The Relevance of Science Education (ROSE) program of Norway asked young learners at the age of 15 from more than 40 countries for their views on science and technology. The results reveal that the more developed a country, the less young people are inclined towards education and careers in mathematics, science and technology.

It is pretty stark what the message holds for whether or not they would like to become a scientist – or to get a job in technology. The researchers suggest that *it might be that we have now passed the era in which the work of physicists, technicians and engineers is seen as crucial to people's lives and well-being*.

Today's youth will make their choices not because it is good for European competitiveness or because they may earn a good salary. They are more interested in *who they will be* rather than *what they will do*. [iv]

Australia was not one of the 40 countries in the study. But, like most other developed countries, high school students in Australia are not very interested in doing science or advanced mathematics in high school[v].

A 2010 survey of 1200 Australians aged 18 and over showed strong support for science and scientists. Over 85 per cent thought that science had made life easier for most people, and the same proportion thought science and technology would create opportunities for future generations.

Scientists were rated third highest, after doctors (scientists themselves, when you think about it) and teachers when contribution to societal well-being was considered.

However, a survey of year 11 and 12 students showed less support or understanding. Of those studying science, 33 per cent thought science was almost always relevant to their future, and 19 per cent thought it almost always useful in daily life. The one-third of the cohort that was not studying science fell this way: 1 per cent thought it relevant to their future 'almost always' and 42 per cent thought it never and 4 per cent thought it 'almost always' useful in everyday life.[vi]

It's probably little wonder that the proportion of enrolments in mathematics and science in Year 12 has decreased over the years and continues to do so slowly.

Some of the numbers are alarming, while year 12 enrolments vary between the states and territories, around 51 per cent take a science subject or subjects, including psychology, amounting to 110,328 in 2010.

But since 1992, when school retention rates stabilised, and 2009, the proportion of year 12 students taking what could be considered core subjects like physics, chemistry and biology, fell by 31 per cent, 23 per cent and 32 per cent respectively.

In 2010, 153,512 students or about 72 per cent of the cohort, took year 12 mathematics. While this might appear solid, it belies the fact that there has been a shift from 'advanced' and 'intermediate' courses to 'elementary.' The back story from this is that Australian capacity has declined substantially where mathematics is needed to underpin professions and only 62,000, less than half, took the advanced or intermediate courses that were prerequisites for certain university courses.

Lest you think this is unique to Australia, it's not, the UK Institution of Engineering and Technology found in 2008 that *the global consensus is that enrolment in STEM studies and/or careers has been in decline for more than a decade.*[vii]

So what to do to capture the attention of students at an early age? You will have heard this before, but time and time again, all the consultations return to the need to have inspirational teachers, teachers who are confident with their subject matter and have the knowledge to teach the curriculum passionately, creatively and imaginatively.

It **is** possible to make mathematics and science interesting without making it simplistic, or dumbing it down, and that is the challenge.

And, just as the Australian Government is seeking to make it easier to translate science and research into a smarter industrial base by bringing scientists and researchers into the same space as our industry leaders, we can inspire our future researchers and scientists by using the same processes.

We are poised to take programs that capture the expertise and enthusiasms of the learned academies such as the Academy of Science through its Primary Connections program, the Australian Academy of Technological Sciences and Engineering and the CSIRO into more schools.

Wherever the programs have been trialled school leaders have welcomed them for the great value they have brought to their programming and their students.

Their value comes from the realities and skills they present, especially for the inquiry based teaching skills outlined in the Australian science curriculum, for their use of quality resources and for the support they provide to teachers in working with the broader community including scientists and industry.

We also need to address issues of teachers who are considered to be teaching 'out of field' or in areas in which they are not qualified. To ensure that teachers have the knowledge and confidence to inspire, we should be implementing the Australian Institute for Teaching and School Leadership national professional standard. This suggests that secondary teachers in particular, should have undertaken at least a major study in one teaching area and at least a minor study in any secondary teaching area.

The theory behind what I have just been exploring is that if we can keep people's attention on science, mathematics and technology long enough in schools, some of that may translate into more interest in higher education study in the STEM disciplines.

Domestic undergraduate degree enrolments have hovered around the 10 per cent mark over the past decade for the natural and physical sciences, including maths, and been pretty steadily fixed at 6 per cent for engineering and related technologies. And similarly graduations have been stable over the past eight years.

We graduate around 20,000 STEM-related students a year, 6,000 of whom are engineers. Engineering Australia has reported that there is a shortage of 20,000 engineers right now. But you can’t say to somebody that although you applied for Biology, Economics or History you must enroll in Engineering because we need more engineers. It is a democracy, still, and students are allowed to choose.

We have to get people **to want** to study engineering – or Chemistry or Physics or Mathematics for that matter.

But we are not alone. There is widespread concern about the decline in the STEM subjects globally, and much effort is committed to working out what to do about it.

Part of the problem is that even after a lot of effort by a lot of people, the numbers still fall, or flat-line at a low level. We need a step function change, not just a bit more – though not less - of what we have been doing.

It comes back to community values and the need to turn them around.

In discussions in my office we have concluded that scientific literacy in the community is not at the level it should be.

The NSW Department of Education and Training has developed a neat definition of what scientific literacy can mean and how we can develop it:

> *Daily we read and hear stories about global warming, cloning, genetically modified foods, space exploration, the collection and use of DNA evidence and new drugs*

that will improve the quality of life and make us look years younger. As a consumer, and as a citizen, we need to critically evaluate the claims made in the name of science and make informed decisions and choices about these and other science based issues. In short, we need to be scientifically literate and more importantly we need to develop scientifically literate students.[viii]

Scientific literacy is about having an understanding of scientific concepts and processes, without necessarily having to be a scientist. I talked about valuing science and technology for what they can deliver to society when I opened this speech, it is about the understandings that give us our sense of value, a sense that inevitably leads to support for science.

I also touched earlier on public debate and the paucity of much of the so-called debate in the media, the culture wars and the ill-informed discussion of what passes for debate on climate change are just two examples.

Science is not doing itself any favours.

Despite a specialisation called Science Communication, communication between science and the media is patchy, science makes an uneven use of the media to get its message out. And that does mean that we have to do better. The UK's Science Media Centre's philosophy sums it up perfectly: *The media will 'do' science better when scientists 'do' media better*[ix]*.*

Social media like Facebook and Twitter can be a hindrance, but used properly, they can be game changers. Social media changes the way science can promote its work here in Australia, it also helps to improve international collaborations, commercialisation and to attract international students. But it also gets science into the mainstream of people's consciousness by making it more accessible and scientists and technologists must take advantage of that access.

In fact we need to rethink the way we communicate science. We have a lot to explain. What it's for? How it's done? Why it's exciting? Why it's important? All of the career options available for somebody with a science degree. The usefulness of an education in science because the method can be applied to a wide range of jobs: because of its rigour, its dependence on evidence, the skills of analysis and observation that are highly developed, the fostering of the scepticism that is fundamental to proper science.

You may think I've thrown a lot of chaff out into the air, so I want to draw some of these thoughts back together.

For the sake of our future prosperity, Australia as a whole must be smarter, more competitive and more productive.

To do this we need the people with, at its most basic, an appreciation of the role of science, technology, engineering and mathematics in doing this.

It is a culture change that we are not going to achieve overnight but it is a change that we need to start on right now and probably should have started decades ago.

This will then, with some of the other resources also aligned, translate into more interest in STEM as a career.

It has been interesting as an observer to watch the transition of Australian Government policy delivery in latter years. Industry policy was brought together with science and research to drive innovation. Now the linkages and possibly the synergies between industry, higher education, research, science and skills are being combined.

It is a long term strategy that complements much of what I have been talking about.

I want to leave you with the dilemma that I started with and that is the United States aspires to have one million additional graduates in the STEM subjects over the coming decade. That is, one million on top of the current three million. Australia will produce more or less 200,000 such graduates if we do nothing, or continue to do what we do now.

Just to keep pace, that is to achieve the same proportion of STEM graduates in our workforce as the US, we need an additional 135,000 graduates over that decade and that represents a 66 per cent increase at a time when the numbers of students (or the proportion of students) taking the necessary subjects in school is still slowly falling – and the place of science in our world is clearly not well understood.

We can and will do it better by being better communicators, better teachers and better advocates of and for science. I thank you for your interest and I look forward to your support.

[i] *Report to the President: Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics*, Executive Office of the President, February 2012

[ii] *Source: February 2011, ABS Labour Market Survey, ACS Compendium*

[iii] *Why Students Leave Their ICT Degrees: A Gender Comparison;* Madeleine R. H. Roberts, Tanya J. McGill, Peter N. Hyland, December 2011.

[iv] ERT Mathematics, Science and Technology Education Report, 2009

[v] Commissioned study.

[vi] Goodrum D, Druhan A & Abbs, J, *The Status and Quality of Year 11 and 12 Science in Australian Schools*, prepared for the Office of the Chief Scientist, Australian Academy of Science, December 2011

[vii] *Studying STEM: What are the barriers?,* The Institution of Engineering and Technologies, UK 2008

[viii] *What is Scientific Literacy?,* NSW Department of Education and Training 1999-2011 http://www.curriculumsupport.education.nsw.gov.au/investigate/index.htm

[ix] Leveson Inquiry