Keynote Address by Chairman A*STAR Mr Lim Chuan Poh
on "Singapore's Research, Innovation and Enterprise Strategies and Strengthening the Pipeline of Engineering Talent"
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Abstract: Mr Lim Chuan Poh's keynote address will discuss Singapore's rapidly-growing research, innovation and enterprise landscape, and how Singapore has actively pursued strategies to increase the research-intensity of Singapore's universities to create peaks of excellence and train specialised R&D talent. Mr Lim will draw from his background and experiences (being the former Permanent Secretary of the Ministry of Education and the current Chairman of the Agency of Science, Technology and Research, Singapore's primary mission-oriented R&D agency) to elaborate on challenges and strategies in educating engineering talents for the 21st century, in the context of Singapore's R&D system. He will also discuss important global trends, such as the increasing need for high-quality engineering graduates yet declining STEM participation. He will relate these back to Singapore and how Singapore is responding to these challenges, including demonstrating a commitment to an open and international education experience as key to generating greater interest among young students in STEM, and engineering in particular.

Introduction

Let me first thank the organisers for inviting me to join you at this very distinguished Global Engineering Education Exchange Annual Meeting in Singapore. I join the co-hosts, Prof Larry Shuman, Ms Peggy Blumenthal and Prof Er Meng Hwa, in welcoming many of you who have travelled from afar to be in Singapore for this meeting, especially for those who are visiting for the first time. Quite apart from the professional exchanges from this meeting, I hope you will also bring back fond memories of Singapore.

This Meeting provides an excellent opportunity for representatives of leading universities from around the world to share and learn best practices and strategies for educating and creating a strong pipeline of engineering talent for the 21st century. This is a critical issue as the emergence of a global, knowledge-based economy built upon technological innovation is demanding a renaissance of engineering education, research and practice.

I have been asked to speak on the evolution of Singapore's research, innovation and enterprise or RIE system and the corresponding transformation of Singapore's universities. This RIE system is fundamental to Singapore's economic strategy. I will also share some perspectives on why Singapore thinks generating high-quality engineering talent is critical, the challenges faced, as well as the policies and initiatives that have been implemented to respond to these challenges. This is clearly a work-in-progress and we look forward to learning more from this gathering.

Development of Singapore's RIE System and Evolution of Universities into Research-Intensive Entities

So let me begin with a brief overview of the development of Singapore's RIE system and the evolving role of universities within this system.

Since gaining independence in 1965 nearly fifty years ago, Singapore has transformed itself from a developing island nation into a vibrant city-state, growing its GDP per capita from below US$500, to one of the highest levels of GDP per capita in the world of over US$50,000 in 2012.

This is a story that I'm sure many of you would have heard about.

But, this could not have been achieved without a strong commitment and belief from the Singapore government to first invest in education and only later on to grow the R&D capabilities and research landscape as part of Singapore's transformation into a knowledge-based innovation-driven economy.

With intensifying global competition from the 1980s onwards, the Singapore government realized that we have to move beyond a labour- and capital-intensive economy to a technology-intensive phase, and to do so at a quickened pace.
In other words, Singapore had to upgrade to higher value-added manufacturing and services, focus on strong intellectual capital creation and embark on innovation-driven growth.

A landmark initiative was the establishment of the National Science and Technology Board, or NSTB, in 1991 to support economic-oriented research and development. NSTB would later become A*STAR a decade later.

NSTB, through its research institutions, was the main research performer in the Singapore R&D landscape back then. However, in the last ten years, dedicated government R&D funding has led to the significant expansion and diversification of Singapore's RIE landscape.

Singapore's Gross Expenditure on R&D (GERD) more than doubled to $7.2 billion in 2012 from $3.4 billion in 2002, or a 9 fold increase from 1991 ($0.8 billion). The number of Research, Scientists and Engineers (RSEs) employees correspondingly doubled from 15,000 to 30,000 from 2002 to 2012.

While in the early 1990s there were only pockets of R&D capabilities collocated with the universities, Singapore now has a vibrant RIE ecosystem comprising public sector research entities such as A*STAR, autonomous universities, hospitals, academic medical centres, as well as the private sector R&D laboratories.

As the foundation of a knowledge-based innovation-driven economy is high-quality research and innovation talent, the Singapore government initiated a transformation of the university sector to prepare for an increasingly R&D-intensive economy. I was with the Ministry of Education at the time and helped oversee two critical stages behind this transformation.

The first stage was a strategic review in 2004 to transform Singapore's public universities into autonomous universities (AUs). Against the backdrop of an increasingly competitive global university landscape, the devolution of autonomy was intended to enable the universities to better differentiate themselves and chart their own strategies towards achieving new peaks of excellence. A completely new governance arrangement was put in place for MOE to work with the autonomous universities or AUs.

The second stage, immediately following the university autonomy review, was to catalyse the transformation of our AUs to become globally competitive research-intensive universities.

This latter review led to the creation of an international Academic Research Council and a new Academic Research Funding Framework, under which MOE's research funding for the AUs nearly tripled. In addition to the significant step-up in MOE funding, the AUs could also access a greater diversity of competitive funding grants, such as from A*STAR and the National Research Foundation.

The review also led to launch of the Research Centres of Excellence or RCEs, aimed at building clusters of world-class research capabilities and undergirding a significant level of research-intensity in the universities.

As the then Minister of Education, Mr Tharman Shanmugaratnam, put it, these transformations of Singapore's universities would allow them to "contribute to the well-being of Singapore and its people, not just economically by producing graduate

manpower to support the economy, but also by propelling Singapore up the curve of knowledge creation through a concerted investment in R&D capabilities."

These strategies, over the years, have successfully enhanced the quality and research-intensity of Singapore's universities. The changes in NUS and NTU have been noted by the various international rankings in recent years.

More specifically, according to the Nature Publishing Group Index 2013, NTU has jumped more than 140 places to finish at 73rd globally, and 12th place in the Asia Pacific region, for the quality of its scientific papers. NUS has also done well, at 6th place in Asia Pacific.

Singapore's Emphasis on Education and STEM

The undergirding strength of our research-intensive universities is Singapore's unwavering emphasis on education, and in particular, STEM education. Since independence, a premium has been placed on education as the driving engine of economic and national development. With no other natural resources, people was our most precious asset and we have to invest in their education to realize their full potential. This is an imperative that was established by the founding political leadership and remain true today. Thus, expenditure on education has increased over the past 10 years by more than 50%-- from $6.8 billion in 2002 to $10.5 billion in 2012 and accounted for more than 20% of government expenditure.

The economic goal of education has also meant that Singapore's education system has a strong focus on the universal development of mathematics, science and technical skills (STEM). Our school curricula aim to give students a deep foundation in sciences and mathematics from a young age. Singapore's successful emphasis on STEM is reflected in our students' consistently top performance in TIMSS and PISA surveys.

But, this is a continuing journey. In response to the demands of an emerging global knowledge-based economy, Singapore's education system has undergone a paradigm shift towards a greater focus on innovation, creativity and research. Our education vision formulated in the late 90s of "Thinking Schools, Learning Nation", signified the shift from a purely knowledge-transmission education model to one that emphasises creativity and self-direction.

These policies are bearing fruit. According to the 2012 PISA findings, Singapore's students have an excellent ability in thinking flexibly and innovatively to solve complex and unfamiliar problems, which is an increasingly important trait in today's society. Singapore was also used as an example of how an education system has embedded 21st century competencies and attitudes, such as inquiry-based authentic learning. Andreas Schleicher, OECD's Acting Director for Education & Skills, said and I quote: "This data demonstrates that Singaporean students are not just spoon-fed. They are actually quite creative thinkers. They are actually able to engage with unfamiliar problems."

Therefore, the 2012 PISA results provide an indication that Singapore's education system is headed in the right direction from one based on rote-learning to creative knowledge application.

It is heartening for Singapore to receive positive feedbacks on our efforts to create a robust STEM-focused education system, as well as world-class research-intensive universities. As in all these efforts, we cannot afford to be complacent.

Global Trends: Growing Importance of, but Shortages in, High-Quality Engineering Talent

The growing importance of scientific and engineering talents in an innovation economy is well recognised. Less acknowledged, however, is the urgency to produce a new breed of engineers with new mindsets and skills.

Complex and dynamic grand societal challenges, the rapid rise of new technologies and the growing convergence of S&T disciplines, are increasingly demanding engineers to be interdisciplinary, creative, flexible and collaborative. Modern engineers also need to have global competence. As the world grows more deeply and extensively connected, engineers will require international exposure and intercultural skills so that they can remain effective in different social cultural contexts and more importantly, operate as part of cross-border efforts to tackle diverse regional or global challenges.

Yet, at this time when our demand for high-quality engineering talent and our expectations of them are increasing, many countries around the world are facing shortages of such talent. In the US, a 2012 report by President Obama's Council of Advisors on Science and Technology declared that 1 million additional STEM graduates will be needed over the next decade.

Similarly in the UK, the Royal Academy of Engineering has also reported a shortage of high caliber engineering graduates, and that the nation will have to graduate 100,000 STEM majors every year until 2020 just to match demand.

The Singapore Perspective- Challenges and Strategies to Strengthen the Pipeline of STEM/ Engineering Talent

In Singapore, our efforts to nurture broad-based proficiency in STEM and to develop research-intensive universities have led to a substantial output of Singaporean students with capabilities in STEM fields. For instance, about one quarter of our high school cohorts pursue a STEM degree in our AUs, which is six times that of the comparable rate in the US (4%). There is also a high output of engineers specifically from our education system. Our AUs together produce about 4,500 engineering graduates a year. About 12% of our high school students pursue an engineering discipline, which again is about six times that in the US (2%).

All these engineering graduates have absolutely no problem finding meaningful employment upon graduation. But, more important than quantity, we face the twin challenges of attracting and retaining the *best* students to enter engineering and science courses.

Singapore has seen a decrease in the overall quality of engineering graduates from our AUs over the last few years. This is because many of our brightest students shun engineering in favour of careers they perceive as more meaningful, prestigious or lucrative such as medicine, law, or business.

Although we have a high student participation rate in STEM, (with more than 5,400 Singaporean students taking up STEM-related jobs after graduation), we face the problem of a leaky STEM pipeline with significant crossover of fresh engineering graduates in the first 5 years of employment to other professions. In a study by NTU on the reasons behind Singapore's shortage of high-quality engineering talent, it was revealed that engineering courses and careers have lost their lustre and prestige among many of our top students.

This is a worrying trend for Singapore and we are undertaking proactive measures to correct the situation to the extent possible.

Enhancing Engineering Courses in Universities

Singapore is revising and refocusing the undergraduate engineering experience, both to improve its attractiveness, and to ensure that our engineering graduates are appropriately prepared to meet the demands placed on the modern engineer.

The internationalisation of engineering education is one critical aspect of the strategy to improve the quality and appeal of university education in general, and engineering courses specifically.

At NUS, over half of all Faculty of Engineering students (55%) gain some kind of international exposure over the course of their studies, while 30% of them participate in student exchange programmes.

This is a higher percentage than both Arts and Sciences students of between a quarter and a fifth 26% and 21% respectively. Therefore, a higher proportion of NUS engineering students are taking part in the most impactful form of international education experience—study abroad exchanges.

Similarly, in NTU, engineering students have abundant opportunities to gain international exposure—over half of all College of Engineering students participate in short-term outbound mobility programmes, which is a far higher percentage compared to other Colleges. 20% of engineering students participate in semester-long outbound mobility programmes, which is the second highest proportion after the College of Science (32%).

A*STAR also contributes significantly to international mobility in education through our scholarships programme, which was initiated to develop a pipeline of the highest quality S&T talent for Singapore. Since 2001, we have sent over 800 Singaporean PhD talent to universities overseas, to give them the international exposure needed in today's globalised scientific community.

A*STAR also offers international scholarship and fellowship programmes to attract the best foreign talent and build up a diverse R&D talent pool. To date, nearly 2,000 students from over 70 countries have been awarded either PhD scholarships or research attachments. A*STAR therefore contributes to the internationalisation of science and engineering education by sending Singaporeans to the world and bringing the world to Singapore.

We therefore applaud and share the ambition of the GE3 programme to provide engineering students with stimulating and meaningful international exposure in the course of their studies. I believe the opportunity of such international exposure would be critical in attracting more students to pursue an engineering degree and later on to pursue it as a career.

Our AUs have also developed innovative programmes to cater to the new skills required of the modern engineer and raise the appeal of engineering courses.

For example, NTU has recently introduced the Renaissance Engineering Programme (REP). This is an integrated and rigorous programme targeted at some of our best students, covering a broad spectrum of multi-disciplinary subjects, and offering the opportunity of one-year overseas study in either UC Berkeley or Imperial College London, both world-class engineering universities.

Similarly, NUS' Global Engineering Programme (GEP) involves both specially tailored leadership programmes and a strong global learning aspect – students will get to spend their fourth year at excellent partner overseas universities.

NUS' Engineering Science Programme is another innovative course that fills the need for multidisciplinary research and education in engineering sciences.

These programmes have been highly successful in attracting more bright young students to pursue engineering in university. The NTU REP Programme has seen nearly a doubling in number of applications over three years —from 90 in AY2011/12 to over 150 in AY2014/15. Graduates of these programmes are of the highest quality, and we have already seen great achievements from a number of them. For example, a NUS ESP student team prevailed over 660 international teams to enter the final stage of the Shell Ideas 360 Competition, which will be held in a few days' time. NUS ESP students have also won top prizes in a number of other international competitions, such as the 2010 IdeaLab Challenge: Future Global Competition. Given their attractiveness and success, we should consider doing more of such innovative programmes, to boost engineering education in Singapore and thereby produce the engineer-leaders of tomorrow.

At the same time, more can still be done to improve the quality and attractiveness of engineering courses.

For one, industry can be involved more closely in the university education process. Such public-private partnerships would ensure that the education curriculum meets industry needs and improve the employment outcomes of students, and provide students with a better understanding on the nature of the engineering profession.

Such efforts would also go a significant way in mitigating the leakage of STEM talent to other sectors of the economy.

In Singapore, we have started an Industrial Postgraduate Programme (IPP) to develop a pool of postgraduate manpower with the essential and critical R&D skill-sets for roles in the industry. Trainees are provided with postgraduate training in a corporate R&D environment and in partnership with local universities. Such a programme is indicative of a recognition that investment in the STEM talent pipeline must be a collaborative effort between all stakeholders in the RIE ecosystem.

Enhancing Engineering Talent at Polytechnics and Institutes of Technical Education (ITE)

Besides the universities, our polytechnics and Institutes of Technical Education (ITE) also play an important role in generating STEM talent for Singapore. Their mission is to develop practice-oriented manpower with the relevant knowledge and skills to meet the needs of Singapore's economy.

Thus, more than half of the courses offered in our polytechnics and ITE are STEM-related, with a strong emphasis on applied learning. We are therefore heavily engaging these institutions in efforts to strengthen the pipeline of engineering talent.

Like the universities, our polytechnics have also been experiencing the challenge of top students eschewing engineering for diplomas in business, media studies and life sciences. One response to this situation is the introduction of hybrid courses in order to change the face of engineering and make it more popular. These multi-disciplinary programmes, which marry engineering with business studies or the life sciences, are gaining greater traction with students interested in STEM, and are also improving the quality of engineering students.

Another key recent initiative is the Applied Study in Polytechnics and ITE Review Committee or ASPIRE, chaired by the Senior Minister of State of Education Indranee Rajah. The Committee aims to improve applied education pathways—by creating more exciting learning and career opportunities for students entering STEM-related areas, and by better matching students' strengths and interests to industry needs.

The consequences of a mismatch can be seen in the US, where despite the apparent STEM talent shortage, many science and engineering graduates are still struggling to find employment, which in turn adversely affects the inclination of prospective graduates to enter STEM careers. Therefore, the work that will be undertaken by ASPIRE will be important in maintaining a STEM talent pipeline that is most relevant and beneficial for Singapore's economy.

STEM Promotion and Outreach

Of course, we all realize that nurturing a pipeline of STEM talent must start before the university, polytechnic or ITE. In fact, we need to spark the interest and enthusiasm of students in STEM as early as possible in the school system. Reports from the UK and the US have attributed their STEM shortages to the lack of awareness among young students about science and engineering professions, and

misperceptions that they are boring and uncreative. This is a severe information gap because while we know that science and engineering have been fundamental to societal and economic well-being today; recognition has lagged far behind their actual contributions.

Therefore, drawing from the findings in the US and UK Study, in Singapore, we focus a significant part of our efforts on building our youth's passion for science, technology and engineering while they are still in elementary and high school. This is to encourage them to view STEM as exciting and meaningful careers from a young age. A recent initiative is the introduction of Applied Learning programmes in secondary schools over the next few years, to help students connect knowledge across disciplines, stretch their imaginations and translate classroom lessons into real-world applications. This new approach aims to make applied learning and engineering more attractive to our young students.

Another way to stimulate student interest in STEM is to immerse them in research opportunities in real lab experience. In this area, A*STAR plays an important role through our research exposure and attachment programmes, whereby students considering a career in STEM are invited to work alongside our researchers, which often further inspires them to pursue a future in science and technology.

Similarly, the Centre for Research and Applied Learning in Science (CRADLE) at the Singapore Science Centre offers students hands-on experimentation to deepen their interest in STEM. Other outreach activities include a variety of national science competitions, festivals and fairs, all of which have contributed to enthusing and engaging students in STEM.

Providing Meaningful Career Pathways for Engineers

Endeavours to strengthen the pipeline of engineering talent would be to no avail if we did not also provide ample meaningful and rewarding job opportunities for our graduates.

In the US, several reports have stated that the real problem behind the shortage of high-quality STEM talent is not so much the lack of graduate numbers, but the decreasing attractiveness of science and engineering careers, characterized by instability and slow-growing wages.

Similarly, in Singapore, the NTU study on the decline in quality of engineering talent showed that this was due to the perception among top students that the engineering profession had limited career prospects and rewards and recognition.

Therefore, our focus cannot just be on churning out more STEM graduates.
It must also create more STEM jobs that are diverse, enduring and satisfying.

This is a matter that the public sector is taking a very close look at. In particular, we need to better encourage our local companies to develop in-house research and innovation capabilities, instead of just leveraging on the public sector.

This would generate greater job opportunities and dynamism in the engineering industry, and thereby make it more attractive for prospective students.

Conclusion

To conclude, let me once gain applaud the initiative and efforts of the GE3 programme to provide engineering students all around the world with a more meaningful and interesting educational experience.

International exchange programmes are a growing imperative in educating the engineers of tomorrow, and will continue to be an important means of raising the attractiveness of engineering courses for future students. Singapore therefore fully supports creating even more opportunities to internationalise the experience of our engineering students.

At the same time, in today's technologically-driven knowledge economy, profound changes to engineering education must take place to meet the growing demands for a new breed of modern engineers.

I therefore greatly welcome the plenary discussions that will take place in this conference which will address strategies and best practices in educating high-quality engineering talents for the 21st century.

These discussions are very timely and will help position Singapore to build up a strong talent base for the global economy's future needs.

On that note, let me wish everyone a meaningful and fruitful meeting.

Thank you.