Injecting an Entrepreneurial Dimension to Science and Engineering Education: The Experience of National University of Singapore (NUS)

Wong Poh Kam
Assoc. Professor, NUS Business School
& LKY School of Public Policy
Director, NUS Entrepreneurship Centre

Conference on Global Innovation Ecosystem,
Kyoto, Sept. 8-9, 2006

Singapore's Challenge in Competing in the Global Knowledge Economy

- Singapore has achieved rapid economic growth in the past 4 decades primarily by leveraging foreign direct investment
- To sustain growth in the future, Singapore needs to be able to compete effectively in knowledge-intensive industries and services, where the ability to *innovate* and *commercialize knowledge* is critical
- While Singapore has made good progress in investing in innovation, there is a need for greater entrepreneurial growth
- Singapore's tertiary S&T educational system thus needs to be able to produce graduates that have both the *S&T knowledge* and *mindsets* relevant for such knowledge-intensive sectors

NUS National University of Singapore

Both entrepreneurship & innovation contribute to economic growth…

GDP/worker growth rate p.a. 1998-2002	Type of Entrepreneurship			
	High Growth Potential TEA	Opportunity TEA	Necessity TEA	Overall TEA
Adj R sq (control)	0.559	0.559	0.559	0.559
Adj R sq	0.648	0.603	0.605	0.602
F	17.571**	14.676**	14.769**	14.634**
Independent Variables (values are standardised coefficient estimates)				
(Constant)	t=5.995**	t=4.048**	t=4.019**	t=3.593**
Log of Base year GDP per worker	-0.536**	-0.475**	-0.529**	-0.491**
Growth in Capital investment per worker, 1997/98 – 2001/02	0.602**	0.625**	0.597**	0.614**
Entrepreneurial propensity (TEA)	*0.207**	0.029	-0.066	-0.007
Innovation intenisty (Ratio of USPTO granted patents to GDP, 1997-2001)	*0.284***	*0.275***	*0.268***	*0.275***

Source: Wong & Ho (2005), TEA data based on 37 countries covered in GEM 2002

* significant at 10% ** significant at 5%

Singapore has achieved rapid economic growth by emphasizing its role as a regional hub for global manufacturing and services MNCs… …

Singapore's Aggregate Economic Growth Performance, 1960-2004

	% real growth p.a				
	1960-70	1970-80	1980-90	1990-2000	2000-04
GDP	8.7	9.4	7.1	7.5	2.7
Labour productivity	n.a	4.3	4.8	3.4	2.1
	S$ at current prices				
GNI per capita[1]	1970	1980	1990	2000	2004
	2,820	9,900	20,100	39,600	41,500

[1] GNP per capita prior to 1997

Source: Calculated from Yearbook of Statistics Singapore (various years), Economic Survey of Singapore (various years). Per capita GNI obtained from Singstat website http://www.singstat.gov.sg/keystats/hist/gnp.html. Mid-year population estimate for 2000 obtained from Singstat website, http://www.singstat.gov.sg/FACT/KEYIND/keyind.html

Singapore's investment in R&D has also increased significantly in recent years…

Comparative R&D Indicators, Singapore vs. Selected OECD/Asian NIEs

Grouping	Country	Year	R&D/GDP (%)	Researchers per 10,000 Labour Force
G-5	Japan	2002	3.1	99
	Germany	2002	2.5	69
	U.S.A	2002	2.7	86[a]
	U.K	2002	1.9	55[b]
	France	2000	2.3	75
Industrialized Small Countries	Finland	2002	3.5	140[c]
	Switzerland	2000	2.6	63
	Sweden	2001	4.3	106
	Ireland	2001	1.1	51
	Netherlands	2001	1.9	55
	Denmark	2002	2.5	93
	Norway	2002	1.7	78[a]
	Australia	2000	1.5	68
	New Zealand	2001	1.2	70
Asian NIEs	Korea	2002	2.5	64
	Taiwan	2001	2.2	61
	Hong Kong	2002	0.6	na
	Singapore	**1990**	**0.8**	**28**
	Singapore	**1996**	**1.4**	**56**
	Singapore	**2003**	**2.2**	**79[d]**

a 1999 figure b 1998 figure c 2001 figure d RSEs per 10,000 labour force

Source : Wong and Singh 2005

Resulting in rapid increase in Singapore's scientific output intensity since the mid-1990s…

Growth of Science & Engineering articles: 1988–2003

Country/economy	1988	1996	2003	Average growth rate 1988-2003
All countries	466,419	593,568	698,726	3.32
United States	177,662	201,798	211,233	1.26
Finland	2,789	4,354	5,202	5.77
France	21,409	29,755	31,971	3.29
Germany	29,292	39,123	44,305	3.42
Ireland	790	1,269	1,758	8.17
Netherlands	8,581	12,438	13,475	3.80
Sweden	7,573	9,697	10,237	2.35
United Kingdom	36,509	47,904	48,288	2.15
Switzerland	5,316	7,489	8,542	4.05
Japan	34,435	50,392	60,067	4.96
China	4,619	10,070	29,186	35.46
Singapore	**410**	**1,181**	**3,122**	**44.10**
South Korea	771	4,728	13,746	112.19
Taiwan	1,414	5,696	9,270	37.04

Notes: Article counts from set of journals classified and covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles assigned on basis of institutional address(es) listed on article. Articles on fractional-count basis
Source: National Science Foundation, Science and Engineering Indicators 2006

…with increasing share in world S&T publications

(source: King 2004)

	% of world publications		% world pub. citations		% of world top 1% most cited	
Period	**1993-1997**	**1997-2001**	**1993-1997**	**1997-2001**	**1993-1997**	**1997-2001**
USA	37.46	34.86	52.30	49.43	65.60	62.76
UK	9.29	9.43	10.87	11.39	11.13	12.78
Germany	8.05	8.76	8.63	10.02	8.59	10.40
Japan	8.69	9.28	7.54	8.44	6.03	6.90
France	6.11	6.39	6.37	6.89	6.05	6.85
Switzerland	1.73	1.84	2.65	2.95	3.45	4.12
Sweden	1.91	2.01	2.43	2.50	2.15	2.46
Israel	1.25	1.27	1.25	1.33	1.30	1.50
Finland	0.86	0.96	1.03	1.14	0.89	1.10
China	2.06	3.18	0.95	1.56	0.44	0.99
India	2.19	2.13	0.76	0.86	0.32	0.54
Korea	0.81	1.53	0.44	0.88	0.28	0.78
Taiwan	0.98	1.25	0.52	0.69	0.26	0.51
Ireland	0.30	0.35	0.25	0.35	0.35	0.36
Singapore	**0.27**	**0.42**	**0.15**	**0.25**	**0.11**	**0.26**

…Singapore's patenting output has also increased rapidly since the late 1990s…

International Comparisons of USPTO Patenting Output

Benchmark Countries	All Patents				All Patents per 10,000 Population			
	1985	1995	2000	2004	1985	1995	2000	2004
Singapore	**10**	**61**	**242**	**485**	**0.036**	**0.172**	**0.599**	**1.114**
Large OECD								
USA	43394	64510	97011	94129	1.820	2.420	3.436	3.183
France	2516	3010	4173	3686	0.456	0.518	0.703	0.610
Germany	6906	6874	10824	11367	0.889	0.842	1.317	1.379
United Kingdom	2620	2685	4092	3905	0.463	0.460	0.687	0.646
Japan	13351	22871	32922	37034	1.106	1.825	2.598	2.908
East Asian NIEs								
South Korea	50	1240	3472	4671	0.012	0.274	0.735	0.960
Taiwan	199	2087	5806	7207	0.103	0.981	2.621	3.148
Hong Kong	66	248	548	641	0.121	0.397	0.823	0.935
Small European Economies								
Ireland	31	55	137	197	0.088	0.152	0.361	0.496
Israel	185	432	836	1092	0.454	0.814	1.431	1.762
Finland	223	387	649	954	0.455	0.758	1.256	1.830
Netherlands	834	894	1410	1537	0.576	0.578	0.887	0.942
Sweden	954	914	1738	1388	1.142	1.036	1.959	1.545
Switzerland	1274	1187	1458	1405	1.941	1.656	2.008	1.886
Emerging Economies								
China	1	63	163	597	9.5E-06	5.2E-04	1.3E-03	4.6E-03
India	11	38	131	376	1.4E-04	4.1E-04	1.3E-03	3.5E-03

Source: Wong & Ho (2006), computed from Database of USPTO (various years) and NUS database of US Patents
Nationality of patent defined by residency of first inventor

…resulting in increasing share in world total patenting output

Share in world patenting and most highly cited patents

	Utility patents (at least one inventor) in each country as share of world total			Share of Top 5% most highly cited		
	1976 to 1985	1986 to 1995	1996 to 2004	1976 to 1985	1986 to 1995	1996 to 2004
Singapore	**0.01**	**0.04**	**0.22**	**0.00**	**0.05**	**0.36**
USA	60.01	54.01	54.48	72.88	73.57	72.83
France	3.40	3.24	2.67	2.14	1.57	1.19
Germany	6.85	8.25	6.97	3.39	2.92	2.45
UK	3.87	3.03	2.66	3.15	2.14	1.86
Japan	12.91	21.50	20.96	11.26	15.12	14.63
Taiwan	0.10	0.95	2.85	0.04	0.49	2.43
Korea	0.02	0.50	2.22	0.03	0.25	1.38
Hong Kong	0.04	0.07	0.14	0.06	0.05	0.13
Ireland	0.03	0.06	0.10	0.03	0.09	0.10
Israel	0.21	0.36	0.63	0.25	0.45	0.80
Finland	0.17	0.33	0.51	2.70	2.41	3.94
Netherlands	1.12	1.05	0.98	3.59	2.78	2.13
Sweden	0.89	0.89	1.02	3.05	3.25	3.25
Switzerland	2.10	1.50	1.10	2.95	2.68	1.43
China	0.00	0.06	0.19	0.00	0.04	0.07
India	0.03	0.04	0.16	0.03	0.02	0.04

Patents where at least one inventor resident in the specified nation
Source: Wong & Ho(2006), computed from Database of the USPTO (various years)

Singapore's Continuing Dependence on Foreign MNCs

- In spite of the great progress Singapore made in economic development and S&T output, the economy is still highly dependent on foreign MNCs
  - – Foreign MNCs continue to account for more than two-third of Singapore's electronics industry output and over 90% of Singapore's pharmaceutical/life science industry in recent years
  - –Foreign firms accounted for over 2/3 of manufacturing R&D and over half of services R&D in recent years
  - –Foreign assignees accounted for more than half of Singapore's USPTO patenting until the early 2000s
- The significant growth of indigenous R&D and S&T outputs has yet to be translated into many local high tech enterprises of significant scale that can compete globally

Thus, while Singapore has done relatively well in S&T outputs, the economy needs to become more entrepreneurial…

GEM 2005 - TEA Prevalence Rate & Rank in OECD

	2005		2004	
Country	Rate (%)	Rank	Rate (%)	Rank
NEW ZEALAND	17.6	1	14.7	1
UNITED STATES	12.4	2	11.3	4
AUSTRALIA	10.9	3	13.4	3
ICELAND	10.7	4	13.6	2
IRELAND	9.8	5	7.7	6
CANADA	9.3	6	8.9	5
NORWAY	9.3	7	7.5	7
SINGAPORE	7.2	8	5.7	11
GREECE	6.5	9	5.8	10
UNITED KINGDOM	6.2	10	6.3	8
SPAIN	5.7	11	5.2	13
GERMANY	5.4	12	4.5	15
FRANCE	5.4	13	6.0	9
FINLAND	5.0	14	4.4	16
ITALY	4.9	15	4.3	17
DENMARK	4.8	16	5.3	12
NETHERLANDS	4.4	17	5.1	14
SWEDEN	4.0	18	3.7	18
BELGIUM	3.9	19	3.5	19
JAPAN	2.2	20	1.5	20
Overall	7.3		6.6	

Rank among subset of OECD countries that participated in both GEM 2004 and 2005 surveys.

…Particularly among the Tertiary Educated, Which has been increasing rapidly, especially in S&T fields…

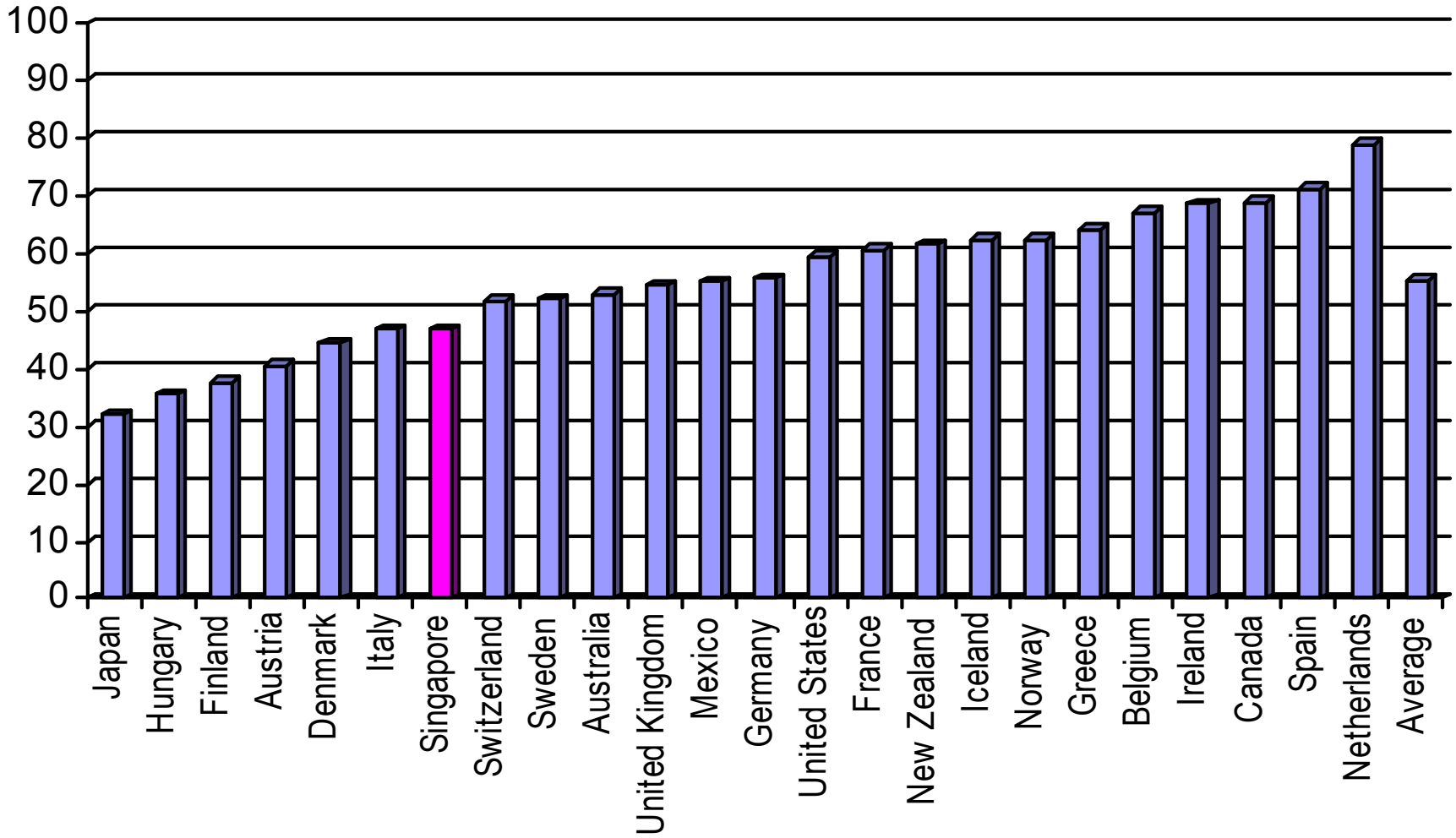
Average Output of Technical Manpower from Tertiary Education Institutions in Singapore, 1970–2004 (No. of graduates per year)

	1970-79	1980-84	1985-89	1990-94	1995-99	2000-2004
University level [a]	680	1,040	2,162	3,215	5,027	8,210
Polytechnic level [b]	1,516	2,463	4,836	6,686	8,595	11,079
Total	*2,197*	*3,504*	*6,998*	*9,901*	*13,622*	*19,289*
University graduates as percentage of total						
	31.0	29.7	30.9	32.5	36.9	42.6

a Includes degree courses from SIM
b Includes diploma courses from ISS and SIM
Calculated from: Singapore Yearbook of Labour Statistics (various years), Singapore Yearbook of Manpower Statistics (various years)

…but change in *Mindset* and *Societal Value* is needed…

GEM 2005 – Starting Business is a Good Career Choice in OECD Countries



Challenges in Tertiary S&T Education in Singapore

- Overall, Singapore has done relatively well in raising the quality of tertiary S&T education, as measured by
  - – overall international ranking of Singapore's universities
  - – increasing attraction of high quality foreign students and faculty
- However, as Singapore's economy shifts towards a knowledge-based economy, with greater emphasis on innovation leading to the creation of intellectual property and its subsequent commercialization in industries, science and engineering graduates not only need to be better equipped with knowledge and skills related to technology commercialization, but also should be nurtured with an *enterprising mindset*
- there is a thus a need to inject an *entrepreneurial dimension* to the traditional curriculum of Science and Engineering educational programs

Recent International Ranking of NUS

- **Ranked 5th in Asiaweek's list of Asia's Best Universities 2000**
- **Ranked 18th and 22nd in the 2004 & 2005 Times Higher Education Supplement Ranking of top 2000 universities in the World**

	2004 ranking	2005 ranking
Overall	18	22
Biomedicine	25	15
Science	35	34
Engineering and IT	9	9
Social Sciences	10	13
Arts and Humanities	17	56

- **NUS is ranked 31st in the world by Newsweek in 2006, top 3 in Asia**

Source: Knowledge Enterprise Online, various issues, downloaded from http://newshub.nus.edu.sg/; The Times Higher Education Supplement (various years)

Injecting an Entrepreneurial Dimension to Tertiary Education: The experience of National University of Singapore

- **Until the end of 1990s, NUS follows traditional British university model of teaching as primary mission, research as secondary function**
- **Major impetus for change in late 1990s:**
  - –Economic slowdowns precipitated by Asian Financial crisis
  - –Growing recognition by policy makers of the need to increase entrepreneurial dynamism of economy
  - –Appointment of a new Vice Chancellor with new visions
    - **Harvard trained, research leadership role at a leading US university and corporate experience at a major US corporation**

Support from Top Political Leadership

"...the three primary roles which a world-class university should play in a modern economy and society:

i. delivering quality undergraduate education;

ii. developing graduate education and research; and

iii. fostering *entrepreneurship* and industry involvement."

Dr Tony Tan Keng Yam, Deputy Prime Minister And Minister For Defence, Official Opening Of NUS' Prince George's Park Residences, 12 August 2002

New Vision of NUS as an "Entrepreneurial" University

- **"NUS aspires to stand among the entrepreneurial universities. This is in line with our vision to become a global knowledge enterprise. We have taken steps to inject an entrepreneurial dimension. We have established NUS Enterprise: A *FREE ENTERPRISE ZONE,* where innovation and entrepreneurship are freed from traditional rules…"**

-- Prof Shih Choon Fong,
State of University Address 2002, 13 August 2002

Creation of a new Organizational Unit -- NUS Enterprise

- Establishment of NUS Enterprise as a new Division in the University that groups together existing units as well as hosts the creation of new units relevant to the enterprise mission
- Appointment as CEO an engineering school professor who was among the first faculty to have founded a spin-off to commercialize his inventions
- Started with a broad mission to "inject more entrepreneurial dimension to NUS education and research", later refined to embrace more specific missions ("An agent of change, promoting the spirit of innovation & enterprise within the NUS community, and generating value from university resources")

NUS Enterprise's Key Initiatives

- **Reform university policies on technology commercialization and industry linkages**

  Reorganized the **Industry and Technology Relations Office (INTRO)** to make it more "inventor friendly" and to emphasize "service to faculty" - more recently renamed as **Industry Liaison Office (ILO)**

- **Expansion of Entrepreneurship Educational Program for all students in NUS**

  Creation of **NUS Entrepreneurship Centre** to initiate a new Technopreneurship Minor Program for all NUS undergraduates, which increased the enrolment of students in entrepreneurship courses from <300 before 2000 to >1400 in AY2005/06

- **Introduce the Overseas College Program (NOC) to offer an "immersion" approach to international entrepreneurship education**
- **Development of extensive entrepreneurship development program outside the traditional classroom for the NUS and Singapore entrepreneurial community**
- Annual national and international business plan competition (StartUp@Singapore, global StartUp@Singapore)
- Networking links with the high tech venture community in Singapore
- **Establishment of Venture Support (NVS) Program to provide assistance for NUS community to engage in new venture activities (incubator, spin-off seed funds)**
- **Initiate Research on Entrepreneurship and Innovation**

Strategic Intents of Entrepreneurship Educational Programs

- Focus on Mindset Change in addition to imparting skills and knowledge
  - –Employee mentality of students
  - –Administration needs to be flexible
- Provide Opportunity for greater Experiential Learning
  - –bringing industry relevance and start-up excitements into the classroom
  - –engaging students in “learning by doing” and real-life challenges outside the classroom
- Start with undergraduates and integrate the entrepreneurial elements into students’ technical learning process, rather than have them take business-related courses after several years of working experience as in the traditional MBA model

Integrating Globalism & Entrepreneurship: The NUS Overseas College initiative

- Aim is to send up to 250 NUS undergraduate students per year to five high tech entrepreneurial hubs in the world

- **"Learning by immersion" Model**

  Work as interns in high-tech start-ups for one year
  Take entrepreneurship-related courses in leading universities in the host region
  Return to NUS to complete their final semester/year

  Infuse entrepreneurial, global mindset
  Influence future career choices towards entrepreneurial and innovative settings
  Establish social networks with overseas entrepreneurial communities
  Serve as catalyst for mindset change among their peers in NUS when they return

- First NOC established in Silicon Valley in 2001 (partnering Stanford), followed by Philadelphia in 2002 (U. Penn), Shanghai in 2004 (Fudan), Stockholm in 2005 (KTH), and Bangalore in 2006 (IIS)

Promoting high tech spin-offs: The NUS Venture Support (NVS) Program

- Primary Aim is to nurture spin-offs that seek to commercialize NUS Intellectual Property as well as other innovative start-up companies involving NUS students, staff, alumni until they receive significant external funding
  - Incubator – facilities on campus to incubate up to 80 companies
  - Seed Funding – NVS Seed Fund (S$5 million) and Student Enterprise Seed Fund, with co-funding from Singapore Government
  - Mentoring – Network of experienced entrepreneurs and venture investors to provide mentoring to NUS spin-offs
- The program also has an educational component in that it provides a "Learning-by-Doing" environment on campus for entrepreneurially-minded students and professorrs
- The long-term goal is to produce role models and infuse the NUS community with a culture and mindset for innovation and enterprise

Raising Innovative Capacity: The Singapore-MIT Alliance Program

- Established in 1998, the Singapore-MIT Alliance (SMA) is an innovative engineering and life science educational and research collaboration involving the National University of Singapore (NUS), the Nanyang Technological University (NTU), and MIT, with students recruited globally
- The program is intended to combine a focus on creativity and entrepreneurship with an intense, hands-on approach to research, leveraging on MIT's experience in developing industrial collaboration and fostering innovation and entrepreneurship among its students. All students will reside a minimum of one semester at MIT. In Singapore, they will attend "live" MIT classes and take part in research meetings with MIT faculty, staff and students through video-conferencing
- The success of the program has led to the establishment in 2006 of the Singapore-MIT Alliance for Research and Technology (SMART) Center in Singapore to support joint research between MIT and Singaporean researchers. The centre will house a new Centre for Technological Innovation (modeled upon the Deshpande Center for Technological Innovation at MIT), to foster collaboration with industry in Singapore/Asia

Other innovation-oriented educational initiatives

- **Management of Science & Technology MSc Program in the Engineering School**
  - While a Management of Technology (MOT) MSc program had been offered in the Business School in the 1990s, this was discontinued
  - the new MOST program is offered in the Engineering School to provide a closer integration with the engineering course curriculum. A minor in MOST was also introduced for selected engineering undergraduate students
- **Intellectual Property Management MSc Program in the Engineering School**
  - The intent of this new program is to turn engineering and science graduates into postgraduate professionals who understand both technical and intellectual property issues

Preliminary assessment of impacts

- **As most of the new educational initiatives are still in an early stage, assessment of impact is necessarily preliminary in nature**
- **Nevertheless, there are encouraging signs**
  - – Enrolment in the Technopreneurship Minor program has grown significantly from less than 300 in 2000 to over 1300 in 2006; response to the Singapore-MIT Alliance and the new MOST and MIP initiatives also exceeded expectations
  - –Technopreneurship Minor and NOC program graduates have exhibited greater entrepreneurial propensity in terms of starting new ventures or involving in start-up companies
  - –Positive response by recruiters of graduates with Technopreneurship/NOC program exposure
  - – Increasing number of foreign students are applying to NUS because of interest in technology entrepreneurship
  - –Increase in invention disclosure, patent application and granted, with growing involvement of students
  - – Interest in start-ups among students and faculty has visibly increased in terms of number of applications for NVS funding and actual number of spin-off companies formed

Challenges Faced in Implementing the New Educational Initiatives

- Resistance by conventional Faculty who are concerned that the technical contents of the S&T curriculum will be diluted
- Concerns with the high cost involved in courses that have a significant experiential learning element (particularly the NOC program)
- Concerns that technology commercialization orientation may distract faculty from pursuing scientific research excellence, or compromise the independence and objectivity of faculty research
- Objection to the use of university resources to support technology commercialization activities at the expense of research
- Unrealistic expectation of results (e.g. revenue from technology commercialization, immediate change in student career choices)

Lessons Learned: Factors that facilitated Implementation of the new initiatives

- Leadership from the Top
- Organizational Innovation & Long-Term Resource Commitment
- Recruit the Right Champions to Lead the Change
- Leveraging of global educational leaders as program partners (MIT, Stanford)
- Growing "Voice" of alumni, students and industry expressing support for the initiatives