Consultant Report

Securing Australia's Future

STEM: Country Comparisons

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Country Report Singapore STEM

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Preface

This country report on Singapore Science, Technology, Engineering and Mathematics (STEM) education is divided into eight main sections: (1) attitudes towards STEM and the priority given to STEM, in families, the community/media, government, educational institutions, employers and professional bodies; (2) the perceived relevance of STEM to economic growth and well-being; (3) current patterns of STEM provision in schooling, including STEM in primary education, and its influence on later participation in STEM, enrolments in STEM disciplines in secondary education, and STEM provision and participation in tertiary (university and non-university) education; (4) the role of STEM disciplines in both general education and vocational and occupationally-specific programs in education and training; (5) student uptake of STEM programs and factors affecting student performance and motivation; (6) access of STEM graduates to the labour markets, and labour market take-up of STEM knowledge and skills; (7) strategies, policies and programmes used to enhance STEM at all levels of education, and judgments concerning the success of those programmes; and (8) consideration of the potential applicability of those policies, strategies and programs to Australia.

The preparation of this country report on Singapore STEM involved close cooperation among all the project members, namely Professor Dato' Dr. Noraini Idris, Dr. Mohd Fadzil Daud, Dr. Chew Cheng Meng, Dr. Leong Kwan Eu and Mr. Ahmad Dzohir Ariffin @ Maarof. We have met regularly to brainstorm ideas and discuss improvements to the initial drafts. Each member took primary responsibility for his or her particular sections. However, every member contributed valuable ideas and suggestions to complete the final draft of the country report.

Project Leader
Professor Dato' Dr. Noraini Idris
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Executive summary

Singapore was one of the top-performing countries in the 2009 Programme for International Student Assessment (PISA) survey. In addition, according to the Trends in International Mathematics and Science Study (TIMSS) in 1995, 1999, 2003, 2007 and 2011, Singapore is among the top-scoring nations in the world in both Mathematics and Science. These achievements reflect the country's STEM based education system.

To understand the practices and policies surrounding the government's program related to the education system, this report presents the findings relating to STEM based education in the country. This report presents the findings gathered through data analysis of published statistical data and articles from the country's official websites, transcripts of speeches by high ranking officers published at the Ministry of Education website, annual reports of various related agencies, published articles related to the country's educational system, and official visits to the ministry of education and schools.

This report outlines the general education system, with specific attention to the diversity and inclusion of STEM disciplines in the country. Finally, the report outlines ways in which the Australian government could consider taking initiatives to enhance STEM based education in the country.

Attitudes towards STEM and the priority given to STEM

Families

Singaporean parents strongly support STEM education as evidenced in the key findings of Raytheon's (2010, p. 1) study:

- 51% of parents in Singapore receive more instruction from educators about how to assist children with math
- 42% of parents in Singapore report the use of tutors for mathematics help for their children
- One third of students in Singapore participated in math competitions
- Children in Singapore are more actively engaged in math-related learning, including the use of math worksheets, workbooks, or assessment books not assigned through school, math competitions, robotics fairs/competitions, and camps focused on math or science
- 92% of Singapore students are engaged in some form of out-of-school math learning.

Raytheon (2010, p. 12) concluded that 'Collectively and collaboratively, stakeholders must employ effective math practices already in place in other parts of the globe. High math performance at the middle-school level most readily occurs when all parties involved in educating students are highly and actively engaged. Singapore, a country that consistently cultivates a top-performing student body in mathematics, demonstrates the following:

- Parental involvement in math help and the provision of math resources: According to Raytheon's report, 39 percent of parents in Singapore use a maths tutor to help their children, compared with 16 percent in the United States and England.

- Educator communication regarding math assignments and exams: 51 percent of Singapore parents report getting help from their child's school or another

organization to help prepare for maths exams, compared with 25 percent in both England and the U.S. (Raytheon, 2010).

- Commitment to excellence in the provision of both remedial and enrichment math instruction: According to the report, 26 percent of Singapore students participated in a camp or extracurricular activity focused on maths, compared with 11 percent in the U.S. and 7 percent in England.
- Student engagement in active math learning such as competitions, camps, and games: According to Raytheon's report, 33 percent of Singapore students (ages 10-14) participated in a maths competition over the past year, compared with 20 percent in England and 9 percent in the U.S.

Parent Support Group (PSG) plays an active role in facilitating STEM education through the following activities:

- organize orientation courses for new parents
- organize extra tutoring classes for students
- create events to appreciate the teachers in their respective schools
- organize talks with parents on the importance of online safety
- provide tips on monitoring the computer usage of their children.

Parent Support Group is set up for each school in Singapore with full support from the Ministry of Education. All parents are encourage to join and actively involved in school activities through this group. According to the website of the Ministry of Education, (http://parents-in-education.moe.gov.sg/parents-in-education), the support group can contribute in the following ways:

- Attending PSG meetings;
- Providing feedback and suggestions on parental involvement through the PSG executive committee;
- Taking leadership positions in the PSG Executive Committee when called upon;
- Attending and supporting school functions and events as members of the PSG;
- Recruiting other parent volunteers to join the PSG;
- Representing parents' voices and providing constructive feedback to help school sustain improvement;
- Offering professional and personal expertise to the PSG to help improve its processes; and
- Supporting and advocating the school's mission, vision and directions.

The following example provides the list of activities organized by Parent Support Group at Woodgrove Secondary school Singapore in 2012. Further details can be found at http://www.woodgrovesec.moe.edu.sg/

DATE	TIME	MEDIUM	PROGRAMME
11 Feb, (Sat)	9am – 6pm	Mandarin	Topic: **Families-In-Action** Speaker: Ms Ngiow May Lee of Fei Yue Community Services Registration Fee: $10/= per family (include lunch and tea)
18 Feb, (Sat)	9am – 6pm	English	Topic**: Families-In-Action** **(Workshop for Parents & Teens)** Speaker: Mr Elias Loo of Fei Yue Community Services Registration Fee: $10/= per family (include lunch and tea)
25 Feb, (Sat)	9am – 12pm	All are welcome	Topic: Welcome Tea for Parents
3 Mar, (Sat)	9am – 12pm	English	Topic: Coffee Talk with the Discipline Master
24 Mar, (Sat)	9am – 12pm	All are welcome	Topic: Coffee Talk with the School Counsellors
31 Mar, (Sat)	9am -- 12pm	All are welcome	Topic: Coffee Talk with the School Leaders
21 Apr, (Sat)	9.30am – 11am	All are welcome	Connecting with Generation 'Y' children (3 Languages)
8 May (Tues)	8am – 11 am	All are welcome	Food from the Heart Day
12 May, (Sat)	9am -- 12pm	All are welcome	Baking Session with your Teens - Family Bonding
19 May, (Sat)	9am -- 12pm	English	EQ, IQ and AQ workshop (EL)
26 May, (Sat)	9am -- 12pm	English	Helping my child cope with exam stress PSG Meeting cum CIP Discussion
2 June (Sat)	9am -- 12pm	All are welcome	PSG Meeting cum Aesthetics Night
23 Jun, (Sat)	9am -- 12pm	English	How to talk and share with your teenager about sex, love and dating
30 Jun, (Sat)	9am -- 12pm	All are welcome	PSG CIP Day
7 Jul, (Sat)	9am -- 12pm	English	Monitoring Games Addiction
14 July, (Sat)	9am -- 12pm	All are welcome	Speech Day
20 Jul, (Sat)	7.15am – 2.15pm	All are welcome	PSG Racial Harmony Food and Games Fiesta
28 Jul, (Sat)	9am -- 12pm	Mandarin	Raising Motivated Teens (CL)
30 Jul, (Mon)	8am – 11am	All are welcome	Food from the Heart Day
11 Aug, (Sat)	9am -- 12pm	Mandarin	EQ, IQ and AQ workshop (CL)
18 Aug & 25 Aug, (Sat)	9am -- 12pm	All are welcome	Yoga @ Mr Thurairaj (2 sessions)
30 Aug, (Thurs	9am -- 12pm	All are welcome	Teachers' Day Celebration
8 Sept, (Sat)	9am -- 12pm	All are welcome	PSG Family Day
28 Sept, (Fri)	8 am – 11am	All are welcome	Food from the Heart Day
13 Oct, (Sat)	9am -- 12pm	All are welcome	PSG Meeting
20 Oct, (Sat)	9am -- 12pm	English	Managing the rebelliousness and misbehaviour of your Teens
21 Dec, (Sat)	9am -- 12pm	English	Sec 1 Registration Sec 1 Talk by Principal

Most parents in Singapore belong to the middle class category but they have a very positive attitude tp STEM related fields. They know that doing well in the subjects of mathematics and science in schools is one way of improving their socio-economic status by securing high earning jobs. With that in mind, they give strong encouragement and support to their children to take STEM related subjects in schools. Many parents would send their children for private tutoring after school hours to improve the achievement scores in these two subjects if they are able to afford it. This is where family income plays a factor (Dahl & Lochner, 2005).

About 30% of parents from a cohort have a degree from the 4 public universities in the country. Nonetheless, there is a high awareness among parents that STEM related fields is the way to go forward in life in line with the government policy. This influences how they guide their children to work in the STEM related jobs in the future.

Singapore has been able to be among the top three performers in the TIMMS study (TIMSS 2003, 2007, 2011) on achievement in science and mathematics. TIMMS studies had consistently shown that students with more reading resources at home have higher scores in the mathematics and science (TIMSS 2011, p.158). There is a

strong relationship between parents with higher education and the achievement of their children. Students from homes with more literacy resources have higher achievement on average in mathematics and science compared to students with less literacy resources (TIMSS 2003, TIMSS 2007). Singapore is one of the countries with 30% of the students reporting having more than 100 books at home. Higher level of parents education are associated with on average higher achievement in science in most countries with students in Singapore reporting 20% of both their parents have tertiary education.

The community / media

Community partners such as social service agencies, alumni and government agencies also play an important role in complementing the efforts of schools that benefit the students. The Ministry of Education takes great effort to work closely with the community and self-help community groups such as the Malay Mendaki, Indian Sinda and Chinese Development Assistance Council (CDAC) to provide a quality and holistic educational experience that includes extra tutoring on the STEM related subjects mainly for weaker and underachieving students. These community organisations are usually self-funded by members of each community to provide assistance for the children in need.

As most Singaporeans live in Housing Developing Board (HDB) flats, the country has developed a system of local town and community councils that identify families in the lower socio-economic status (SES) and provide a range of support including financial assistance in STEM related subjects. This is to reduce the gap between the underachieving students with lower SES and students with higher SES for all subjects including science and mathematics for both primary and secondary students.

The media has been very supportive of the role of STEM in the country. Magazines and newspapers have highlighted the careers in STEM related fields and also provided avenues for STEM related companies to put advertisements on job opportunities. Documentary on R&D in STEM and advertisements on STEM research opportunities in the field are also done through radio, television and internet. The media is perceived orchestrated by the government, a corporate organization known as *MediaCorp*.

Government

The policy to have a strong focus on mathematics, science and technical skills has been put in place especially in education since 1968 through the formation of the Ministry of Science and Technology. This effort has been further enhanced in post-secondary and tertiary education to develop human resources in high technology and the knowledge economy in the 1990's. Having sufficient human capital in the science and technology is essential for the development of the country.

With that in mind, the government made a paradigm shift in the education system by focusing on innovation, creativity and research. Usage of ICT in enhancing the teaching and learning environments was introduced in 2000 by the Ministry of Education. The 1st and 2nd ICT Master plans recognized the importance of equipping students with the necessary ICT skills and knowledge that could stimulate creativity and innovation. While the vision of the first two ICT Master plans was to transform the student learning environment, ICT Master plan 3 envision developing student competencies for self-directed and collaborative learning through effective use of ICT.

The reasons for the students to engage in self directed learning are: ownership of learning; management and monitoring of own learning; extension of own learning

(http://ictconnection.moe.edu.sg). The reasons for the students to engage in collaborative learning are: effective group processes; and individual and group accountability of learning (http://ictconnection.moe.edu.sg).

In the future, Singapore wants science learning to be student-centred and value-driven. It is hoped that through science students are able to develop critical thinking and make important decisions based on the knowledge and skills gained for the better of the country.

The government Agency for Science, Technology and Research (A*Star) which provides funding for research in the scientific area is also attracting top scientists and scientific companies to work in Singapore. This had resulted in collaborations between renowned universities in the world with local universities in selected fields of bioinformatics, information science and medical technologies. (OECD 2010). In the S&T 2010 Plan, A*STAR was provided funds to drive R&D and support the development in the fields of biomedical sciences (BMS), chemicals, electronics, info-communications & media and engineering.

Educational institutions

Singapore realizes the need for talent to advance in STEM related fields. One way of doing this is by attracting experts in the research field of biomedical sciences. International experts such as Jackie Ying from the Massachusetts Institute of Technology and David Townsend, the co-inventor of the positron emission tomography assisted in setting up the R&D in the biomedical field (Lim, 2010).

The formation of the Singapore-MIT Alliance for Research and Technology (SMART) reflects the importance of collaboration of the 3 research institutions: the National University of Singapore (NUS), the Nanyang Technological University (NTU), and the Massachusetts Institute of Technology (MIT). As one of the first research centre outside USA, the SMART centre in Singapore focuses on innovative engineering and life science educational and research collaboration. The link with MIT is an example of a wider set of policy initiatives.

The improved university rankings for both National University of Singapore (NUS) and Nanyang Technological University (NTU) according to the Times Higher Education and the QS World University Rankings reflects the hard work of the faculty and good leadership. These institutions offer many programs in STEM related fields in line with the needs of the country.

Ranking of universities in Singapore based on the Times Higher Education World University Rankings 2012-2013 are as shown in the following table.

University	Rank
National University of Singapore	29
Nanyang Technological University	86
Singapore Management University	N/A
Singapore University of Technology and Design	N/A
Singapore Institute of Technology	N/A

The increased usage of ICT in the educational institutions are well known. With online learning becoming more accessible, students are able to download notes, submit assignments and organize online discussion without attending classes. Many universities and colleges are trying out the ‘flipped classrooms’ idea where discussions and questions are posed in class while recorded lectures are watched online at home

by students. These exemplify the use of ICT in the tertiary level. It also enhances a transformative and innovate learning experience of college students.

Universities, polytechnics and ITE provide opportunities for their students to participate in community based projects that are STEM related. Students not only are exposed to the social problems but may even come out with innovative ideas to solve them. For example, a project called Mission Sevapur from Singapore Polytechnic went to India to generate funds for a non-profit organization that run social programmes benefitting the villagers in Sevapur.

The following table shows in general the employment rate of Singapore graduates from the institutions of higher learning.

H.2 KEY STATISTICS ON EMPLOYMENT OUTCOME OF GRADUATES FROM INSTITUTIONS OF HIGHER LEARNING, 2009 – 2011

Institutions	Employment Rate (%)									Median Monthly Gross Starting Salary ($) of Graduates in Full-time Permanent Employment		
	Full–time Permanent			Part–time/Temporary			Total			2009	2010	2011
	2009	2010	2011	2009	2010	2011	2009	2010	2011			
Universities	84.7	84.8	86.4	5.8	5.9	5.0	90.6	90.7	91.4	2,700	2,900	3,000
Polytechnics												
Fresh Graduates	62.8	68.5	67.0	25.7	23.0	25.1	88.5	91.5	92.1	1,700	1,800	1,850
Post-NS Graduates	71.1	81.3	80.1	16.6	14.1	14.6	87.7	95.4	94.7	2,000	2,000	2,100
Institute of Technical Education (ITE)												
Fresh Graduates	57.6	57.8	63.5	23.5	26.9	20.6	81.1	84.7	84.1	1,200	1,291	1,300
Post-NS Graduates	78.4	78.3	79.7	10.0	12.0	10.0	88.4	90.4	89.6	1,500	1,600	1,600

Source: Graduate Employment Surveys conducted by various institutions of higher learning

Source: Singapore Yearbook of Manpower Statistics 2012.

Employers

Singapore's collaborative model among institutions and industries has resulted in employer's satisfaction of graduates as well as workforce. One example of an encouraging feedback is given by the Operations Director of Sentosa Development Corporation on the Institute Technical of Education (ITE) graduates. ITE graduates who have a can-do attitude are very enthusiastic and have great potential to be energetic workers. The ITE graduates are very good at their jobs doing it hands on (Speech by the Minister of Education at ITE Graduation Ceremony 2012, http://www.moe.gov.sg/media/speeches/2012/05/30/address-by-mr-heng-swee-keat-a-1.php). Once they are shown how to do a particular task, they are able to pick up the skills quickly.

Singapore attracts many well educated and renowned experts in the STEM related fields such as engineering and the medical sciences. Employers are willing to invest and open the companies here because they know that the country has sufficient human capital in the field. Another important factor attributed to the success is that enough competent technical graduates have been produced by the polytechnics. With the setting up of numerous multinational companies in the STEM related fields, Singapore has been able to provide sufficient jobs in the field. This allows the country to attract talents from across the globe.

Professional bodies

The Ministry of Trade and Industry (MTI) is the main agency in charge of science and technology activities in Singapore. A*STAR coordinates the research and development in the science and technology area. The four main bodies under MTI that organize the related science and technology activities are:

- The Biomedical Research Council (BMRC)
- The Science & Engineering Research Council (SERC)
- Corporate Planning and Administration Division
- Exploit Technologies Pty Ltd. (UNESCO, 2010, p.3)

The Science & Engineering Research Council (SERC) is in charge of all public research in the physical sciences and engineering. SERC is focussed on attracting multinational companies (MNC) to base its operations in Singapore. Using Singapore's manufacturing industry as an important sector in developing new technological opportunities. SERC also coordinates multidisciplinary research from various tertiary institutions to develop new technological based solutions. (UNESCO, 2010, p.3) The Biomedical Research Council coordinates and take control of all R&D in the public human sector life sciences. It also oversees the human resource development in Singapore.

The perceived relevance of STEM

Economic growth

The perceived relevance of STEM in the country is explicitly mentioned in the Economic Strategies Committee (ESC) report in 2010. According to the report, to achieve sustained and inclusive growth, Singapore's medium-term economic strategies are aimed at the key goals of high-skilled people, an innovative economy and a distinctive global city by 2020. The strategy focused on skills, innovation and productivity as the basis for economic growth. These three strategies are relatively oriented towards applications of STEM based education.

The Singapore government has invested continuously in education and training, in the universities, polytechnics and also in vocational and technical education. The government spending on education has increased steadily from 24% in 2006 to 26% in 2010 and 28% in 2011 in the country's yearly budget. Specifically, the government's recurrent expenditure on education per student (in Singapore dollars) for Institute of Technical education has increased steadily from $10,209 in 2006 to $11,839 in 2010 and $11,914 in 2011 (Department of Statistics Singapore, 2012).

Special attention has been given by the government to vocational and technical education, of which the Institute of Technical Education (ITE) was established in 1992 to spearhead the development of secondary vocational education, industrial training and technical teacher training.

The goal was associated with the government's vision of building the manufacturing and services sectors for economic growth to overcome their lack of natural resources. With limited resources, the government began manpower planning and skills development at the national level as it was a strategic tool in attracting foreign investments. ITE has effectively rebuilt and transformed the former system of traditional 'vocational institutes' into top-line modern 'regional colleges' to meet the skilled manpower needs of Singapore.

The institute has become an integral part of the national education system where the main function is to train technician and skilled personnel for jobs and careers in all the major sectors of the economy. Focusing on these educational and training institutions contributes to the manpower needs of new emerging industries for the nation's economic restructuring and development process.

The economic growth of Singapore in relation to perceived relevant of STEM based education are reflected in the movement from 'Factor-Driven' economy in 1960s-1970s, progressed to an 'Investment-Driven' economy in 1980s-1990s and the 'Innovation-Driven' economy in the year 2000 onwards. During the 'Innovation-Driven' economy, concerted efforts have been made to attract and nurture new growth sectors such as the Biomedical Sciences, Information-Communications, Creativity Technology, Integrated Resorts and High-Value Engineering. Based on the OECD report on the economic performance and structure of the economy of Singapore, manufacturing has remained important to the economic growth, with its share of GDP remaining above 25% for most years in the last two decades.

According to the International Labour organization report on Singapore (ILO, 2012), the country has been recognized as a high income nation with the manufacturing sector the largest employer in the economy accounting for more than 20% of total employment. According to Singapore statistics 2012, the manufacturing sector offers 16% of the total available jobs in the country.

Well-being

The country's income and wealth are essential components of the well-being of the societies, which is reflected by the manufacturing sector as the largest employer in the economy. According to the report from the Committee on University Education Pathways Beyond 2015 (CUEP), more places in science and technology (S&T) should be made available by 2020 to ensure Singapore's future growth. The committee have proposed that courses such as allied health and aerospace engineering would serve an important role in supporting the well-being of the society and economy. The perceived relevance of the measures are related to the fact that manufacturing accounts for the

largest proportion of the jobs in the country. Singapore manufacturing sector contributes between 20% - 30% of the GDP annually. Labour market indicators indicate that average monthly earnings in manufacturing sector increased from 4,246 in 2010 to 4,484 in 2011 (Singapore Dollar/employee). The country's manufacturing wage index increased from 107.4 in 2004 to 116.6 in 2007. According to Singapore statistics 2012, employees in the manufacturing sector enjoyed above-average paid hours at 50.4 hours per week respectively.

Polytechnic graduates in Singapore have good employment opportunities, where nine out of ten found jobs within six months after graduation in 2011 (GES survey). On average, the fresh graduate's mean starting salaries are about $1,930 and a post-National Service graduates are about $2,370. This is one indication of the relevance of STEM base education in the country, which reflects efforts to establish effective polytechnic system to support the well-being of the nation.

Current patterns of STEM provision in schooling

The Singapore school system is divided into pre-school, primary, secondary and post-secondary levels.

STEM in pre-school

Pre-schools in Singapore are divided into 2 categories: kindergartens and child care centres. Kindergartens support the academic development of kids while child care centres provide full or partial care for children from 2 months and above. Some child care centres also provide kindergarten lessons. Generally, pupils go to kindergarten for three years beginning at the age of 4 till 6. Specific activities focussed on science are not explicitly mentioned in the 'Framework For A Kindergarten Curriculum In Singapore', however Science Centre Singapore is the main organization that is organizing science activities for the preschoolers (http://www.science.edu.sg/schoolprogrammes/Pages/Preschool.aspx).

Raytheon's report indicates that Singapore students begin to learn math at age 6, and based on Singapore Ministry of education website (http://www.moe.gov.sg/education/preschool/) regarding preschool, the children are taught about basic number concepts.

Most kindergartens are run by the private sector. Children will learn basic number skills, creative and problem solving besides English and the mother tongue language. Currently, the pre-school enrolment rate is estimated at an all time high of 88% (WDA, 2012). The government estimates that 99% of primary one child have at least one year of pre-school education (MOE 2012; MCYS 2012).

STEM in primary education and its influence on later participation in STEM

One of the overall aim of primary education in Singapore is to help children master mathematics. Primary education starts at age 7 for a period of six years. Mathematics and science are two core subjects taught in the primary level which is compulsory and taken by all students. At the primary level, students begin taking mathematics in Grade 1 and science in Grade 3. This shows the importance of both the subjects. Students are exposed to it since young to inculcate the love of the STEM subjects. It also reflects the importance of these two basic subjects to the country. Science and mathematics teachers are specialist trained, where they were given the opportunities to visit leading international schools to improve their teaching method. All pupils sit for the Primary School Leaving Examination (PSLE) at the end of Grade 6. The PSLE assesses the

readiness of the pupils for secondary education and places them at the suitable secondary course (Singapore IBE UNESCO 2011.p.12). There are no emphases on particular subjects in PLSE. The test is used to measure students' capabilities regarding their educational stream based on their future academic career.

Enrolments in STEM disciplines in secondary education

At the secondary level, students enrol in one of the three courses according to the learning abilities and interests. Others are placed in either the Express or Academic Course. The Express Course is a four-year course which leads to the GCE O Level exam where students learn English and the Mother Tongue as well as Mathematics, Science and Humanities. In the year 2011, approximately 61% of students from each grade level were placed in the Express Course, 25% in the Normal (Academic) and 14% placed in the Normal (Technical) Course (Singapore Stats, 2012).

The Normal (Technical) Course is geared towards technical and vocational education that includes training in technical institutes. It prepares students for higher technical jobs or doing the postsecondary ITE after completing four years of secondary education. Some subjects offered in the Elective Module include digital animation and precision engineering. Students are also given opportunity to experience and benefit practice oriented learning in polytechnics collaborating with schools.

Specialised Independent Schools (SIS) have been set up to provide students the opportunity to excel in their respective scientific areas such as the National University of Singapore (NUS) High School of Mathematics and Science, and School for Science and Technology.

The following tables provides an overview of the enrolment from the secondary education.

6 SECONDARY ENROLMENT BY AGE, LEVEL AND COURSE, 2011

Level & Course	Sex	Age (in years)										
		≤ 11	12	13	14	15	16	17	18	19	≥ 20	Total
Total	**MF**	**8**	**41321**	**47236**	**49819**	**50711**	**14681**	**3210**	**776**	**191**	**21**	**207974**
	F	**5**	**20085**	**22823**	**24115**	**24477**	**6978**	**1433**	**344**	**80**	**6**	**100346**
Secondary 1	**MF**	**8**	**41314**	**2483**	**1069**	**276**	**62**	**1**	**-**	**-**	**-**	**45213**
	F	**5**	**20083**	**1132**	**514**	**128**	**24**	**1**	**-**	**-**	**-**	**21887**
Express	MF	7	25778	1044	705	169	29	-	-	-	-	27732
	F	4	13266	528	354	79	9	-	-	-	-	14240
Normal(A)	MF	1	10519	597	237	66	16	-	-	-	-	11436
	F	1	5057	276	103	33	5	-	-	-	-	5475
Normal(T)	MF	-	5017	842	127	41	17	1	-	-	-	6045
	F	-	1760	328	57	16	10	1	-	-	-	2172
Secondary 2	**MF**	**-**	**7**	**44740**	**2883**	**1314**	**349**	**60**	**3**	**-**	**-**	**49356**
	F	**-**	**2**	**21685**	**1362**	**635**	**169**	**23**	**-**	**-**	**-**	**23876**
Express	MF	-	7	28085	1177	757	183	17	-	-	-	30226
	F	-	2	14623	624	393	99	5	-	-	-	15746
Normal(A)	MF	-	-	11555	834	373	97	23	-	-	-	12882
	F	-	-	5361	402	168	43	10	-	-	-	5984
Normal(T)	MF	-	-	5100	872	184	69	20	3	-	-	6248
	F	-	-	1701	336	74	27	8	.	-	-	2146
Secondary 3	**MF**	**-**	**-**	**13**	**45855**	**4576**	**1990**	**428**	**86**	**13**	**-**	**52961**
	F	**-**	**-**	**6**	**22229**	**2019**	**960**	**176**	**36**	**9**	**-**	**25435**
Express	MF	-	-	12	29079	2388	1158	205	26	1	-	32869
	F	-	-	5	15166	1165	627	91	15	-	-	17069
Normal(A)	MF	-	-	1	11421	1371	587	163	34	2	-	13579
	F	-	-	1	5268	551	252	66	12	1	-	6151
Normal(T)	MF	-	-	-	5355	817	245	60	26	10	-	6513
	F	-	-	-	1795	303	81	19	9	8	-	2215
Secondary 4	**MF**	**-**	**-**	**-**	**12**	**44543**	**4456**	**1707**	**436**	**104**	**5**	**51263**
	F	**-**	**-**	**-**	**10**	**21694**	**2015**	**785**	**195**	**35**	**2**	**24736**
Express	MF	-	-	-	12	28345	2363	1009	222	31	2	31984
	F	-	-	-	10	14914	1193	518	113	11	1	16760
Normal(A)	MF	-	-	-	.	11146	1424	527	153	55	2	13307
	F	-	-	-	.	5162	565	207	62	19	1	6016
Normal(T)	MF	-	-	-	.	5052	669	171	61	18	1	5972
	F	-	-	-	.	1618	257	60	20	5	.	1960
Secondary 5*	**MF**	**-**	**-**	**-**	**-**	**2**	**7824**	**1014**	**251**	**74**	**16**	**9181**
	F	**-**	**-**	**-**	**-**	**1**	**3810**	**448**	**113**	**36**	**4**	**4412**

Source: Education Statistics Digest 2012, Singapore Ministry of Education.

19.4 ENROLMENT IN GOVERNMENT AND GOVERNMENT-AIDED SECONDARY SCHOOLS AND JUNIOR COLLEGES BY LEVEL AND AGE

Number

	2001	2006	2007	2008	2009	2010	2011
Total	211,457	245,823	249,689	249,660	249,340	246,808	240,270
Level							
Secondary 1	53,070	50,772	50,687	50,214	50,083	48,670	45,213
Special	5,175	4,262	4,238	-	-	-	-
Express	27,633	26,973	27,396	30,873	30,808	29,785	27,732
Normal (Academic)	11,983	12,419	11,981	12,811	12,489	12,394	11,436
Normal (Technical)	8,279	7,118	7,072	6,530	6,786	6,491	6,045
Secondary 2	44,482	50,807	52,026	51,830	51,043	50,935	49,356
Special	4,149	4,316	4,277	4,156	-	-	-
Express	22,569	26,747	27,473	27,781	31,159	31,296	30,226
Normal (Academic)	10,590	13,191	13,282	12,879	13,445	12,978	12,882
Normal (Technical)	7,174	6,553	6,994	7,014	6,439	6,661	6,248
Secondary 3	40,063	53,027	53,660	54,557	54,440	53,178	52,961
Special	3,917	5,155	4,818	4,751	4,626	-	-
Express	20,400	27,541	27,856	28,456	28,959	32,933	32,869
Normal (Academic)	10,119	13,557	14,386	14,481	13,932	14,048	13,579
Normal (Technical)	5,627	6,774	6,600	6,869	6,923	6,197	6,513
Secondary 4	41,578	51,463	51,525	50,919	52,186	52,073	51,263
Special	4,011	4,764	4,894	4,629	4,535	4,053	-
Express	21,744	27,503	26,771	26,648	27,488	28,356	31,984
Normal (Academic)	10,258	13,377	13,072	13,333	13,479	13,003	13,307
Normal (Technical)	5,565	5,819	6,788	6,309	6,684	6,661	5,972
Secondary 5 Normal (Academic)	7,888	9,028	10,164	9,561	9,478	9,532	9,181
Junior College 1 / Pre-U 1	12,487	15,144	17,156	16,836	16,739	16,898	16,746
Junior College 2 / Pre-U 2	11,518	15,258	14,080	15,423	15,014	15,165	15,203
Pre-U 3	371	324	391	320	357	357	347

Source: Yearbook of Statistics Singapore 2012.

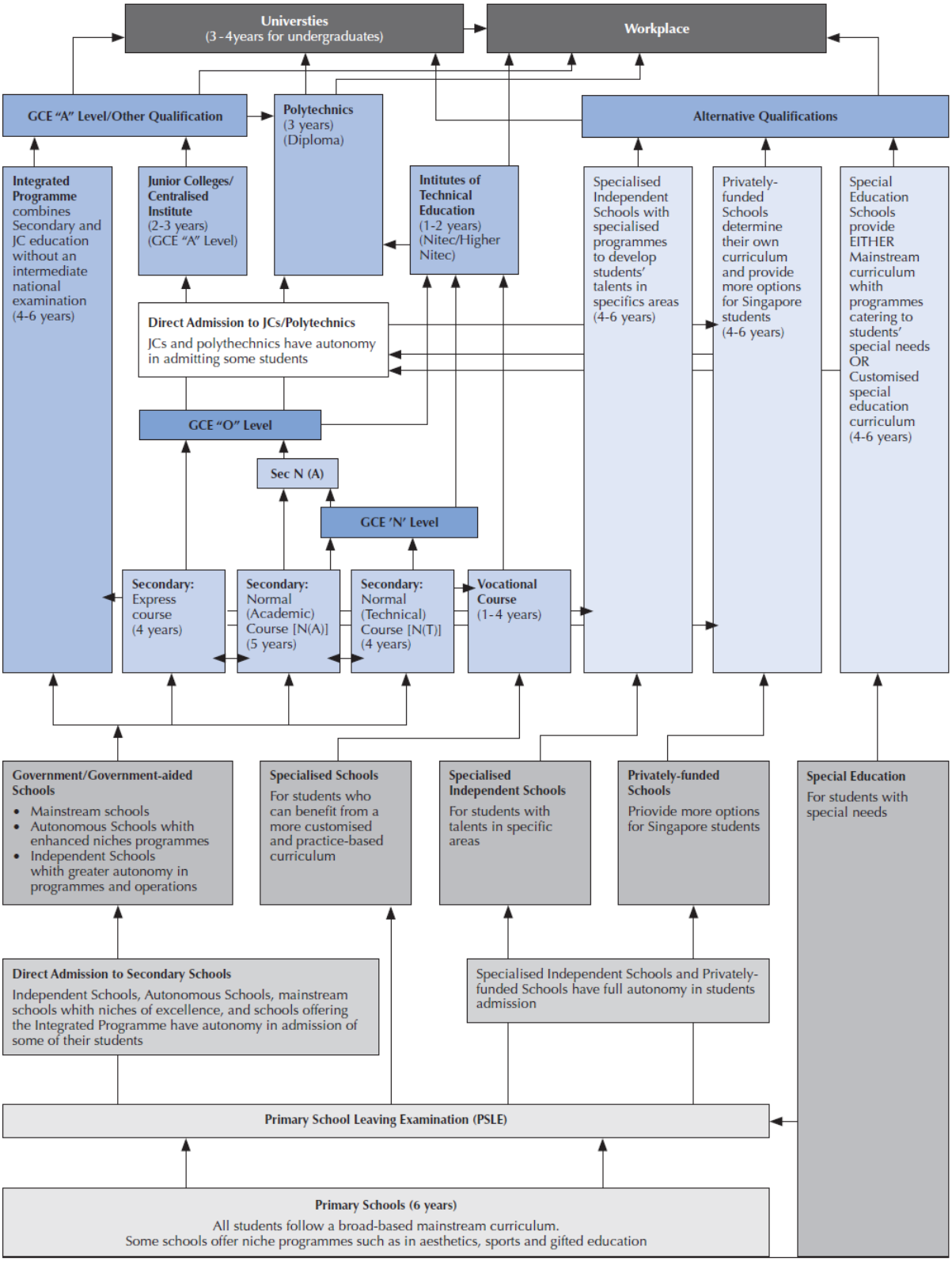
STEM provision and participation, in tertiary (university and non-university) education

Most students go through 10 years of general education before doing their post-secondary education at either junior colleges (31% of students), polytechnics (43%) or ITE (22%) (OECD, 2010). At the tertiary education level, more than fifty percent of the courses offered are science and technology based. The value of technical education was given prominence with the setting up of the Institute of Technical Education (ITE) in 1992. In 2000, more than 82% of ITE students completed their training and found employment in their respective fields. ITE is perceived as more high-tech, as the curriculum are driven by industries, whereas at the polytechnics, the curriculum are designed within the context of the Ministry of Education.

Many successful polytechnic and ITE students also continue their tertiary education in university. Currently, students who attend local universities are about 25% of a cohort and this is expected to increase to 30% in 2015 (OECD 2010).

Singapore educational system is as depicted in the following diagram.

Singapore's education system organisation



Source: Singapore Ministry of Education website: www.moe.gov.sg/education. and OECD 2010 Report, 'Singapore: Rapid Improvement Followed by Strong Performance'.

The role of STEM disciplines in both general education and vocational and occupationally-specific programs in education and training

The role of STEM disciplines in both general education and vocational and occupationally-specific programs in education and training was to deliver the human capital engine for economic growth and to create a sense of Singaporean identity (OECD, 2010).

General education

In general education, Singapore has focused on the universal development of strong mathematics and science knowledge and skills since primary school. Hence, at the primary level, Mathematics and Science are core subjects that every student must take. Mathematics is taught from Grade 1 onwards while Science is taught from Grade 3 onwards (OECD, 2010). In year 2000, at the foundation stage of primary education, the number of weekly teaching periods for Mathematics (each teaching period lasts 30 minutes) in Grades 1, 2, 3 and 4 were 7, 9, 11 and 11, respectively. For Science, the number of weekly teaching periods (each teaching period lasts 30 minutes) in Grades 3 and 4 at the foundation stage of primary education were 3 and 4, respectively. In year 2000, at the orientation stage of primary education, the number of weekly teaching periods for Mathematics (each teaching period also lasts 30 minutes) in EM 1, EM 2, and EM 3 streams were 9, 10 and 13, respectively. For Science, the number of weekly teaching periods (each teaching period also lasts 30 minutes) in EM 1, EM 2, and EM 3 streams at the orientation stage of primary education were 5, 5 and 3, respectively (International Bureau of Education of UNESCO, 2011). From upper primary onwards, students have specialist teachers in Mathematics and Science (OECD, 2010).

In addition, through a bilingual education policy and a requirement for all schools to teach Mathematics and Science in English starting from Grade 1, Singapore has gradually and steadily fostered an educational environment that embraces and facilitates STEM education (Agency for Science, Technology and Research, 2011).

At the secondary level, Mathematics and Science are also core subjects that every student must take. In year 2000, at the lower secondary education (Forms 1 and 2), the number of weekly teaching periods for Mathematics (each teaching period lasts 40 minutes) in Special/Express, Normal (Academic) and Normal (Technical) courses were 5, 6, and 8, respectively. For Science, the number of weekly teaching periods (each teaching period lasts 40 minutes) in Special/Express, Normal (Academic) and Normal (Technical) courses at the lower secondary education were 6, 5 and 4, respectively. In year 2000, at the upper secondary education (Forms 3 and 4), the number of weekly teaching periods for Mathematics (each teaching period also lasts 40 minutes) in Special/Express, Normal (Academic) and Normal (Technical) courses were 24-26, 6, and 9, respectively. For Science, the number of weekly teaching periods (each teaching period also lasts 40 minutes) in Special/Express course at the upper secondary education was 24-26 (International Bureau of Education of UNESCO, 2011).

In addition, for the Normal (Technical) courses at the lower secondary education, the number of weekly teaching periods for technical studies and home economics (each teaching period lasts 40 minutes) in year 2000 was 4. For the Normal (Technical) courses at the upper secondary education, the number of weekly teaching periods for computer applications (each teaching period lasts 40 minutes) in year 2000 was 4 (International Bureau of Education of UNESCO, 2011).

From upper secondary onwards, a range of specialised mathematics courses at higher levels are available for students who are interested. At the tertiary level, more than half the programmes are geared towards science and technology (OECD, 2010).

Vocational and occupationally-specific programs in education and training

In vocational and occupationally-specific programs in education and training, Singapore has focused on the development of strong technical knowledge and skills. Students who have completed secondary education (Secondary 4 or Secondary 5) with GCE O certificates as well as technical and commercial inclinations can opt for three-year diploma programmes in the polytechnics, which offer a wide range of STEM related courses in fields such as engineering, business studies, accountancy, maritime studies, and nursing. Students who do well in these programmes can proceed to the universities for degree STEM related programmes (International Bureau of Education of UNESCO, 2011).

Students with GCE O-level or N-level certificates can also opt for part-time or full-time programmes in the Institutes of Technical Education which offer a wide range of STEM related courses in fields such as engineering, business studies and drafting. Students who do well in these programmes can proceed to the polytechnics for diploma programmes (International Bureau of Education of UNESCO, 2011). In fact, the Institute of Technical Education (ITE) is the principal provider of Career Technical Education in Singapore at the technician and semi-professional level, and the principal authority in developing National Occupational Skills Certification and Standards to enhance Singapore's workforce competitiveness, locally and globally. Thus, ITE plays an important social and economic role in catering to 25% of post-secondary students in Singapore's STEM related education (Institute of Technical Education, 2012). ITE has four specific STEM related programmes in education and training (ITE, 2012, p. 2):

- Full-time Pre-Employment Training (PET) Programmes (National ITE Certificate or Nitec and Higher Nitec Certifications and Technical Diplomas for secondary school leavers [GCE 'O', N(A) and N(T) levels])
- Part-time Continuing Education and Training (CET) Programmes (Master Nitec/Higher Nitec/Nitec, short courses and other academic programmes)
- Industry-based Training (IBT) Programmes [offered through Approved Training Centre (ATC) and Certified On-the-Job Training Centre (COJTC) Schemes with industry training partners]
- International Programmes [Nitec (International) or Higher Nitec (International) Certifications through training providers on a commercial basis outside Singapore].

The main objective of these STEM related programmes is to prepare and expose students of different abilities, talents and interests to the new realities and challenges of the global job market. Hence, the programmes are based on a holistic 'Hands-on, Minds-on, Hearts-on' STEM related education and training approach. The 'Hands-on' training aims to equip students with the required skills-set for employment while the 'Minds-on' learning aims to develop them into independent-thinkers and flexible practitioners, equipped to manage rapid changes in the global environment. In addition, the 'Hearts-on' learning aims to develop students who have the passion for what they do, self-belief and care for the community and society. These programmes provide a comprehensive STEM related education and training, where students integrate theory with practice through coursework, industry exposure, projects and experiential learning (ITE, 2012).

ITE works closely with key partners to enhance the diversity of its products and services and strengthen its core capabilities. The key partners include (ITE, 2012, p. 5):

- School Partners (Secondary Schools);
- Training Partners (under the Industry-based Training Schemes); and
- Corporate and Industry Collaboration Partners, which comprise local and international companies and educational institutions.

Further, in striving for global leadership in technical education, ITE forged various strategic alliances with Vocational and Technical Education (VTE) institutions of international repute in countries such as Australia, Canada, France, Germany, Hong Kong, Switzerland, United Kingdom and the United States of America (ITE, 2012).

There are also apprenticeship programmes under the New Apprenticeship System (NAS) in ITE and most of these programmes cater to the needs of the manufacturing, commerce, technical support and health care industry leading to certification at the NTC-2 level (International Bureau of Education of UNESCO, 2011).

Mentor programmes for students

A*STAR works closely with the Ministry of Education, Schools, Science Centre Singapore and the scientific community to augment the capacity of educators and scientists to mentor and guide students in research projects. For example, A*STAR collaborates with the Science Centre to pilot a centre that provides students with mentored research opportunities and develops teacher-researchers and teacher-mentors to enhance Science, Technology, Engineering and Mathematics (STEM) education.

The Science Mentorship Programmes (SMP) consist of two main programmes, namely SMP with teachers as mentors and SMP with scientists as mentors (Gifted Education Branch, Ministry of Education Singapore, http://www.gebsp.moe.gov.sg/SMP/index.htm). SMP with teachers as mentors is known as School-Based Science Mentorship Programme. The programme aims to cultivate the spirit of inquiry as well as to develop attitudes and values for the proper conduct of science among Secondary 2 and 3 pupils which will help to prepare and equip them better for a mentorship experience with a professional scientist when they are ready. Specifically, the objectives of this programme are: (a) to promote scientific study through investigative science fair projects; (b) to encourage the use of creative and innovative methods in problem solving; (c) to heighten pupils' awareness and generate interest in scientific research and technological development; and (d) to nurture values and positive attitudes towards scientific inquiry and competitions (Gifted Education Branch, Ministry of Education Singapore, http://www.gebsp.moe.gov.sg/SMP/index.htm). The project work in this programme requires pupils to initiate and design scientific investigations under the guidance of science teachers as their mentors (Ministry of Education Singapore, http://www.moe.gov.sg/education/programmes/gifted-education-programme/special-programmes/science-programmes/science-mentorship-programmes/).

There is a wide range of programmes with scientists as mentors. These programmes are jointly organised by the Gifted Education Branch of the Ministry of Education with the following institutions as shown below:

- Applied Science Programme (ASP) - Singapore Polytechnic (SP)
- Biotechnology Programme (BP) - Ngee Ann Polytechnic (NP)
- Defence Science Programme (DSP) - Defence Science and Technology Agency (DSTA)
- I^2R Mentorship Programme (I^2R-MP) - Institute for Infocomm Research (I^2R)

- IHPC Mentorship Programme(IHPC-MP) - Institute of High Performance Computing (IHPC)
- Nanyang Polytechnic Explorations in Science and Technology (NEST) - Nanyang Polytechnic (NYP)
- NTU-Mentorship Programme (NTU-MP) - National Institute of Education (NIE/NTU)
- NUS-Computer Mentorship Programme (NUS-CMP) - National University of Singapore School of Computing (NUS)
- NUS-Engineering Mentoring Programme (NUS-EMP) - Faculty of Engineering, National University of Singapore (NUS)
- NUS-Science Mentorship Programme (NUS-SMP) - Faculty of Science, National University of Singapore (NUS); - National Parks Board (NPB)
- RP-Human Performance Programme (RP-HPP) - School of Sports, Health and Leisure, Republic Polytechnic (RP)
- RP-Science Exploration Programme (RP-SEP) - School of Applied Science, Republic Polytechnic (RP)
- Science Centre Mentorship Programme (SC-MP) - Science Centre Singapore
- (Gifted Education Branch, Ministry of Education Singapore, http://www.gebsp.moe.gov.sg/SMP/index.htm).

The aims of these programmes are to develop Secondary 3 and 4 pupils' interest and talent in scientific research, to provide opportunities for them to deepen their knowledge in a particular area, to learn about the latest research developments and to be challenged by the intellectually stimulating process of scientific research. Specifically, the objectives of these programmes are: (a) to provide enrichment that includes current scientific advances; (b) to develop skills for conducting investigations and inquiry in science; (c) to stimulate and nurture pupils' interest in science; (d) to provide opportunities for pupils to interact with teachers and scientists for a better understanding of the activities, beliefs and traits good scientists should have; and (e) to motivate pupils to take up scientific research to benefit mankind (Gifted Education Branch, Ministry of Education Singapore, http://www.gebsp.moe.gov.sg/SMP/index.htm).

These programmes comprise two main parts, namely Mentorship Attachment/Project Work and Youth Science Conference. For Mentorship Attachment, mentors from the participating institutions are invited to offer projects for the programmes and pupils who are keen to participate in the programmes select the projects that interest them. They will be exposed to the scientific process of problem solving, exploration and discovery to develop their intellectual skills and curiosity that will stimulate them to evaluate and challenge information rather than be passive learners. Pupils work on their projects 3 hours weekly from January to July and spend 2 weeks full-time during the June holidays at the tertiary institutions. They are required to write a scientific paper for publication in the Proceedings of the Youth Science Conference. While for Project Work, pupils initiate and design scientific investigations under the guidance of science teachers as their mentors. The second part of these programmes is the Youth Science Conference which showcases all the projects in the programmes through posters and oral presentations to an audience of peers, teachers and scientists. These projects are judged by panels of professional scientists and awarded with prizes. The 18th Youth Science Conference was held last year and the 17th Youth Science Conference Proceedings can be accessed at http://www.gebsp.moe.gov.sg/SMP/index.htm (Gifted Education Branch, Ministry of Education Singapore, http://www.gebsp.moe.gov.sg/SMP/index.htm). Therefore, the Science Mentorship Programmes (SMP) can be said to be successful in terms of the number of projects

that have been conducted and the number of Youth Science Conferences that have been held.

Further, at the Junior College and Upper Secondary school level, local undergraduate scholarships and A*STAR Science Awards will continue to be offered to support young talent interested to pursue studies and careers in STEM.

A*STAR Undergraduate Scholarships (AUS) support bright individuals with a keen interest in research for a Bachelor's degree in science or engineering at:

- National University of Singapore (including the Yale-NUS College)
- Nanyang Technological University
- Singapore University of Technology and Design
- Singapore Management University (School of Information Systems).

Upon graduation, AUS scholars have the flexibility to pursue their PhD studies locally or abroad on A*STAR or other university scholarships. They can look forward to research attachments at A*STAR's Research Institutes with state-of-the-art facilities and be part of A*STAR's community of diverse and renowned scientists and researchers (Agency for Science, Technology and Research, http://www.a-star.edu.sg/AwardsScholarships/ScholarshipsAttachments/ForUndergraduateStudies/ASTARUndergraduateScholarship/tabid/1079/Default.aspx).

In 2010, A*STAR offered 10 AUSs, that is 3 AUSs in Biomedical Sciences and 7 AUSs in Physical Sciences & Engineering. In 2011, A*STAR offered 15 AUSs, that is 7 AUSs in Biomedical Sciences and 8 AUSs in Physical Sciences & Engineering. In 2012, A*STAR offered 18 AUSs, that is 12 AUSs in Biomedical Sciences and 6 AUSs in Physical Sciences & Engineering (Agency for Science, Technology and Research, http://www.a-star.edu.sg/People/OurScholars/ScholarshipAwardeesbyYear/ASTARUndergraduateScholars2012/tabid/1224/Default.aspx). Therefore, the AUS initiative can be said to be successful in terms of the increasing numbers of AUSs that have been offered since 2010.

Singapore Academy of Young Engineers and Scientists (SAYES)
(http://sayes.science.edu.sg)

The role of the Singapore Academy of Young Engineers and Scientists (SAYES) is to support Science, Technology, Engineering and Mathematics (STEM) education by galvanising aspiring engineers and scientists in a nation-wide youth science movement that is self-driven and self-sustaining. SAYES is the brainchild of the Science Centre Singapore and the Agency for Science, Technology and Research (A*STAR), and supported by the Ministry of Education. It brings together science clubs and institutions across Singapore to augment existing Science, Technology, Engineering and Mathematics (STEM) activities, and encourage young engineers and scientists to join Singapore's Research, Innovation and Enterprise (RIE) endeavour. Senior student members, with the guidance of adult mentors from science and engineering backgrounds, take on leadership roles and chart the academy's direction. SAYES provides members with a wide spectrum of resources at the Science Centre and A*STAR such as open houses, field trips, lectures by Nobel Laureates and top scientists, training programmes and peer group activities. Membership is open to students 15 to 19 years of age, with or without existing affiliations to other science societies or clubs and membership to SAYES is an officially recognised co-curricular activity (Media release, 29 April 2011).

As for the number of members, SAYES currently has about 110 members. SAYES was not an initiative to reach out to the masses. It's a science club where like minded people can be engaged in STEM activities. The members are given the opportunities to attend talks and workshops that are organised. They are then encouraged to give back to the community through outreach activities with the public (personal communication with the Assistant Manager, Research & Web Outreach, Science Centre Singapore, through email).

The activities that were held successfully are as follows:

- SSYSF Student's Seminar (25 May 2011)
- Shell Elemental Challenge (30 May 2011)
- SSYSF Public Seminar (4 June 2011)
- Systematic Creative Thinking Workshop (23 July 2011)
- Fizglow (22 to 24 July 2011)
- Star Lecture (29 July 2011)
- Singapore Science Festival 2011 (22 July to 13 August 2011)
- Stem Cell Symposium (13 August 2011)
- Career Talk (19 August 2011
- A Public Forum on Forests (20 August 2011)
  (Singapore Academy of Young Engineers and Scientists, http://sayes.science.edu.sg/index.php/news-topmenu).

Students uptake of STEM programs and factors affecting students

Performance

According to the results from two international studies, TIMMS 2011 and PIRLS 2011, Singapore has made significant progress in the performance of its students. The studies found that the students are highly competent in all the three areas of Reading, Mathematic and Science in all of the primary school. Similarly, the students were also found to be highly competent in both Mathematic and Science. The results have shown that the students at primary and secondary level have acquired the level of competence needed in STEM based education. The students' reasoning ability, as observed from their approach to science and mathematic reflected the achievement of the curriculum which moves towards more inquiry-based teaching and learning in the school. The ministry of education aspiration of maintaining the strong fundamentals of student-centric and value driven education system has undoubtedly played a major role in motivating the students.

In terms of mathematics education, test of Primary School Leaving Examination (PLSE) has shown the percentage of students who scored A + to C remained above 83% from 2005 to 2010. In terms of science education of the same cohort, the percentage of students who scored A+ to C remained above 90% from 2005 to 2010.

Results of GCE 'O' level from 2005 to 2011, revealed that the percentage of students who passed mathematics remained above 87%. Results of students success rate from ITE in 2008 is 80.2%. The percentage remained above the mark through the year of 2009 and 2010 with the graduate employment rates of more than 90% within 3 months of their graduation. The employment figure refers to 65.3% of STEM graduates, which include courses of Applied & Health Sciences, Engineering and Electronics & Info-Com Technology (Education Statistics Digest, 2010 and 2011, Ministry of Education Singapore).

Motivation

The number of students who attended science enrichment programmes at Singapore Science Centre steadily increased from 178,676 in 2008, to 211,539 in 2009 and to 248,245 in 2010. Among the activities organized by the science centre to motivate students across the education system through science outreach and competitions are as follows:

- A*STAR *Talent Search* – Agency for Science and Technology Research
- *Science and Technology Festival* (e.g. Singapore Science and Engineering Fair, Singapore Science Festival, Science Buskers Festival - show-and-tell performances, RoboCup 2010, GeneFest 2010, MindFest 2010)
- *Science in the masses at shopping malls* (e.g. Science in the Mall)
- *Recognition and Award* (e.g. Sony Creative Science Award, Tan Kah Kee Young Inventors' Award, Shell Singapore Youth Science Festival)
- *Competition* (e.g. NIC X-Site 2010 - challenged students to develop designs for online platforms, Amazing Science-X Challenge 2010, National Junior Robotics Competition 2010
- *Awareness* (e.g. Meet the Scientist, Brain Awareness Week, Science in the Café, StaR Kits – Kit for students to explore science concept).

The rate of enrolment in institutions related to STEM reflects students' motivation towards STEM based education. Enrolment at ITE increase over the years from 22,954 in 2006, to 24,789 in 2010 and 25,279 in 2011. The phenomena was also observed in the total number of enrolment in the polytechnics, from 67,667 in 2006, to 83,542 in 2010 and 85,279 in 2011. Enrolment in the universities also increased over the same period, from 62,918 in 2006, to 74,534 in 2010 and 75,655 in 2011 (Year Book of Singapore Statistics, 2012). According to the Singapore Ministry of Trade and Industry, total polytechnic graduates increased from 22,200 in 2010 to 24,000 in 2011. The figure has shown that students' motivation towards STEM based learning increase over the past few years.

Access knowledge and skills of STEM graduates

The labour markets

The occupations that are said to be in demand is based on the Strategic and Skills-in-Demand List (SSL), which was updated on 16 August 2012 by the Ministry of Manpower (MOM) Singapore. SSL was drawn up by MOM in consultation with the respective industries and relevant government agencies. The list contains occupations and recommended qualifications that are expected to be in strong demand by industries in the coming years and are key to supporting the growth of key economic sectors in Singapore. MOM regularly updates the list to factor in labour market trends (MOM, http://www.mom.gov.sg/skills-training-and-development/skills-in-demand/Pages/skills-in-demand.aspx).

Based on the latest SSL, STEM graduates with the required knowledge and skills have access to a variety of occupations mainly in the first five industries:

Manufacturing industry

The occupations in the various Manufacturing industries that are in demand for STEM graduates with the required knowledge and skills are as follows:

- Electronics and Precision Engineering: Firmware R&D Engineer, HDD-related R&D Engineer, Media Process Engineer, Network Storage Engineer, and Water Fabrication Process Engineer
- Chemicals and Biomedicals: Chemist/Process Development Chemist, Electrical Engineer/Technician, Environment (Water) Engineer, Automation/Process Engineer, and QA/QC Specialists
- Aerospace and Marine & Offshore: Design Engineer, Petroleum Engineer, Project Engineer, Reservoir Engineer, Well Engineer and Nano Engineer.

Healthcare industry

The occupations that are in demand in the Healthcare industry for STEM graduates include Clinical Audiologist, Dietician, Doctor, Medical Diagnostic Radiographer, Medical/Laboratory Technologist, Nurse, Occupational Therapist, Pharmacist, Physiotherapist, Podiatrist, Radiation Therapist, Respiratory Therapist, Speech Therapist, Clinical Psychologist, Medical Social Worker, Dentist, Dental Hygiene Therapist and Pharmacy Technician.

Finance industry

There are various occupations in the Finance industry that are in demand for STEM graduates. They are Compliance Managers, Risk Management Managers, Information Technology Professionals, Product Controllers, Fixed Income, Currencies and Commodities (FICC) Sales/Traders, Investment Management Professionals, Project Management Professionals, Research Analysts and Structurers in Shipping, Aviation, Commodities, Infrastructure Finance, Real Estate, as well as Underwriters and Actuaries in Marine Hull, Aviation, Energy, Political Risk, Terrorism and Agriculture Insurance.

Construction industry

The occupations that are in demand for STEM graduates in the Construction industry comprise Civil/ Structural/ Bridge Engineer, Design Engineer, Geotechnical Engineer, Mechanical & Electrical/Aircon/Fire/Instrumentation Engineer, Quantity Surveyor, Resident Technical Officer/Engineer, Testing & Commissioning Engineer, Supervisor and General Foreman, Crane & Hoist Operator/BC Cutter Operator/Bored Piling Operator/Drilling Operator, Draftsman structural/ M&E/architectural)/Autocad Operator, Architectural Assistant/Technician, Jet-grouting Specialist, as well as Building and Construction Project Manager.

Information Communication and Digital Media industry

There are also numerous occupations that are in demand for STEM graduates in the Information Communication and Digital Media industry such as Analyst Programmer, Software Engineer, Database/Network and Computer Systems Administrator, System Analyst, IT / Project Manager, Security Consultant, Solution / Software Architect, Chief Information Officer, Game Producer, Game Programmer, 2D and 3D Artist, Animator, Character Artist, Character Designer, Computer Graphic (CG) Artist, Concept Artist, Director (TV/Film, Animation & Games), Environment Artist, Gaffer, Games Designer/Level Designer, Grip, Lighting and Rendering Artist, Line Producer, Matchmove Artist, Modeler and Texture Artist, Producer (Film/TV, Animation & Games), Production Assistant (Animation & Games), Rigger, Rotoscope Artist, Screenwriter/ Scriptwriter, Storyboard Artist, Technical Artist, Visual Effects (VFX) Artist/Technician and Visual Effects (VFX) Supervisor/Lead.

In addition, the Career Services Centre of ITE provides career counselling, talks and fairs, industry visits, as well as job matching and placement to graduating students in their job search. Further, the ITE Alumni Association helps to engage alumni with value-added initiatives for their career and workplace effectiveness by organising Graduates' Reunion Nite and ITE Scholars' Nite, supported by a new interactive networking platform on Facebook, to enhance outreach to students, graduates and stakeholders (ITE, 2012).

ITE is a major technical institution which provides training to meet the skilled manpower needs of industries in Singapore. Thus, ITE recognises the importance of providing assistance and support to its graduates in their career development effort especially in assisting its graduates to take up a career which is related to their areas of training. At the same time, ITE also recognises the importance of its students taking up part-time jobs which are relevant to their course of training to add value to their training and employability skills upon their graduation. To achieve these aims, ITE has established a Career Services Centre (CSC) to provide a range of career-related services to its students and graduates. CSC also extends its services to employers who wish to recruit staff with ITE qualifications by providing the following services (ITE, http://www.ite.edu.sg/wps/portal/):

- On-Line Recruitment Service: Employers can post details of job opportunities in their companies using CareerNet@ITE.
- Career Talks and Career Fairs: The CSC can assist employers who wish to give career talks to ITE students or to participate in career fairs organised by ITE.
- Information Resources: ITE provide employers with information on ITE qualifications, courses, skills and capabilities of ITE students and graduates.

Labour market take-up of STEM knowledge and skills

The role of the Council for Professional and Technical Education is to ensure that there is an adequate supply of professional, technical and skilled labor to meet the needs of industry by making projections and recommending enrolment targets and the corresponding staffing and financial requirements for universities, polytechnics, and vocational and training institutes of the Vocational and Industrial Training Board and the Economic Development Board (Goh and Gopinathan 2008, cited in Toh, 2012).

Table 1 shows the average monthly recruitment rate by industry and occupational group from 2006 to 2011(Ministry of Trade and Industry, 2012a).

Table 1. Average monthly recruitment rate by industry and occupational group from 2006-2011

Per Cent

	2006	2007	2008	2009	2010	2011
Total	2.8	2.9	2.8	2.2	2.8	2.7
Industry						
Manufacturing	2.4	2.3	2.0	1.5	2.0	2.0
Construction	2.9	3.3	3.7	2.5	2.5	2.8
Services	3.0	3.2	3.0	2.5	3.2	3.0
Wholesale & Retail Trade	3.3	3.5	3.3	2.7	3.6	3.2
Transportation & Storage	2.0	2.4	2.5	1.4	2.3	2.4
Accommodation & Food Services	5.1	5.1	4.6	3.8	4.7	4.9
Information & Communications	3.1	3.0	2.9	2.0	3.2	3.0
Financial & Insurance Services	2.7	3.1	2.4	1.6	2.7	2.4
Real Estate Services	4.5	4.0	3.8	3.6	3.9	4.1
Professional Services	3.5	3.6	3.4	2.3	2.7	2.8
Administrative & Support Services	4.9	4.9	4.6	4.3	4.8	4.9
Community, Social & Personal Services	1.6	1.8	2.0	2.0	2.3	1.9
Others [1]	1.7	3.0	3.0	2.3	2.0	2.1
Occupational Group						
Professionals, Managers, Executives & Technicians	2.2	2.3	2.2	1.6	2.2	2.1
Clerical, Sales & Service Workers	3.6	3.7	3.7	3.1	4.0	3.8
Production & Transport Operators, Cleaners & Labourers	2.9	3.1	2.9	2.3	2.7	2.8

Source : Labour Market Survey (LMS), Ministry of Manpower

Note : Prior to 2006, data pertain to private sector establishments with at least 25 employees.
From 2006, data also include the public sector.
Data are classified according to the Singapore Standard Industrial Classification (SSIC) 2010.

1 Includes Agriculture, Fishing, Quarrying, Utilities and Sewerage & Waste Management.

Source: Ministry of Trade and Industry (2012a, p. 74)

As shown in the table, the labour market take-up of STEM graduates in the STEM related industries like manufacturing, construction, information and communications, financial and insurance services, and professional services industries was generally positive from 2006-2011 although the average monthly recruitment rate in these industries was the lowest in 2009. Likewise, the labour market take-up of STEM graduates in the STEM related occupations especially the professionals, managers, executives and technicians was generally positive from 2006-2011 although the average monthly recruitment rate in these occupation groups was the lowest in 2009.

Table 2 shows the number of employed residents aged 15 years and over by industry from 2001 to 2011 (as at June 2012) (Ministry of Trade and Industry, 2012a). As shown in the table, the numbers of employed residents aged 15 years and over in the STEM related industries such as manufacturing, construction, information and communications, financial services, and business services industries were generally high from 2001-2011 although the numbers of employed residents aged 15 years and over in the manufacturing, construction, information and communications, financial services, and business services industries were the lowest in 2010, 2006, 2006, 2005 and 2002, respectively.

Table 2. Number of employed residents aged 15 years and over by industry from 2001-2011

Thousand

	2001	2006	2007	2008	2009	2010	2011
Total	1,582.5	1,796.7	1,803.2	1,852.0	1,869.4	1,962.9	1,998.9
Manufacturing	307.8	301.7	304.5	311.9	293.6	291.4	292.4
Construction	100.0	95.0	100.8	105.5	113.8	104.0	99.7
Services	1,160.6	1,377.5	1,377.2	1,411.9	1,441.1	1,529.9	1,583.3
Wholesale & Retail Trade	253.8	301.1	277.0	269.5	272.4	281.7	300.5
Transport & Storage [1]	190.1	174.0	179.9	182.4	179.9	191.3	192.0
Hotels & Restaurants	105.0	128.8	123.1	120.0	124.9	128.9	135.2
Information & Communications	na	74.8	87.8	87.0	94.3	99.9	85.4
Financial Services	89.1	106.3	109.7	123.6	121.9	126.0	145.5
Business Services [2]	199.7	217.3	223.9	237.5	243.4	253.5	271.6
Community, Social & Personal Services	322.9	375.1	375.8	391.9	404.4	448.6	453.1
Others [3]	14.1	22.5	20.7	22.7	20.9	37.6	23.5

Sources : Labour Force Survey, Singapore, Ministry of Manpower (up to 2009)
Comprehensive Labour Force Survey (LFS), Singapore, Ministry of Manpower (wef 2010)

Notes : Residents comprise Singapore citizens and permanent residents.
Data across the varies years may not be strictly comparable due to revisions in the industrial classification.
Data for 2001 are classified according to the Singapore Standard Industrial Classification (SSIC) 2000.
Data for 2006-2009 are classified according to SSIC 2005.
Data from 2010 are classified according to SSIC 2010.
Data for 2007 have been adjusted following the revision of population estimates to faciliate comparison with data from 2008 onwards.

1 Data for 1994-2004 refer to transport, storage & communications.

2 Data for 2001 refer to Real Estate, Renting and Business Activities.
Data from 2006 onwards include Real estate, Professional, Scientific & Technical, Administrative & Support Services.

3 Data for 2001 and 2006-2009 include agriculture, fishing, mining & quarrying, utilities & activities not adequately defined.
Data from 2010 include agriculture, fishing, quarrying, utilities and sewage & waste management.

Source: Ministry of Trade and Industry (2012a, p. 67)

Table 3 shows the number of employed residents aged 15 years and over by occupation from 2001 to 2011 (as at June 2012) (Ministry of Trade and Industry, 2012a). As can be seen from the table, the numbers of employed residents aged 15 years and over in the STEM related occupations such as professionals, technicians and associate professionals, production craftsmen and related workers, as well as plant & machine operators and assemblers were generally high from 2001-2011 although the numbers of employed residents aged 15 years and over in the professionals, technicians and associate professionals, production craftsmen and related workers, as well as plant and machine operators and assemblers were the lowest in 2001, 2001, 2010 and 2010, respectively.

Table 3. Number of employed residents aged 15 years and over by occupation from 2001-2011

Thousand

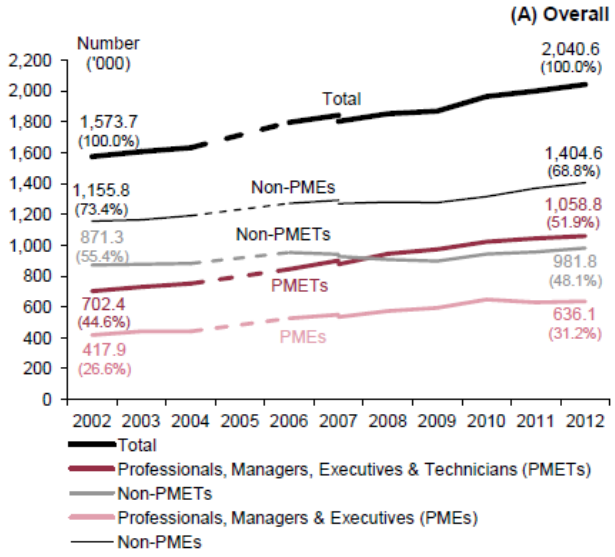
Occupation	2001	2006	2007	2008	2009	2010	2011
Total	1,582.5	1,796.7	1,803.2	1,852.0	1,869.4	1,962.9	1,998.9
Legislators, Senior Officials & Managers	224.0	268.9	263.4	284.7	291.4	335.2	355.9
Professionals	195.9	256.2	270.7	288.3	301.6	312.6	273.5
Technicians & Associate Professionals	281.2	319.8	342.4	371.9	379.7	373.4	413.9
Clerical Workers	231.5	251.6	247.5	249.7	238.3	240.5	245.2
Service & Sales Workers	191.2	215.7	209.5	208.2	208.8	246.4	248.0
Production Craftsmen & Related Workers	101.5	95.0	94.2	89.5	87.3	86.5	89.5
Plant & Machine Operators & Assemblers	176.7	173.3	167.0	156.4	158.5	154.2	157.7
Cleaners, Labourers & Related Workers	115.6	149.3	145.3	140.0	140.3	145.5	145.7
Others [1]	64.9	66.9	63.1	63.4	63.5	68.7	69.6

Sources : Labour Force Survey, Singapore, Ministry of Manpower (up to 2009)
Comprehensive Labour Force Survey (LFS), Singapore, Ministry of Manpower (wef 2010)
Notes : Residents comprise Singapore citizens and permanent residents.
Data across the varies years may not be strictly comparable due to revisions in the occupational classification.
Data for 2001 are classified according to the Singapore Standard Occupational Classification (SSOC) 2000.
Data for 2006-2009 are classified according to the SSOC 2005.
Data from 2010 are classified according to the SSOC 2010.
Data for 2007 have been adjusted following the revision of population estimates to faciliate comparison with data from 2008 onwards.
1 Include Agricultural & Fishery Workers and Workers Not Classifiable by Occupation.

Source: Ministry of Trade and Industry (2012a, p. 66)

In addition, according to the Manpower Research and Statistics Department (2012, p.7), 'The employment rose over the year for both professionals, managers, executives and technicians (PMETs). Figure 1 shows that PMETs experienced employment gains over the year. Driven by the strong increase in clerical, sales & service workers (7.0%) which outweighed the decrease in production & related workers (-1.8%), resident non-PMET employment increased by 2.7% in 2012, faster than the growth of 1.5% for PMETs. Consequently, the PMET share of resident employment dipped from 52.2% in 2011 to 51.9% in 2012. This was still higher than the 44.6% in 2002 as PMETs experienced faster employment growth (4.5% p.a.) than non-PMETs (1.4% p.a.) over the decade. Similar trends were observed for professionals, managers & executives (PMEs), whose share of resident employment rose from 26.6% in 2002 to 31.5% in 2011 before dipping to 31.2% in 2012 (Chart 6).'

Chart 6: Employed Residents By Occupation, 2002 To 2012 (June)



Annualised Change (% p.a.)

	2002-2012*	2002-2007*	2007-2012*	2011-2012
Total	**2.9**	**3.2**	**2.5**	**2.1**
PMETs	4.5	5.1	3.9	1.5
Non-PMETs	1.4	1.6	1.2	2.7
PMEs	4.6	5.7	3.6	1.1
Non-PMEs	2.1	2.2	2.0	2.6

(Manpower Research and Statistics Department, 2012, p. 7)

Moreover, the results of the Annual Graduate Employment Surveys conducted by the Institute of Technical Education (ITE) on its full-time graduates who are new entrants in the labour market from 2006 to 2010 showed that the graduates were able to secure jobs within six months after graduation in spite of the less-than-buoyant job market in the last few years. The full-time graduates' employment rates in 2006, 2007, 2008, 2009 and 2010 were 89%, 93%, 90%, 84% and 88%, respectively. Further, the results of the Employers' Satisfaction Surveys showed that the employers' satisfaction with ITE graduates in 2006, 2007, 2008, 2009 and 2010 were consistently over 90% (exceeding targets), that is 95%, 94%, 94%, 91% and 91%, respectively. The results indicated that there was strong endorsement on the quality of ITE's STEM related programmes in education and training (ITE, 2012).

However, not all ITE graduates are identified as STEM graduates. Only ITE graduates of School of Applied & Health Sciences, School of Design & Media, School of Electronics & Info-comm Technology, and School of Engineering are identified as STEM graduates.

The ITE Graduates' Employment Performance based on the ITE 2011 Graduate Employment Survey is described according to schools of studies as follows:

School of Applied & Health Sciences

The survey revealed that a high percentage of graduates of School of Applied & Health Sciences were able to obtain employment within 3 months from graduation or completion of full-time National Service. Their indicative gross salary range is given in Table 1.

Table 1. School of Applied & Health Sciences Graduates' Employment Performance

School	Level / Course	Year 2011 Results of ITE's Graduate Employment Survey	
		Employment Rate	Gross Salary (Mean)
School of Applied & Health Sciences	*Higher Nitec*		
	Biotechnology	88%	$1,850
	Paramedic & Emergency Care	88%	$1,850
	Nitec		
	Applied Food Science	79%	$1,450
	Chemical Process Technology	85%	$1,610
	Nursing	95%	$1,370

Source: ITE, http://www.ite.edu.sg/wps/portal/

School of Design & Media

The survey revealed that a high percentage of the graduates of the School of Design & Media were able to obtain employment within 3 months from graduation or completion of full-time National Service. Their indicative gross salary range is given in Table 2.

Table 2. School of Design & Media Graduates' Employment Performance

School	Level / Course	Year 2011 Results of ITE's Graduate Employment Survey	
		Employment Rate	Gross Salary (Mean)
School of Design and Media	*Nitec*		
	Digital Animation	82%	$1,350
	Product Design	75%	$1,650
	Space Design (Architectural)	87%	$1,320

Source: ITE, http://www.ite.edu.sg/wps/portal/

School of Electronics & Info-comm Technology

The survey revealed that a high percentage of the graduates of the School of Electronics & Info-comm Technology were able to obtain employment within 3 months from graduation or completion of full-time National Service. Their indicative gross salary range is given in the Table 3.

Table 3. School of Electronics & Info-comm Technology Graduates' Employment Performance

School	Level / Course	Year 2011 Results of ITE's Graduate Employment Survey	
		Employment Rate	Gross Salary (Mean)
School of Electronics & Info-Comm Technology	*Higher Nitec*		
	Electronics Engineering	93%	$1,680
	Information Technology	86%	$1,650
	Wireless Technology	81%	$1,570
	Nitec		
	Digital Audio & Video Production	79%	$1,520
	Electronics	83%	$1,510
	Info-Communications Technology	87%	$1,540

Source: ITE, http://www.ite.edu.sg/wps/portal/

School of Engineering

The survey revealed that a high percentage of the graduates of the School of Engineering were able to obtain employment within 3 months from graduation or completion of full-time National Service. Their indicative gross salary range is given in Table. 4

Table 4. School of Engineering Graduates' Employment Performance

School	Level / Course	Year 2011 Results of ITE's Graduate Employment Survey	
		Employment Rate	Gross Salary (Mean)
School of Engineering	*Higher Nitec*		
	Electrical Engineering	94%	$1,490
	Mechanical Engineering	89%	$1,540
	Mechatronics Engineering	91%	$1,570
	Nitec		
	Aerospace Technology	84%	$1,670
	Automotive Technology (Heavy Vehicles)	96%	$1,610
	Automotive Technology (Light Vehicles)	89%	$1,630
	Electrical Technology	94%	$1,570
	Facility Technology	75%	$1,320
	Mechanical Technology	83%	$1,620
	Mechatronics	84%	$1,630
	Precision Engineering#	83%	$1,470

Source: ITE, http://www.ite.edu.sg/wps/portal/

Strategies, policies and programmes used

To enhance STEM at all levels of education

A major factor in the success of the students is the monetary investment in the education system by the leaders and policymakers towards STEM based education. Key strategies to enhance and sustain STEM at all levels include:

- Comprehensive visions and planning
- System alignment across stakeholder groups
- Long-term adherence to a well-developed strategy
- Integration of content and higher-order thinking skills
- Researched and skill base curriculum
- Investment in teachers.

Integrated Programme

The country has introduced the Integrated Programme into their school system since 2004, which provides a special route for high performance students to the university who were projected to do well in a less structured environment. The programme starts selecting students from the secondary school and junior college of which these students were exempted from taking intermediate national examinations. The strategy is designed to engage the students to a broader learning experience in higher education. Additionally, selected schools in the country are already embracing alternative curricula and qualifications such as the International Baccalaureate and High School Diploma.

New Institute of Technical Education Certification System

The country has introduced the Institute of Technical Education (ITE) Certification system into their public school system since 2002, replacing traditional Technical and Vocational schools. This system was introduced to meet the needs of requiring certifications from related emerging industry, especially the service sector. The certification system is designed to allow post-secondary technical educational programmes as well as the institute's skills training courses to offer certification system

based on level of training. The ITE certification system is developed to enable students and adults learners to progress through their career within the generic certification system within the intended framework. The career path as a mechanism to achieve upward students' mobility and prestige has proved to be most effective in attracting students to STEM based education.

Customised Vocational Programme

In Singapore, selected schools provide customised vocational curriculum, formed within the secondary schools, instead of a specialised vocational or technical school. The system is developed to provide opportunities to these technical students and other Normal students from the secondary school to enrol in STEM based education in higher institutions. The system also enables small groups of students from primary school to join the enhanced vocational programmes. Graduates from the customised vocational curriculum can progress to further education at mainstream technical institutes or employment in the labour market, or even apprenticeship with industries.

Continuing education and training: Singapore Workforce Skills Qualification system

The country has developed their own national Workforce Skills Qualifications (WSQ) system that trains, develops, assesses and recognises adult workers for competencies and performance in order to enhance their employability. The qualification system was developed based on Singapore Workforce Development Agency (WDA) supported by the industries which ensures the workers acquire STEM based skills needed by employers. The system's training and competency certification system which were monitored by WDA are not solely based on formal qualifications. Approach to the educational opportunities to the workers with clear progression pathways has attracted the interest and engaged the youth to join STEM based careers.

'Teach less, learn more'

In Singapore, the Prime Minister Lee Hsien Loong has introduced the concept of 'Teach Less, Learn More'. The vision has been applied across the education system under the umbrella of 'Thinking Schools, Learning Nation'. The principles that guide the strategy aim to give curriculum developers the opportunity to engage students more deeply in learning. According to the Director General of Education, 2010, the strategy aims to 'touch the hearts and engage the minds of learners by promoting a different learning paradigm in which there is less dependence on rote learning, repetitive tests and instruction, and more on engaged learning, discovery through experiences, differentiated teaching, learning of lifelong skills, and the building of character through innovative and effective teaching approaches and strategies'. Although the strategy was designed to address the country's education system in general, it is in line with STEM based education, where the diversity of teaching and learning approaches are pursued.

Teaching talent is identified and nurtured

Comprehensive approach of identifying and nurturing teaching talent in the education system has been well known internationally from the country's performance in TIMSS. The approach has been developed to enhance education delivery by focusing on selecting, training, compensating and developing teachers and principals. Key elements in the system are:

- Recruitment

- Training
- Compensation
- Continuous Professional Development
- Performance Appraisal
- Career development
- Leadership selection and Training

Training of school leaders

Singapore has been recognized by the OECD as having the best school leaders. Their young teachers are continuously assessed based on leadership potential, where opportunities to develop their leadership capacity were provided by the government. In the education system, all education leadership positions are part of their teaching-career structure. More experienced school leaders mentor newly appointed leaders. School principles are periodically transferred among schools as part of the government continuous improvement strategy. The strategies are having their own advantages, especially in shaping STEM education in the country. The decision makers managing related programs can comprehend the diversity of the fields, and the teaching and learning styles associated with the programs.

Primary students are given strong foundation in science and mathematics

Secondary students are enrolled in classes or schools according to learning abilities and interests. This leads to possible less attrition rate among students. A clear pathways and educational link is set in place to expand their career path in STEM based disciplines. Specialised independent schools have been set up to propel students into various scientific lead by National University of Singapore (NUS) High School of Mathematics and Science, and School of Science and Technology. The country has developed a STEM based curriculum that is based on the culture of the society as envisioned by their leaders, for instance, Singapore Mathematics Curriculum. In addition, more than 50 per cent of courses in universities are STEM based disciplines. Various enrichment programs are provided: see 1.5 (b). Programs for developing the pipeline of strong foundation in mathematic and science education is supported by the setting up of the Institute of Technical Education (ITE) and provisions for the graduate to continue education in universities. The ITE curriculum is developed based on the needs of industries of which industries have a major role in the curriculum development. This leads to a high employability rate among ITE graduates.

TE21 model of teacher education

Singapore's TE21 (Teacher Education for the 21st Century) model seeks to provide the theoretical foundation to produce the 'thinking teacher' while concurrently having a strong partnership with key stakeholders and the schools. The model can be considered as the general education setting. Nevertheless, the provision made in the country's educational system together with the economic growth has consequently raised the status and effectiveness of STEM teachers. The model was developed to enhance key elements of teacher education, which are closely linked to STEM based educational approach. Three value paradigms of the model include Learner-centered, Teacher Identity and Service to the Profession and Community. The model also emphasizes the required knowledge and skills that teachers must possess in order to respond to the latest global trends by improving student's learning outcomes. All the key elements are those that underlie STEM based education.

Singapore's internationally known system of teacher education and employment for teacher development consists of three aspects, which are:

- Serious Career Management - Enhanced Performance Management System
- Strong Sense of Professionalism
- Strategic Use of Financial Rewards - Bonuses and Promotions, Funded Professional Development Opportunities, Retention Funds.

Vocational and Technical Education (VTE)

From the perspective of the country's vocational and technical education, significant policy change took placed since 1973 with the establishment of Industrial Training Board as Statutory Board. The governing body were given greater autonomy and flexibility in shaping the educational system. More specialized education focusing on technical skills against general vocational education were established. The policy change had a significant impact on the VTE system, where pre-employment of training for young school leavers outside normal school system were formalized. The VTE model has since be used in Singapore, where it is subjected to reviews and restructuring by regulators.

Institute of Technical Education (ITE) was established as the prime mover of VTE, of which it has been recognized as a post-secondary institution in the country's educational system. Students from the institution can continue their studies to Polytechnic and from the Polytechnic to the University based on performance. The role of the 'educational link' is to expand their career path. The provision of resources and expertise to this institute are assured with the institutionalization of this institute within the country's educational structure. This government funded institution, besides Universities and Polytechnics, is dedicated to train technicians and skilled personnel for various jobs in the major sectors of the economy.

The institution's close partnership with industries has become the dominant factor in the formation of broad industrial support from companies which eventually enhance STEM based educational practices throughout the country's educational system. Various Industry-based Training (IBT) Schemes, such as, Traineeship, Approved Training Centres and Certified On-the-Job Training Centres, have been established to facilitate training by industry. In addition, the joint partnerships have been identified as a key component in the creation of Centres of Excellence in various technologies to facilitate exchange of technology, expertise and training resources.

Collaboration/partnership with leading institutions

Singapore's university landscape is dominated by research intensive universities, which is supported by a research oriented agency known as A*STAR. Agency for Science, Technology and Research (A*STAR), placed under the Ministry of Education, play an important role in coordinating and supporting the growth of Singapore's STEM based education throughout the entire education system. The agency has served well in the provision of high quality pairing of research and education in the country.

A*STAR is the lead agency for fostering world-class scientific research and talent for vibrant innovation-driven Singapore. The agency oversees 14 biomedical sciences and physical sciences and engineering research institutes, and six consortia and centres. IT supports Singapore's key economic clusters by providing intellectual, human and industrial capital to its partner in industry. The agency also supports research in the universities, hospitals, research centres and with other local and international partners.

High-tech infrastructure to enhance STEM based education

Singapore Science Park

In 1980, the government created the Singapore Science Park, where the centre has served to promote STEM based education for the communities. A*STAR has also been developed which served as an incubator for high-tech industries and became the nucleus for R&D in Singapore. The centres have become the prime mover in promoting and attracting the younger generation to participate in STEM based careers.

Biopolis and Fusionopolis

Biopolis and Fusionopolis, set up and managed by A*STAR, are state-of-the-art research facilities in the country to support the growth of the economy. A wealth of resources is available at the research centres, empowering scientists and researchers with accessibility and convenience to carry out their own research oriented towards the country economic activities. The research centres were developed to play an important role in Singapore's R&D activities. Strategically co-located at one-north, they are home to the Agency for Science, Technology and Research (A*STAR)'s research institutes, consortia and centres spanning multiple research disciplines from bioimaging to microelectronics.

Biopolis: At this research centre, scientists can tap into the scientific resources offered by the Biopolis Shared Facilities (BSF) to save time and costs. BSF is dedicated resources to managing and providing scientific equipment, services and supplies to researchers. Core services, such as glassware washing and media preparation have been operational since end 2004. The media preparation service provides in-house production of a variety of the most commonly used tissue culture and bacterial culture media, while the supply centre stocks a wide range of chemical, plastics and glassware that enable users to reduce both purchasing delays and cost. In addition, BSF has a number of scientific platforms coupled with technical expertise support.

Fusionopolis: Spread across 30 hectares of land within one-north, Fusionopolis is envisioned to be Singapore's R&D hub for Infocommunication Technology, Media and Physical Sciences & Engineering. It was developed to foster close linkages in interdisciplinary research and forge international links with renowned scientific institutions through research and graduate training partnerships.

The development of high tech infrastructure can be considered directly related to STEM based education as the infrastructure served as the underlying supporting system for promoting and accelerating network growth in the education system.

The A*STAR resource web portal

This portal serves as a consolidated reference to the varied resources, especially scientific equipment, of the Biomedical Research Council (BMRC) and the Science and Engineering Research Council (SERC) of A*STAR. Both BMRC and SERC promote, support and oversee Research and Development initiatives in Singapore. This portal aims to assist both members of A*STAR as well as the Research community within Singapore in locating, booking and using A*STAR's resources, thereby enhancing and promoting multidisciplinary research collaborations in Singapore. The country has developed their own research database known as the Singapore Researchers Database (SRDB) which has a database related to Biomedical Sciences, Science and Engineering. The database serves the researchers and clinicians working in Singapore.

The resources are meant for local and overseas collaboration and serves as a useful reference for students interested in research. For more details, please refer to SRDB.

Emphasis on broad-based and holistic learning

The Singapore Ministry of Education aims to provide students with the key competencies and mind sets of the 21st century while maintaining strong fundamentals in teaching and learning. Their schools are required to expose their students with rich diversity of experiences to help them grow holistically. Besides academic curriculum, the students are encouraged to be actively involved in music, arts and sports through co-curricular programmes (e.g. Nanyang Technical University). Students' participations in community service are also emphasized. These activities will nurture the students' creativity, confidence, compassion and perseverance.

Teacher quality

The ministry emphasize good teachers and school leaders in their education system. They aim to nurture and motivate their teachers to achieve their highest performance by taking care of their aspiration and interests. The teachers are provided with comprehensive pre-teacher training, at their National Institute of Education (NIE). The institute also provides opportunities for the teachers to develop their capabilities as teaching professionals. Teacher academies and language institutes have been established to foster a strong teacher-led culture of professional excellence.

In general, NIE serve to train Singapore teachers. Nevertheless, Science and Mathematics education are strongly emphasized by the formation of several academic groups related to the subjects. Three out of twelve academic groups in the institute are related to STEM based education. The three academic groups are known as Learning Sciences and Technologies, Natural Sciences and Science Education, and Mathematics and Mathematics Education. As an example, according the website (www.nie.edu.sg), Mathematics and Mathematics Education academic group constantly seek new and innovative ways of delivering mathematics content and pedagogy courses in an effort to develop best practices in mathematic education in the country. In addition, there is a special research center known as Centre of Excellence in Learning Innovation of which one of the function and responsibilities is to look into areas to refine, adapt and evaluate Singapore's Mathematics and Science curricula in the United States.

Integration of Information and Communication Technologies (ICT) in the classroom

The government emphasizes the integration of ICT in the classrooms to enhance students' learning. 'Future schools' are established in which these schools use state-of-the-art technology to pilot new teaching and learning experiences with the help of industry players.

Partnership with parents

The ministry of education values Singaporean parents' involvement and support of school programmes, in which they actively encourage parents and the community to work together with schools administrators.

Partnership with leading scientists and educators from all over the world

In tertiary education, the country higher institutions work closely with world leading universities. The country has a strong partnership with leading scientists and educators from all over the world through visiting fellowships and faculty exchange. Some of them were employed to set up and run their own research lab under A*STAR.

STEM education programs

Various STEM related programs are actively organized in the country to promote and create awareness related to STEM. These activities are organized by the Singapore Science Centre and also in collaboration with A*STAR. It must be recognised that these agencies are directly responsible for promoting, nurturing and supporting STEM based education in the country. As reported by the Singapore Science Centre annual report 2010/2011, the number of students who attended science enrichment programmes increased from 178,676 in 2008, to 211,539 in 2009 and up to 248,245 in 2010. Therefore, these two agencies are accountable for ensuring that government's strategies and policies concerning STEM based education are achieved. Both agencies have achieved their target as reported by their annual report. For instance, in 2010, A*STAR has achieved target in training and producing PhD graduates by 252.3%.

As reported by the Singapore Science Centre annual report 2010/2011, there were 3,320 volunteers in 2011 with 15,400 volunteer hours committed at the centre. In addition, there were 21 distinguished guests from all over the world visited the centre from April 2010 to February 2011.

Among the programmes organised by the agencies are as follows:

1. Discover Science Resources

Discover Science Resources is part of an educational outreach project that will make available science resources such as kits, mini-exhibits and posters to teachers for use in their lessons, Science Days, Science Fairs, Science Camps, Open Houses, etc for schools. Each box has a variety of materials on a specific science theme corresponding to the school syllabus. Discover Science Resources is an initiative by The Agency for Science, Technology & Research (A*Star) and the Singapore Science Centre to promote interest in science and technology in the young by engaging and challenging them in fun, innovative and creative activities different from their school exposure to science. Through online booking and delivery system, schools can look forward to the support and availability of several unique and attractive science aids to help them make their science related projects or lessons more memorable. Items available through this 'lending library' would fall into the following categories:

- Science kits with worksheets, video for teacher's guide, and materials for groups of students.
- Science displays i.e. graphic panels with information, science posters etc.
- Mini-interactive science exhibits with worksheets and materials for students.

With materials available from the 'library', schools will be able to select suitable kits, interactive exhibits and attractive posters to make their science programmes such as Science Day or Science Fair more appealing. The themed resource boxes will allow for quick and efficient set-ups. There will be a minimal transportation charge for loan items that require delivery. Charges are waived for self pick-up. Each kit can be loaned for a period of up to 3 weeks.

2. National Junior Robotics Competition

The National Junior Robotics Competition (NJRC) is an event organized annually by the Singapore Science Centre and the Agency for Science Technology and Research (A*STAR). This robotics competition encourages students to develop problem solving skills, entrepreneurial skills, creative thinking skills and team spirit among the participants. Over the past 13 years, more than 40,000 participants and 200,000 supporters have gathered for this premier robotics competition. The competition has provided an excellent opportunity for students to interact with their peers, teachers and judges where the participants are from tertiary institutions, research institutions and experts from various industries. It has been the platform of celebrating the process of learning through interactive and meaningful experiences.

3. Science Buskers Festival

The Science Buskers Festival is a festival that encompasses the idea of developing the individual's communication skills through expressions of science in creative manners. Organized as a competition, this event serves as an excellent platform to spread key messages relating to the importance of inspiring an interest in science. During the competition, contestants will do a 'show-and-tell' on any science topic, and judging will be based on audiences' votes and judges' scores. The objectives of this festival are:

- To promote science communications and expressions of science in creative manners.
- To generate greater vibrancy and interest in the science communication scene locally.
- To promote the learning of science in a fun and engaging way.
- To raise the awareness of the public in the general field of science.

The festival, in 2010 has attracted 170 aspiring young students to show-and-tell performances which demonstrate their scientific principles phenomena. It was reported in the Singapore science centre annual report (2010/2011) that the competition has a twofold increase in participation since 2008.

4. Science in the Mall

Science in the Mall brings exhibits, science performances, demonstrations and hands-on activities to heartland shopping malls during the school holidays. It aims to engage families with children in simple hands-on science experiments and activities, and to encourage parents to be more actively involved in promoting their children's interest in science. The event is held twice annually during the June and November school holidays, each time over 3 consecutive days, usually from Fridays to Sundays. Over the years, Science in the Mall has reached out to more than 230,000 children, their families and the general public. It was reported (Singapore Science Centre Annual report 2010/2011) that in 2011, more than 19,000 children and their families attended the events.

5. Singapore Science Festival

Jointly organised by the Agency for Science, Technology & Research (A*STAR) and the Singapore Science Centre, the Singapore Science Festival is an annual national event celebrating the dynamism of science, engineering, technology and biomedicine. The Singapore Science Festival, previously known as the Science Month is Singapore's biggest annual science event. The name reflects

the aim of the Festival as a celebration of Science and Technology for everyone, young and old alike.

6. Meet the Scientist

Meet the Scientist is a series of monthly talks at the Singapore Science Centre, for which distinguished scientists from A*STAR share their experiences. These talks allow students and Singapore Science Centre visitors to interact with real-life scientists, learn more about interesting scientific research topics, and find out what makes scientists passionate about their work.

7. Singapore Science & Engineering Fair

The Singapore Science & Engineering Fair (SSEF) is a national competition organised by the Ministry of Education (MOE), the Agency for Science, Technology and Research (A*STAR) and the Singapore Science Centre (SCS). The SSEF is affiliated to the prestigious Intel International Science and Engineering Fair (Intel ISEF), which is regarded as the Olympics of science competitions. The SSEF is open to all secondary and pre-university students between 15 and 21 years of age where the participants are required to submit research projects from the Science Research Programme (SRP), Technology & Engineering Research Programme (TERP), Science Mentorship Programme (SMP) or projects done at school or cluster level. The projects cover all areas of science and engineering. In 2010, the event itself has attracted 469 entries (Singapore Science Centre annual report, 2010/2011), where participation is open to students from the secondary school up to the higher learning institutes.

8. Sony Creative Science Award

The Sony Creative Science Award (SCSA) is an annual competition jointly organised by the Singapore Science Centre and Sony Electronics Asia Pacific Pte Ltd, with the support of the Ministry of Education and the Agency For Science, Technology and Research (A*STAR). The main objective of this competition is to promote creativity among primary students. The competition also provides an opportunity for students to learn about science beyond the classrooms in a fun and enjoyable way. The competition is divided into two categories:

- Scizkid Award is an open category which comprises of 2 sections- ‘Primary 1 & 2’ and ‘Primary 3-6’. The students are allowed to choose any suitable materials to create a toy which demonstrates at least one scientific principle. The rule of the competition is that the toy has to be sturdy and safe to play with.
- Whizkid Award. Create a dream toy which the students would love to take on a holiday. The toy can be made of any material, as long as it is fun to play with. The students should also be required to submit a fifty word description on why this is the dream toy which will keep them entertained during their travels. In addition, the toy must demonstrate at least one scientific principle.

9. Tan Kah Kee Young Inventor's Award

The Tan Kah Kee Young Inventors' Award has been in existence since 1986 to praise inventors for their inventions that are original, practical and which can be commercialised to generate wealth for the country. Tan Kah Kee Young

Inventors' Award is jointly organised by the Tan Kah Kee Foundation, the Agency for Science, Technology and Research (A*STAR), the Defence Science and Technology Agency (DSTA) and the DSO National Laboratories, with the support of the Singapore Science Centre. The award seeks to stimulate creativity amongst the young and to promote scientific and technological research in Singapore.

10. The National Science Challenge

Launched in 2004, the National Science Challenge aims to promote science among students and the local public. The competition tries to provide a fun and informal learning experience for the participants and promote science education in the country.

11. A*STAR Talent Search

The A*STAR Talent Search (ATS), sponsored by the Agency for Science, Technology and Research (A*STAR) and organised with the support of the Singapore Science Centre (SCS), recognises students who have excelled in scientific research. The agencies are engaging and nurturing interested secondary and pre-university students to be a researcher in a long-term run.

- In a secondary school or pre-university
- Interested in a long-term career as a researcher
- Only individual category. No team category.
- Individual applications can be submitted for team projects

12. DNA Learning Laboratory

Students and public can now engage in unravelling the secrets of life with the launch of the DNA Learning Lab at the Singapore Science Centre. Opened on 29 March 2003, the new facility allows students and the public to keep pace with the DNA revolution and advances in the life sciences. The main objective of setting up the DNA Learning Lab is to give our students a deeper understanding of life sciences topics and issues, and at the same time stimulate students' interest in taking up careers in the life sciences. This would educate students to be more scientifically literate and later, as adults, they would have more considered views about life sciences issues and concerns.

Built at a cost of a million dollars and funded by the Ministry of Education, the DNA Learning Lab is one of the two centres set up as part of the collaboration between the Ministry of Education and Cold Spring Harbor Laboratory's Dolan DNA Learning Center in New York. The Science Centre's facility allows students to have hands-on experience in conducting genetics experiments. The Agency for Science, Technology and Research (A*STAR) provide funding for the recurrent cost of running the DNA Learning Lab. The Lab offers classes for primary to junior college levels. The programmes range from introductory classes to hands-on experiments, such as the study of cells and bacteria, gene transfer of fluorescent protein from jellyfish to bacteria and sequence inspection using computer.

Judgements concerning the success of those programmes

Singapore continues to lead the world in TIMSS 2011 in mathematics achievement. The country was among the top-performing countries at the fourth and eight grades. At

the fourth grade, the country score 606 to the benchmark of 500, the first in the list. The achievements were much higher than the previous years, where the score steadily increased from 590 in 1995, to 594 in 2003, to 599 in 2007 and 606 in 2011.

Additionally, the country had 43 percent of their students reach the TIMSS Advanced International Benchmark. At the eight grade, the country scored 611 to the benchmark of 500, second in the list. The score maintained above the benchmark of 500 since 1995, where the score in 1995 was 609, in 1999 was 604, in 2003 was 605 and in 2007 was 593. In general, nearly half of the students in this grade reached the Advanced International Benchmark (48%).

In TIMSS 2011, Singapore continues to be the top-performing country in Science at the fourth grade. The country has shown an increased score in the all four TIMSS International Benchmarks between 1995 and 2011. In the results, the country ranked second, with average scale score of 583. The results also have shown that one-third of the Singaporean students reached this advanced level of performance.

At the eight grade, Singapore had the highest average achievement. The country ranked the highest in the reported scale score with the average of 590. Additionally, at this grade, Singapore had the largest percentage of students reaching the Advanced International Benchmark (40%). In general, trends in the Science achievement were reported to be among the greatest increase from 1995 to 2011.

Singapore government has developed multiple pathways for students that are successful in delivering occupational skills at the secondary level. It is expressed in the provision of the country schooling system where relevant STEM based courses are provided.

The increased supply of local skilled labour is one of the evidence which support the effectiveness of the strategies used to enhance STEM based education. The relative supply of the labour which were based on workers with post secondary school and above, has been rising steadily from 0.19 in the 1980s, 0.41 in the 1990s and 0.92 between 2000-2011. The share of local skilled labour has grown from 41.1% between 2000-2005 to 46.9% between 2000-2011. On the other hand, the share of low skilled labour fell from 90.3% to 58.9% over the same time period. The observable facts revealed that longer schooling, more individual/company-led skills training and higher enrolment in STEM related education. Factors that may influence the increased rate of skilled labour supply are the relative demand for skills workforce and the shortage of skilled labour.

Singapore is a top list of countries on STEM education. It has a number of world-class university programs in science, engineering and technology. Government grants encourage international collaboration between researchers and leading international universities have set up their Asian campuses in Singapore which include MIT, Wharton and INSEAD. The government has invested more than a billion dollars to make the country a medical science hub and attract the world's best talent.

Consideration of the potential applicability of those policies, strategies and programs to Australia

1. Development of Regional to National educational policies with the inclusion of technology integration in STEM related courses.
2. Adherence to the strategies of enhancing and prolonging the effect of activities related to STEM based education throughout the region.

3. The development of a special agency directly under the supervision of Ministry of Education, such as A*STAR in Singapore, to manage, monitor, evaluate and organise STEM related activities and programmes throughout the country.
4. Tapping of talents related to STEM based careers right from secondary school taking into account of regional natural resources.
5. Encourage more industry collaboration in developing vocational and technical curriculum in STEM related subjects.
6. Comprehensive approach of identifying and nurturing teaching talent in the education system. Key elements in the system should be:
    - Recruitment
    - Training
    - Compensation
    - Continuous Professional Development
    - Performance Appraisal
    - Career development
    - Leadership selection and Training
7. Emphasize more on student-centered learning that enhance students' problem solving skills.
8. Special attention to STEM inclined students right from the pre-school.
9. Researched and skill based Curriculum such as the internationally well-known Singapore's mathematics curriculum and textbooks.

References

Agency for Science, Technology and Research (2011). Science, Technology and Enterprise Plan 2012.

Dahl, G. B. & Lochner, L. (2005). The impact of family income on child achievement. (Working paper 11279). National Bureau of Economic Research.

Institute of Technical Education (2012). Transformation in technical education changes. Singapore: Institute of Technical Education. International Bureau of Education of UNESCO (2011). World data on education: Singapore, 7th edition, 2010/2011.

International Bureau of Education of UNESCO (2011). World data on education Singapore. 7th edition, 2010/2011.

Lim, C.P. (2010). Betting on medical sciences. Issues in Science and Technology, Spring 2010. University of Dallas, Texas.

Manpower Research and Statistics Department (2012). Singapore workforce, 2012. Ministry of Manpower Singapore.

MCYS (2012) 'Government recognises the importance of pre-school' http://app1.mcys.gov.sg/PressRoom/Governmentrecognisestheimportanceofpreschool.aspx Media release (29 April 2011). New national academy to further science education and engagement among youths. Singapore: Agency for Science, Technology and Research.

Ministry of Manpower (2012a). Strategic and Skills-in-Demand List (SSL). Retrieved on January 3, 2013 from http://www.mom.gov.sg/skills-training-and-development/ skills-in-demand/Pages/skills-in-demand.aspx

Ministry of Trade and Industry (2012a). Yearbook of statistics Singapore, 2012. Department of Statistics, Ministry of Trade and Industry. Ministry of Trade and Industry (2012b). Research Innovation Enterprise 2015: Singapore future.

Research Innovation and Enterprise Secretariat, Ministry of Trade and Industry. MOE (2012) Speeches. 'FY2012 Committee of Supply Debate: Speech by Mr Lawrence Wong, Minister of State for Education, on Better Pre-Schools, Stronger Tertiary Institutions, More Education Opportunities For All' http://www.moe.gov.sg/media/speeches/2012/03/08/fy2012-committee-of-supply-debate-mos-wong.Php

Mullis, I.V.S., Martin, M.O., and Foy, P. (2008). TIMSS 2007 International Mathematics Report: Findings From IEA's Trends in International Mathematics and Science Study at the Eighth and Fourth Grades. Chestnut Hill, MA: Boston College.

Mullis, I.V.S., Martin, M.O., and Foy, P (2012). TIMSS 2011 International Mathematics Report: Findings From IEA's Trends in International Mathematics and Science Study at the Eighth and Fourth Grades. Chestnut Hill, MA: Boston College OECD (2010). Strong Performers and Successful Reformers in Education: Lessons from PISA for the United States.

OECD Secretariat (2012). Draft of OECD Review of Innovation in Southeast Asia, Country Profile of Innovation: Singapore. OECD Publishing.

OECD, (2012). SouthEast Asian Economic Outlook 2011/2012. OECD Publishing.

Raytheon (2010). A Cross-Country Exploration of Math-Related Learning in the United States, England, and Singapore: Parent Perceptions and Practices Regarding Math Education During the Middle School Years'. Retrieved on January 2, 2013 from http://www.raytheon.com/newsroom/rtnwcm/groups/ncs/documents/content/raytheoneduventures12-2010_pdf.pdf

Schleicher, A. (2012), Ed., Preparing Teachers and Developing School Leaders for the 21st Century: Lessons from around the World, OECD Publishing.

Sclafani, S. (2008). Rethinking Human Capital in Education: Singapore As A Model for Teacher Development. A Paper Prepared For The Aspen Institute Education and Society Program.

Seng, L. S. (2011). Case Study on 'National Policies Linking TVET with Economic Expansion: Lessons from Singapore', Paper commissioned for the EFA Global Monitoring Report 2012.
Toh, M. H. (2012). Internationalization of Tertiary Education Services in Singapore.
Asian Development Bank Institute (ADBI) Working Paper Series 388. Tokyo: ADBI. Retrieved on December 2012 from http://www.adbi.org/working paper/2012/10/12/5263.internationalization.tertiary.educ.singapore/
Toh, R. and Tat, H. W. (2012). TRADE LIBERALIZATION, LABOUR DEMAND SHIFTS AND EARNINGS INEQUALITY IN SINGAPORE, Review of Urban and Regional Development Studies, Department of Statistics Singapore (2012). Singapore in Figures 2012.
UNESCO (2005). Science and technology system in Singapore. Retrieved on December 20, 2012 from http://portal.unesco.org/pv_obj_cache/pv_obj_id_FEF9DC982079B3D65A213313DF13C4FCFB7D0200/filename/Singapore.pdf
WDA (2012). Early Childhood Education. Retrieved from http://www.wda.gov.sg/content/wdawebsite/L202-SingaporeJOBSpedia/L302-010B-EarlyChildhoodCareEdu.html
World of Work Report 2012: Better jobs for a better economy, International Institute for Labour Studies. Report of the Committee on University Education Pathways Beyond 2015 (CUEP), 2012. Ministry of Education Singapore. Report and Recommendations for Education Policy Leaders from The Pearson