Best practices in STEM partnerships: Experiences from Singapore

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What is STEM?

- STEM stands for Science, Technology, Engineering and Mathematics.
- Commonly, when we refer to STEM, it can refer to the separate subjects within STEM or an integrated discipline connecting all the separate subjects.
- We will use the above framework for this presentation.

Why is STEM so important?

- With globalization, new developments in ICT and advances in science & technology impacting on society, the competitiveness of nations are at stake – jobs are taking flight, some traditional vocations are at the risk of becoming irrelevant, and job functions are coalescing and moving up the value chain.
- Nations need to take attention of these developments and respond accordingly to the challenges so that their people are better equipped with the skill sets to thrive in the new economy.
- Modern economy is very much driven by STEM.
- Imperative to lay good foundation for STEM in schools for students.

Education system in Singapore

- Has attracted international recognition.
- Latest global education rankings, released by the Organization of Economic Co-operation and Development in May 2015, put Singapore at the top for quality, equity and efficiency of school systems.
- In the 2021 QS World University rankings, Singapore has two universities in the top 15 in the world – National University of Singapore (11) and Nanyang Technological University (13).
- Singapore students regularly do well in the international Olympiads in sciences and mathematics as well as in PISA and TIMSS.

External benchmarking: TIMSS rankings for Singapore

Year	Science (Grade 4)	Maths (Grade 4)	Science (Grade 8)	Maths (Grade 8)
2015	1	1	1	1
2011	2	1	1	2
2007	1	2	1	3
2003	1	1	1	1

Trends in International Mathematics and Science Studies (TIMSS) is conducted by International Association for the Evaluation of Educational Achievement

External benchmarking: PISA rankings for Singapore

Year	Maths literacy skills	Reading literacy skills	Science literacy skills
2015	1	1	1
2012	2	3	3
2009	2	5	4

PISA is the OECD's Programme for International Student Assessment.

Approaches to promote STEM in schools in Singapore

- Among STEM subjects, only science and mathematics are taught in schools.
- Engineering and technology are not taught as mainstream subjects in schools.
- Use of ICT is very pervasive in science and mathematics subjects.
- Emphasis is on building competencies in sciences and mathematics in school while promotion of integrated STEM is left to other players.
- When we talk about STEM, basically we are referring to STEM subjects as well as ICT subjects.

Partnerships in STEM education

- STEM is too broad an area to be pursued by any one entity.
- In Singapore, while schools lay the basic foundations for science and mathematics, this is made possible with other partners as well as taken to the next level through various partners.
- This multi-faceted partnership model is a reason why STEM education in Singapore is highly regarded internationally.
- We will look at various partnership models.

Factor 1: National Institute of Education (NIE)

- NIE is the sole teacher training institution in Singapore – quality of teachers is thus controlled at the source.
- It is part of Nanyang Technological University and is supported by Ministry of Education.
- Pre-service teacher education in STEM subjects is very rigorous.
- Academic staff are research-active.
- Wide range of in-service courses to cater to needs of teachers.

Factor 2: Ministry of Education (MOE)

- MOE plays key role in teacher recruitment, funding for professional training of teachers, and formulation of educational policies.
- Performance of schools closely tracked on various measures, including how well they prepare students.
- Good administrative machinery ensures that policies are effectively implemented at school level.
- Provides very good support to schools.
- Provides very good support for STEM education.

Factor 3: Linkages with science center

- Singapore Science Center was established in 1977.
- Promotes science and technology to students and the public through science enrichment programs, exhibitions on various themes, science promotional activities and science publication programs (Tan & Subramaniam, 1998, 2003).
- Over 200,000 students attend its science and mathematics enrichment programs every year.

Tan, W.H.L. & Subramaniam, R. (1998). Developing countries need to popularise science. *New Scientist*, 2139, 52.

Tan, W.H.L. & Subramaniam, R. (2003). Science and technology centres as agents for promoting science culture in developing nations. *International Journal of Technology Management*, 25(5), 413-426

Factor 4: Applied Learning Program in STEM

- Spearheaded by STEM Inc., a separate unit within the Singapore Science Centre.
- Offered to secondary schools.
- Emphasis is on coming up with solutions to real world problems using integrated STEM.
- Schools can choose any one of 12 themes for their students to work on over a period of time.
- Supported by Ministry of Education.

Earlier themes in Applied Learning Program

- Embedded Electronics
- Engineering Design & Modelling
- Robotics
- Food Science & Technology
- Alternative Energy
- Urban Design & Innovation
- eWater Sensors & Water Technology
- Materials Science
- eHealth Sensors
- Applied Health Sciences
- Flight & Aerospace
- Game Design & Simulation

Current themes in Applied Learning Program

Primary School themes

- Game Design & Making
- Health Science
- Materials Science
- Sustainability
- Transportation

Secondary School Themes

- Cities and Urban Landscapes
- Emerging Technologies
- Future of Transportation
- Health and Food Science
- Sustainability

Factor 5: Emphasis on project work

- Project work in sciences and mathematics helps to show application of their principles in addressing problems
- It is a great way for school students to emulate the work of scientists in some way
- Two schemes, which have been in place for some time, are now shared
- Both schemes driven by scientific societies (Tan & Subramaniam, 2009): Singapore National Academy of Science, Singapore Association for the Advancement of Science, and Science Teachers' Association of Singapore as well as Singapore Science Centre

Tan, W.H.L. & Subramaniam, R. (2009). Role of scientific academies and scientific societies in promoting science and technology: Experiences from Singapore. *International Journal of Technology Management*, 46, 38-50.

Project work: Young Scientist badge scheme

- Allows primary students to individually engage in project-based investigations in 17 disciplines:

  Geology, Zoology, Mathematics , Physics, Ornithology, Botany, Astronomy, Chemistry, Entomology, Ecology, Meteorology, Environment. Information Technology, Food Technology, etc.

- Students need to complete tasks in an Activity Card and get these certified by the class teacher
- Successful completion of an Activity Card gets student a highly coveted 'I am a Young Scientist' Badge in the appropriate discipline.
- Has been in operation since 1982.
- Now fully online

‘I am a Young Physicist’ card

	TO QUALIFY FOR A "I AM A YOUNG PHYSICIST" BADGE, EARN 15 STARS	Teacher's signature on completion of activity
★★★	Make an instrument that can be used to measure temperature.	
★★★	Make an instrument that can be used to measure weight.	
★★★	Make an instrument that can be used to measure time or time intervals.	
★★★★	Write a biography of between 150–200 words of a famous Physicist. Bring one of the Physicist's inventions to your class or Science Club meeting and explain to your fellow pupils how it works OR explain to your fellow pupils why you consider him/her to be such a great scientist.	
★★	List 10 famous Physicists and indicate their most important discovery or invention.	
★★★	Write a short science fiction story based on Physics or involving gadgets that are applications of Physics.	
★★	Collect 10 objects which are applications of Physics. Label them, stating the Physics principle each depends on.	
★★★	Make a simple solar heater.	
★★★★	Carry out an experiment that is not found in your school textbook on electricity (caution: Do not use household current; use batteries). Keep a record of the experiment.	
★★	Draw a famous Physicist.	
★★	Visit the Science Centre and make notes about 2 of the Physics exhibits that interest you.	
★★★	Make a labelled model of an atom or a molecule.	
★★	Write a poem that involves Physics.	
★★	Collect 8 objects that convert one form of energy to another. Label them, stating the energy change that occurs.	
★★★	Write an article about the use of nuclear energy.	
★★★	List at least 5 machines that could have been used by the Egyptians to build the pyramids. Make a model to illustrate the use of one these machines OR make a working model of one of these machines.	
★★★	Make a periscope.	
★★★	Make a sound-making instrument that produces musical notes. You should be able to play a simple tune using the instrument.	

Date started ..... Date completed .....

Teacher's name .....
(please print)

Principal's signature .....

School's tel. no. .....

School stamp ..... Date .....

Authorisation of award by the Singapore Science Centre

Date awarded

.....

Project work: Questa Club badge scheme

- Not structured like that of Young Scientist badge scheme but is more open-ended
- Secondary students can engage in a science project of their liking
- Successful completion of project gets them a coveted Gold or Silver Questa badge, depending on the quality of the project
- Has been in operation since 1988.

Factor 6: Other partnership programs to promote STEM education

- National Robotics Competition – *organized by Singapore Science Centre with support of Ministry of Education and other partners.*
- Singapore Science Festival – *organized by Singapore Science Centre & Agency for Science, Technology & Research.*

Factor 4: Other programs to promote STEM education (cont'd)

- Tan Kah Kee Young Inventor's Award – *organized by Tan Kah Kee Foundation.*
- Singapore Science & Engineering Fair- *organized by Ministry of Education, Agency for Science, Technology and Research, and Singapore Science Centre*

These programs provide opportunities for students to engage with STEM in real world settings.

Factor 5: Promoting research among school students

- Selected schools in Singapore have research laboratories staffed by PhDs.
- Students get opportunities to have hands-on experience with some of the latest research techniques.
- Restricted to top students who are interested in research.

DNA test kit developed by students

Dunman scores with new DNA test kit

It's cheaper...

Costs $30, instead of $200 to $500 for commercial kits

... and works faster too

Test takes 30 minutes, compared to one to four hours

By TAY SHI'AN

DUNMAN Secondary School has come up with a DNA extraction kit that it says is 20 to 30 times cheaper than what is available in the market and just as effective.

The school's kit also takes just 30 minutes to separate DNA from other cell components, compared to the one to four hours needed for commercial kits.

Genes are made up of a DNA code and studying the DNA can help scientists determine genes which cause hereditary diseases such as types of cancer and diabetes.

tion kits are priced between $200 and $500 for 100 extractions.

The principal, Mrs Edelweis Neo, said the school may package the kit for sale next year, and that she was "very proud" of the students' achievement.

The kit was developed and tested by Secondary 3 students Neo Yi Xian and Chan Li Fang; second-year Singapore Polytechnic biotechnology students Martin Tay and Lin Lili, who are on attachment with Dunman Secondary's life sciences research centre; and Mr Chow Jeng Yeong, 20, a research assistant at the school.

things only when they are in polytechnic or university."

Dr Dennis Yeo, a molecular geneticist and head of the centre, said the team decided to make its own kit because commercial ones are expensive.

"The school had an incentive to create its own solutions because we do not have as much funds as research institutes, for instance, which simply buy large quantities of commercial kits."

Dr Yeo, who supervised the project, estimated that the school would save $1,000 a month using its own kits.

Human DNA is commonly extracted using cheek cells,

HOW HWEE YOUNG

One month was all it took for the team to hit upon the right formula for the kit, which the school may package for sale next year. The five involved are (from left), Lili, Mr Chow, Yi Xian, Martin and Li Fang.

Factor 6: Promoting invention culture

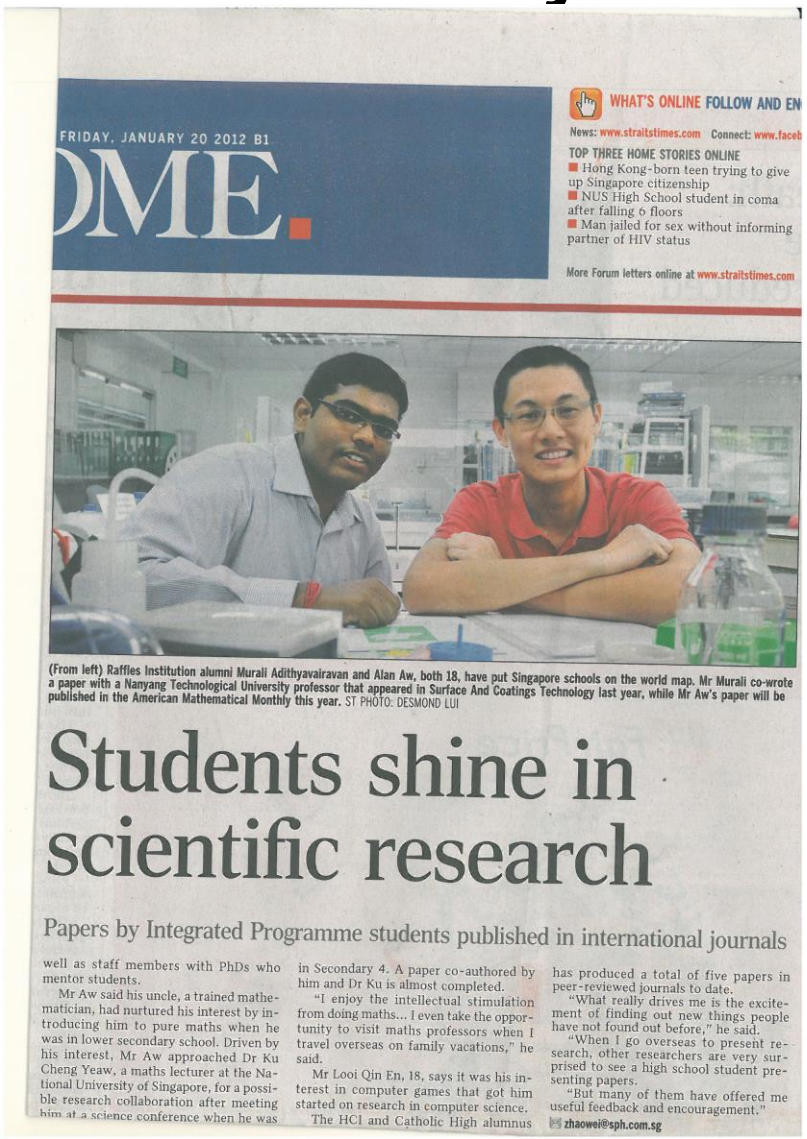
- Encouragement given to students to engage in invention pursuits.
- Pursuit of inventive endeavors is a way to showcase STEM in action.
- At the primary level, a key program is the SONY Creative Science Award, which is driven by a partnership between Singapore Science Centre and SONY Group companies in Singapore, with the support of the Ministry of Education.

Pupils displaying toy inventions at Sony Creative Science Award competition

Factor 7: Research internships for school students

- Scientists are natural role models for students.
- Two initiatives are in place for school students to work with university scientists on their research: *Science Research Programme* of National University of Singapore and *Technology, Engineering & Research Programme* of Nanyang Technological University.
- *Science Mentorship Programme*, administered by the Gifted Education Unit of the Ministry of Education in conjunction with a range of institutions, offer students placements in various laboratories at higher education institutions and research institutes.
- Some students' work have been published in international journals through these initiatives.

School students publish papers in international journals!



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WHAT'S ONLINE FOLLOW AND EN

News: www.straitstimes.com Connect: www.faceb

TOP THREE HOME STORIES ONLINE

- Hong Kong-born teen trying to give up Singapore citizenship
- NUS High School student in coma after falling 6 floors
- Man jailed for sex without informing partner of HIV status

More Forum letters online at www.straitstimes.com

(From left) Raffles Institution alumni Murali Adithyavairavan and Alan Aw, both 18, have put Singapore schools on the world map. Mr Murali co-wrote a paper with a Nanyang Technological University professor that appeared in Surface And Coatings Technology last year, while Mr Aw's paper will be published in the American Mathematical Monthly this year. ST PHOTO: DESMOND LUI

Students shine in scientific research

Papers by Integrated Programme students published in international journals

well as staff members with PhDs who mentor students.

Mr Aw said his uncle, a trained mathematician, had nurtured his interest by introducing him to pure maths when he was in lower secondary school. Driven by his interest, Mr Aw approached Dr Ku Cheng Yeaw, a maths lecturer at the National University of Singapore, for a possible research collaboration after meeting him at a science conference when he was in Secondary 4. A paper co-authored by him and Dr Ku is almost completed.

"I enjoy the intellectual stimulation from doing maths... I even take the opportunity to visit maths professors when I travel overseas on family vacations," he said.

Mr Looi Qin En, 18, says it was his interest in computer games that got him started on research in computer science.

The HCI and Catholic High alumnus has produced a total of five papers in peer-reviewed journals to date.

"What really drives me is the excitement of finding out new things people have not found out before," he said.

"When I go overseas to present research, other researchers are very surprised to see a high school student presenting papers.

"But many of them have offered me useful feedback and encouragement."

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Factor 8: Allowing room for external vendors to offer STEM programs

- Schools in Singapore are already doing a lot to promote STEM through curricula efforts.
- To further promote STEM, an environment is also in place whereby external vendors are given opportunities to offer suitable programs for students, either in school or outside.
- This is greatly aided by two government schemes: Edusave Pupils Fund for each student and Edusave Fund for each school. The former scheme puts money into very student's account annually while the latter scheme also gives money to schools according to their enrolment. The money is from Ministry of Education.

Summarizing comments

- Today's students are living in an age of ICT, globalization, and rapid advances in science & technology,
- Singapore places considerable emphasis on ensuring that its students are inculcated with the necessary mindset while they are still in school so that they are better prepared for the challenges of the workforce in the new economy. In this context, STEM is very important.
- In promoting STEM education, Singapore places emphasis on building competencies in the sciences and mathematics as well as ICT skills among students while leaving informal science education providers the task of offering integrated STEM programs.
- Success of STEM education in Singapore is very much due to partnership model with various stakeholders.