香港教育大學
The Education University of Hong Kong

STEM
From Learning to Aspiration

Professor Winnie SO
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Associate Dean, Graduate School
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Active promotion of STEM education

Educate to Innovate initiative, 2009

Global Education Initiative

Why is STEM Education Important?

STEM Job Crisis

Need of enterprises
To build talent pool

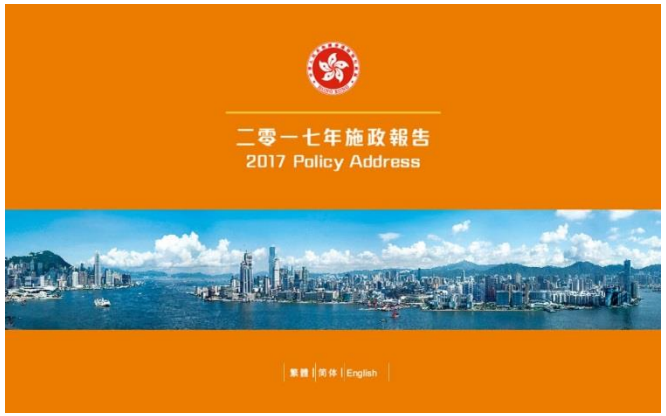
STEM professionals supply for future economy

Build 21st century workforce with "21st century skills"

Bridge the gender gap in STEM jobs

Carmody (2016), *Why Is STEM Education Important?*
NATURE (2017) , *Building the 21st Century Scientist*

Chief Executive's Policy Addresses on STEM education



The Education Bureau will renew and enrich the curricula and learning activities of Science, Technology and Mathematics, and enhance the training of teachers, thereby allowing primary and secondary pupils to fully unleash their potential in innovation

(Item 152 in 2015)

The Government will step up efforts to promote STEM (Science, Technology, Engineering and Mathematics) education and encourage students to pursue the study of these subjects

(Item 89 in 2016)

The Education Bureau should strive to promote STEM education with the provision of additional resources for primary schools at the beginning of last year, and be prepared to provide each public sector secondary school with an additional one-off subsidy of $200,000 to facilitate the implementation of school-based programmes related to STEM education (Para. 212 in 2017)

Chief Executive's Policy Address

Highlighted **innovation and technology** as one of the main policy directions for economic development. To boost innovation and technology in **eight key areas** to help HK become an **international I&T hub**

(1) resources for research and development, (2) nurturing a talent pool, (3) venture capital, (4) scientific research infrastructure, (5) legislation review, (6) opening up data, (7) government procurement and (8) **popular science education**

2018-19 Budget

Boost Innovation and Technology Development

The 2018-19 Budget

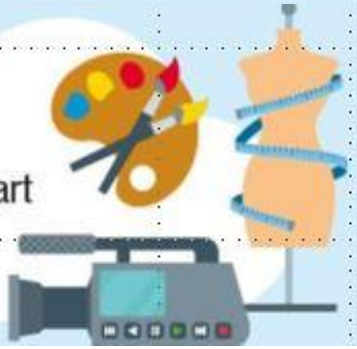
https://www.budget.gov.hk/2018/eng/ec.html

Innovation and Technology

- Focus on 4 areas: biotechnology, artificial intelligence (A.I.), smart city and financial technologies
- Set aside $20 billion for the first phase of the Hong Kong-Shenzhen Innovation and Technology Park in the Lok Ma Chau Loop
- Inject $10 billion into the Innovation and Technology Fund to support applied research and development
- Earmark $10 billion for the establishment of two research clusters on healthcare technologies and on A.I. and robotics technologies, to attract top scientific research institutions and technology enterprises
- Allocate $10 billion to upgrade facilities of the Science Park and enhance support for enterprises in the Park
- Allocate $200 million to Cyberport to enhance support for start-ups, and another $100 million to develop e-sports

Creative Industries

- Inject $1 billion into the CreateSmart Initiative to support development of the creative industries



Construction Industry

- Set up a $1 billion Construction Innovation and Technology Fund to support the industry to harness innovative technology

Global Innovation Index 2018

Energizing the World with Innovation

Singapore

Hong Kong

Global Innovation Index 2018 rankings

Country/Economy	Score (0–100)	Rank	Income	Rank	Region	Rank	Efficiency Ratio	Rank	Median: 0.61
Switzerland	68.40	1	HI	1	EUR	1	0.96	1	
Netherlands	63.32	2	HI	2	EUR	2	0.91	4	
Sweden	63.08	3	HI	3	EUR	3	0.82	10	
United Kingdom	60.13	4	HI	4	EUR	4	0.77	21	
Singapore	59.83	5	HI	5	SEAO	1	0.61	63	
United States of America	59.81	6	HI	6	NAC	1	0.76	22	
Finland	59.63	7	HI	7	EUR	5	0.76	24	
Denmark	58.39	8	HI	8	EUR	6	0.73	29	
Germany	58.03	9	HI	9	EUR	7	0.83	9	
Ireland	57.19	10	HI	10	EUR	8	0.81	13	
Israel	56.79	11	HI	11	NAWA	1	0.81	14	
Korea, Republic of	56.63	12	HI	12	SEAO	2	0.79	20	
Japan	54.95	13	HI	13	SEAO	3	0.68	44	
Hong Kong (China)	54.62	14	HI	14	SEAO	4	0.64	54	
Luxembourg	54.53	15	HI	15	EUR	9	0.94	2	
France	54.36	16	HI	16	EUR	10	0.72	32	
China	53.06	17	UM	1	SEAO	5	0.92	3	
Canada	52.98	18	HI	17	NAC	2	0.61	61	
Norway	52.63	19	HI	18	EUR	11	0.64	52	
Australia	51.98	20	HI	19	SEAO	6	0.58	76	
Austria	51.32	21	HI	20	EUR	12	0.64	53	
New Zealand	51.29	22	HI	21	SEAO	7	0.62	59	
Iceland	51.24	23	HI	22	EUR	13	0.76	23	
Estonia	50.51	24	HI	23	EUR	14	0.82	12	
Belgium	50.50	25	HI	24	EUR	15	0.70	38	
Malta	50.29	26	HI	25	EUR	16	0.84	7	
Czech Republic	48.75	27	HI	26	EUR	17	0.80	17	
Spain	48.68	28	HI	27	EUR	18	0.70	36	
Cyprus	47.83	29	HI	28	NAWA	2	0.79	18	
Slovenia	46.87	30	HI	29	EUR	19	0.74	27	
Italy	46.32	31	HI	30	EUR	20	0.70	35	

Global Innovation Index 2018
Energizing the World with Innovation

Singapore

Hong Kong

Innovation Input Sub-Index rankings

Country/Economy	Score (0–100)	Rank	Income	Rank	Region	Rank	Median: 42.51
Singapore	74.23	1	HI	1	SEAO	1	
Switzerland	69.67	2	HI	2	EUR	1	
Sweden	69.21	3	HI	3	EUR	2	
United Kingdom	67.89	4	HI	4	EUR	3	
Finland	67.88	5	HI	5	EUR	4	
United States of America	67.81	6	HI	6	NAC	1	
Denmark	67.43	7	HI	7	EUR	5	
Hong Kong (China)	66.71	8	HI	8	SEAO	2	
Netherlands	66.45	9	HI	9	EUR	6	
Canada	65.67	10	HI	10	NAC	2	
Australia	65.66	11	HI	11	SEAO	3	
Japan	65.41	12	HI	12	SEAO	4	
Norway	64.18	13	HI	13	EUR	7	
Korea, Republic of	63.42	14	HI	14	SEAO	5	
New Zealand	63.41	15	HI	15	SEAO	6	
France							
Germany							
Ireland							
Israel							
Austria							
Belgium							
Iceland							
Spain							
United Arab Emirates							

Elements of the national economy that enable innovative activities:

- Institutions,
- Human capital and research,
- Infrastructure,
- Market sophistication, and
- Business sophistication

Global Innovation Index 2018
Energizing the World with Innovation

Innovation Output Sub-Index rankings

Country/Economy	Score (0–100)	Rank	Income	Rank	Region	Rank	Median: 25.39
Switzerland	67.13	1	HI	1	EUR	1	
Netherlands	60.19	2	HI	2	EUR	2	
Sweden	56.94	3	HI	3	EUR	3	
United Kingdom	52.37	6	HI	6	EUR	6	
Germany	52.79	5	HI	5	EUR	5	
United States of America	51.81	7	HI	7	NAC	1	
Luxembourg	52.87	4	HI	4	EUR	4	
Finland	51.38	8	HI	8	EUR	7	
China	50.98	10	UM	1	SEAO	1	
Israel	50.83	11	HI	10	NAWA	1	
Korea, Republic of	49.84	12	HI	11	SEAO	2	
Ireland	51.25	9	HI	9	EUR	8	
Denmark	49.34	13	HI	12	EUR	9	
Iceland	44.26	19	HI	18	EUR	13	
Estonia	45.39	17	HI	16	EUR	12	
France	45.40	16	HI	15	EUR	11	
Malta	45.84	14	HI	13	EUR	10	
Japan							
Czech Republic							
Austria							
Belgium							
Singapore							
Slovenia							
Hong Kong (China)							
New Zealand							
Norway							

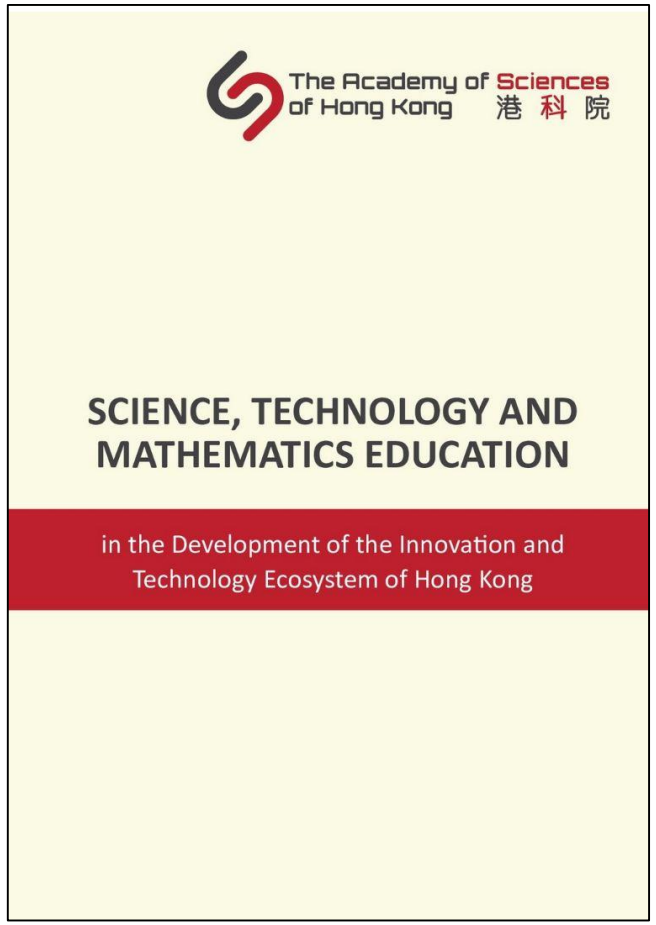
Singapore

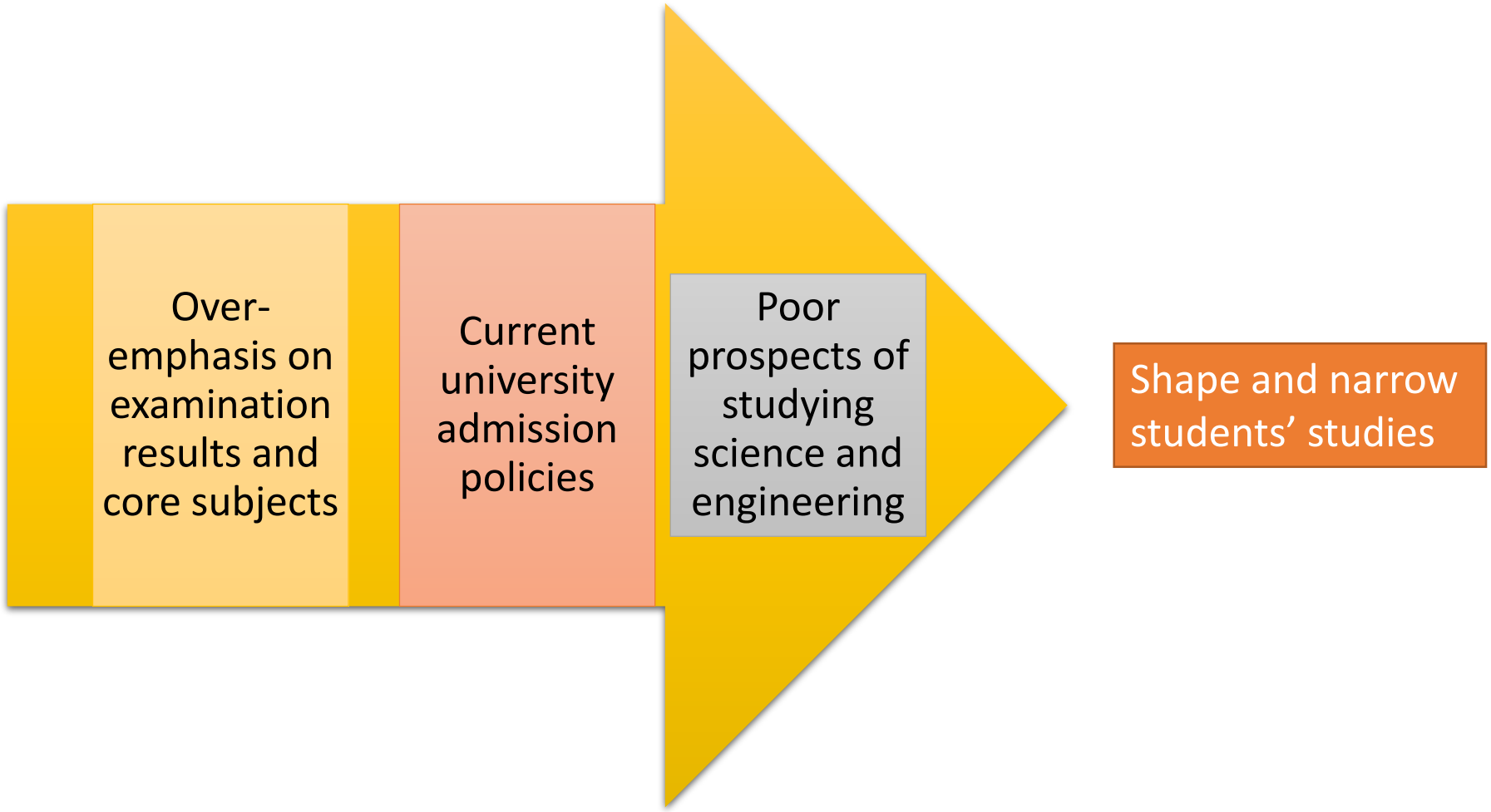
Hong Kong

Outputs are results of innovative activities within the economy:

- Knowledge and technology outputs
- Creative outputs

Difficulties in STEM education





Academy of Sciences of HK (2017)

Difficulties in STEM education

"STEM Education in Primary Schools" Survey

香港青年協會
the hongkong federation of youth groups

Excessive homework

Unattractive activities

Expensive activity fees

Lack of support, training and confidence of teachers in STEM

Hinder students' participation in STEM-related extra-curricular activities

Students have limited exposure to STEM learning activities

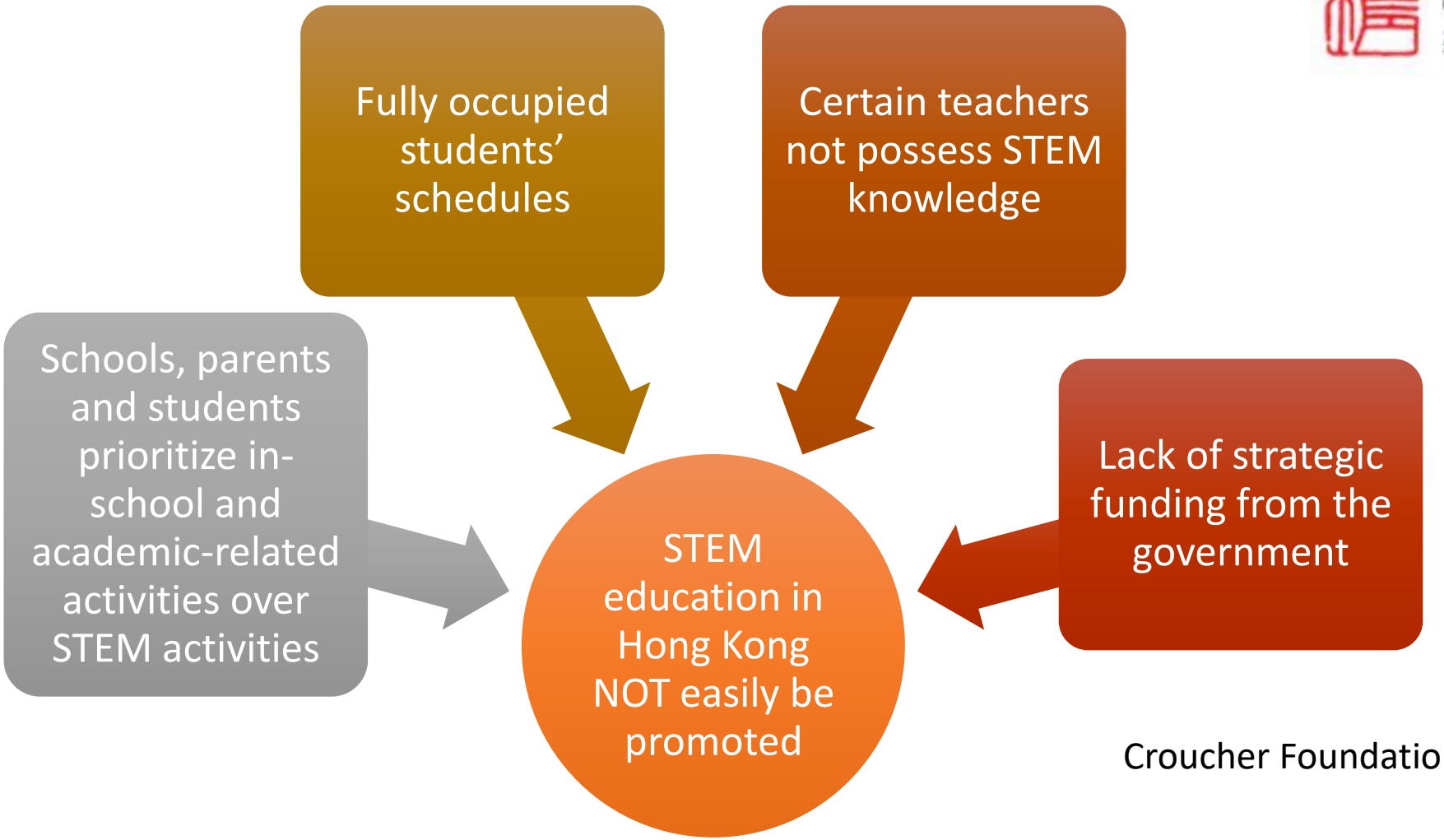
Affect the effectiveness of teaching and learning

HK Federation of Youth Groups (2017)

Difficulties in STEM education

***"The Out-of-School STEM Ecosystem"* in HK**

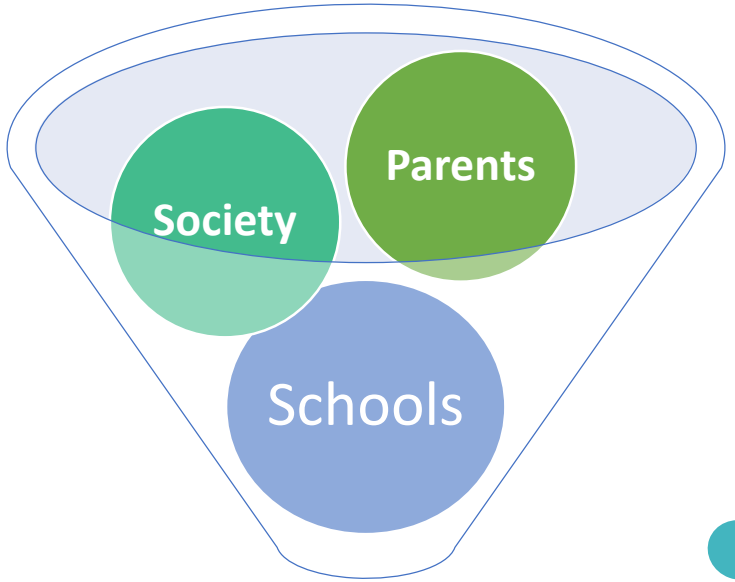
Croucher Foundation
裘槎基金會



Croucher Foundation(2016)

Difficulties in STEM education

"To STEM or Not STEM? Factors influencing Adolescent Girls' Choice of STEM subjects"



- Early experience and exposure to STEM
- Self-perceived ability
- Self-interest
- Aspirations

Girls' intention to study STEM-related subjects

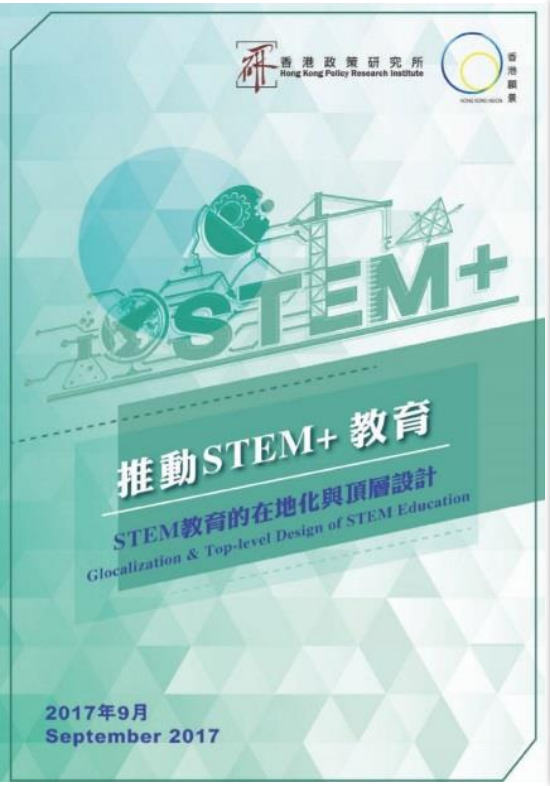
Gender stereotypical beliefs of both students and teachers

Parents lack information on STEM career options

The Women's Foundation (2017)

Promoting STEM education

"Globalization & Top-level Design of STEM Education"



Creating a positive environment for STEM and career development

- Creating a 'STEM+ Promotion Centre'
- Promoting different teaching strategies
- Establishing STEM+ literacy framework & STEM+ business-school platform
- Improving the university admissions system

Joint efforts of :

Government

Business

Educational sector

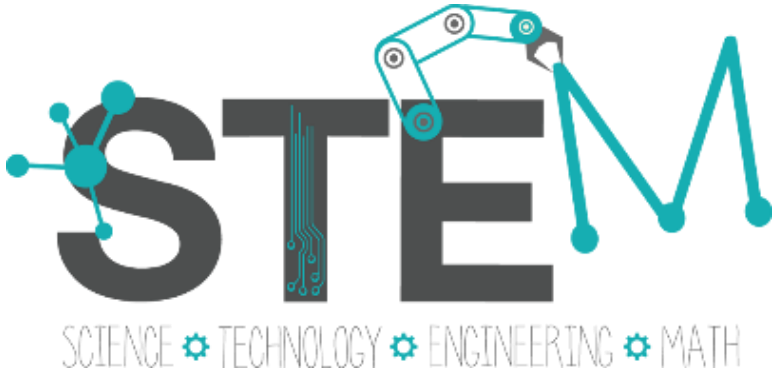
HK Policy Research Institute & HK Vision (2017)

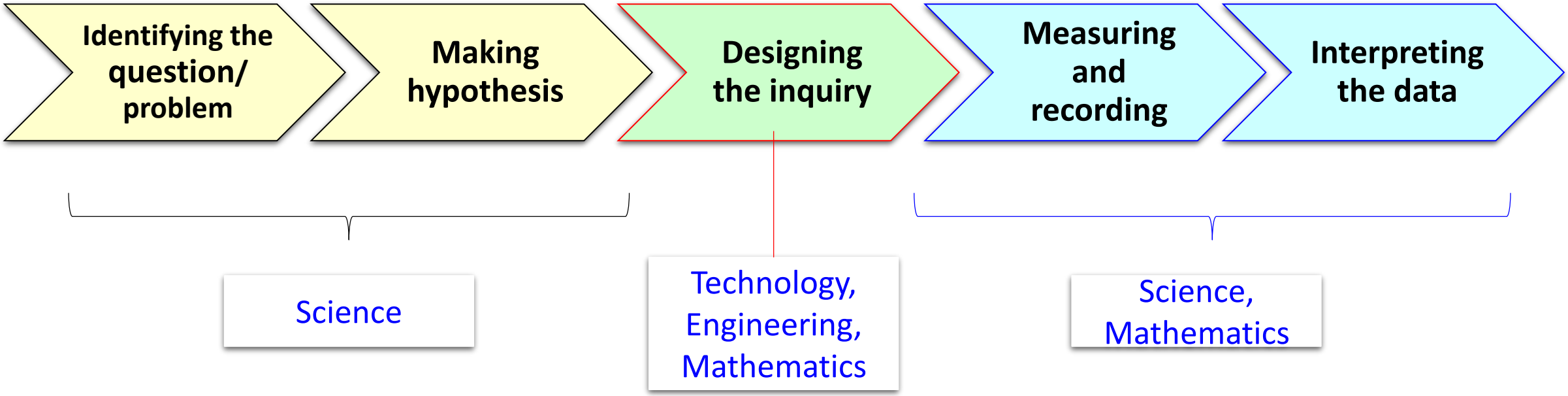
Change students' learning

from studying discrete bits of the knowledge and using rote procedures to investigate the interrelated facets of real world problems

National Governors Association (2007),"Innovation America: Building a STEM Agenda"

Science Inquiry



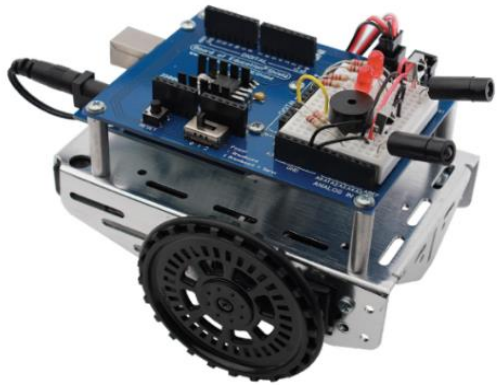


National Governors Association (2007). *Innovation America: Building a Science, Technology, Engineering and Math Agenda.*

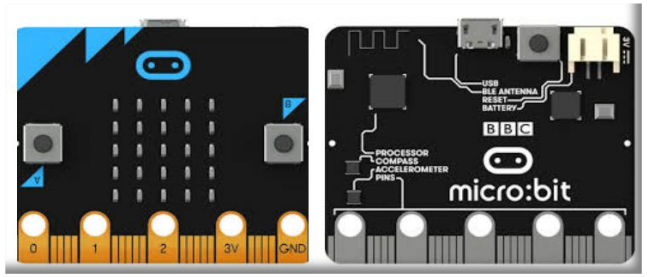
Robotics

Making & Design

Arduino



BBC micro:bit



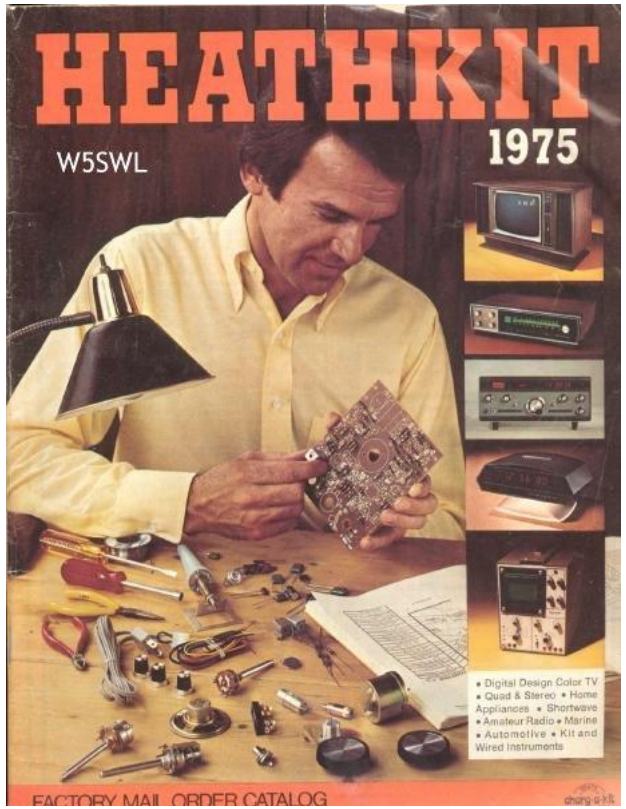
Data Loggers

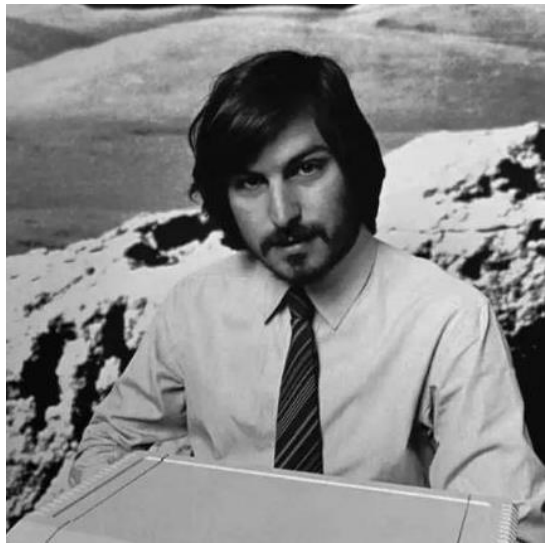
Technological products provided
convenience and **tools**
for making and investigation

Aerial Camera

Making & Design

Consumers of products→ Creators of products





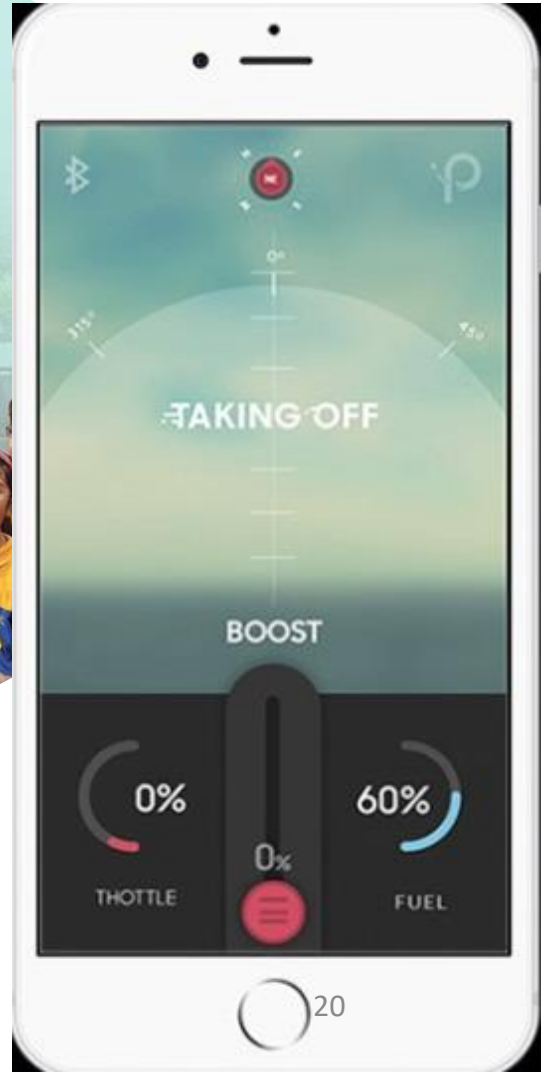
"I was very lucky, because when I was a kid both my dad and the **Heathkits** made me believe I could build anything."
——Steve Jobs

Availability of right tools → **Inspire the quest to make and to create**

Making
&
Design

New meets old -
Paper plane controlled by mobile App

(Powerup 3.0 App – adding mobile control to paper planes)



Enhance the quality of life

Essential for sustainable development of our planet

Innovation

STEM Fair – Platform for exchanging innovative ideas

Innovation

STEM Fair – Platform for exchanging innovative ideas

22

Years

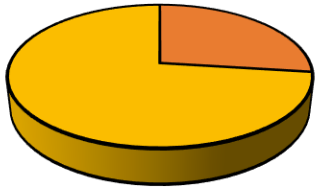
from 1997 to 2018

3,000

STEM projects

20,000

Students and Teachers



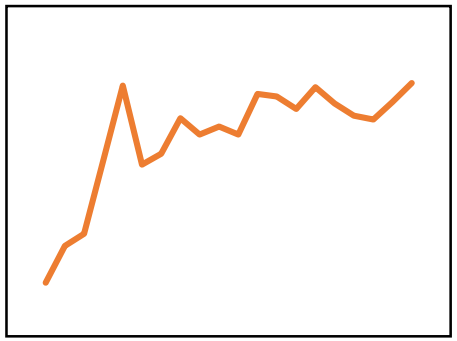
>30%

Hong Kong Primary Schools participated

10+

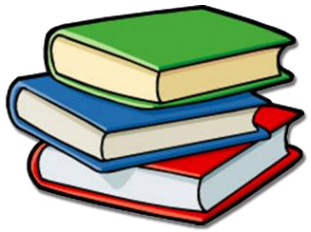
Teams from other regions

from 2006 to 2018



90%

Growth in participation rate



22

Booklets of STEM projects

200

Online Outstanding awarded teams videos

Innovation

STEM Fair – Platform for exchanging innovative ideas

Moss Filtration System

Fruit Enzyme Detergent

Rooftop Heat Insulation

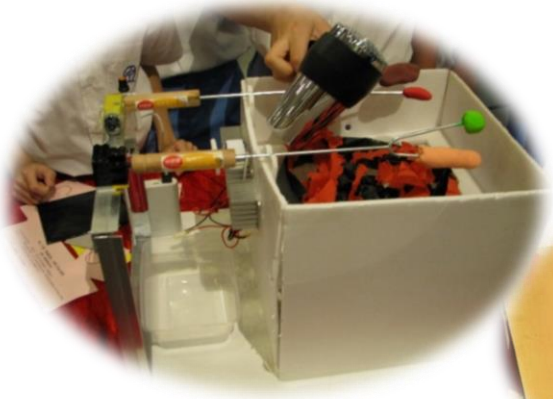
Insulated Container

Sound Energy Generator

Urban Farming Investigation

DIY Red Tea Hair Dye

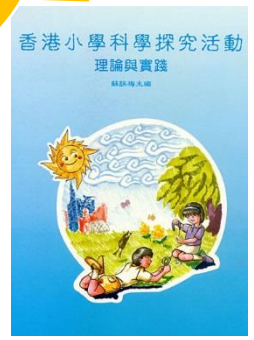
High Efficiency Barbecue Grill

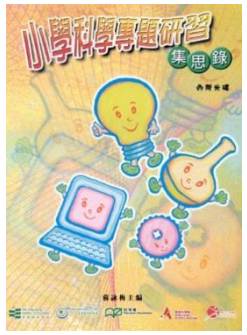


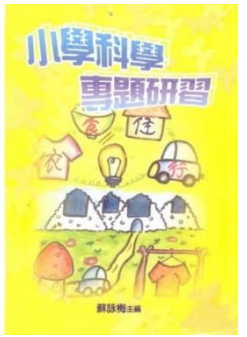
Eggshell Toothpaste

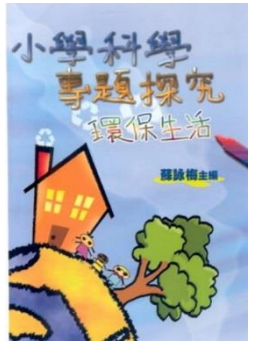
Innovation

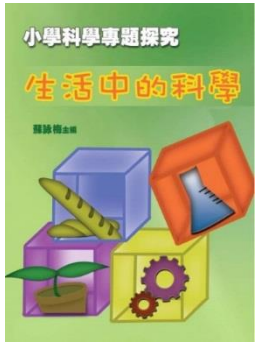
STEM Fair – Platform for exchanging innovative ideas

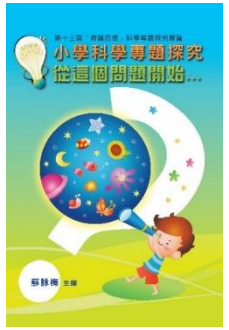


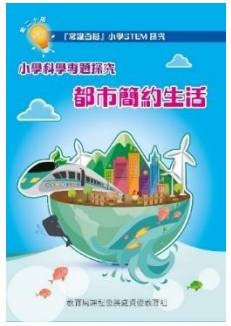






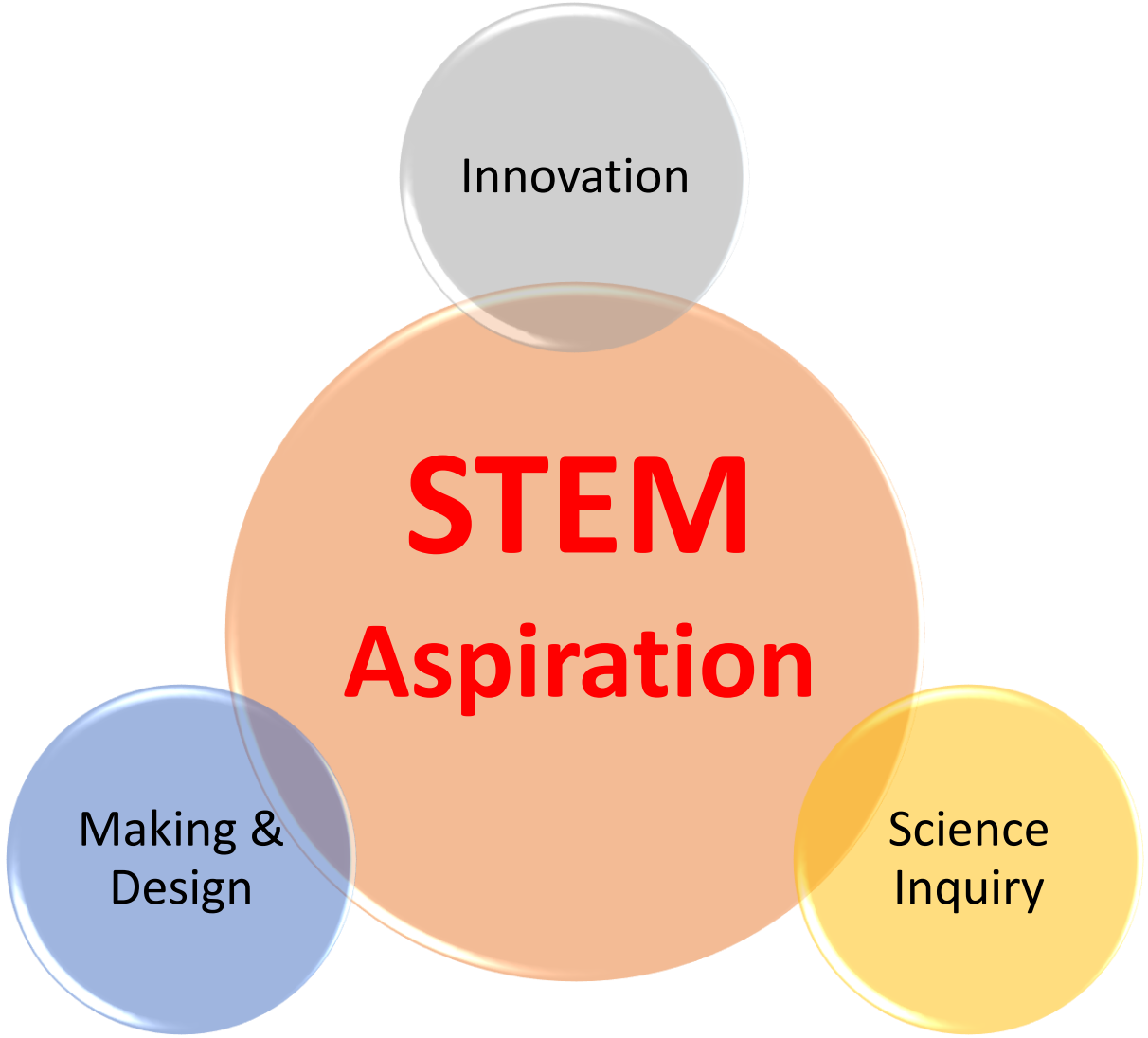






https://www.hkedcity.net/pspe/archive

Challenges – STEM Aspiration



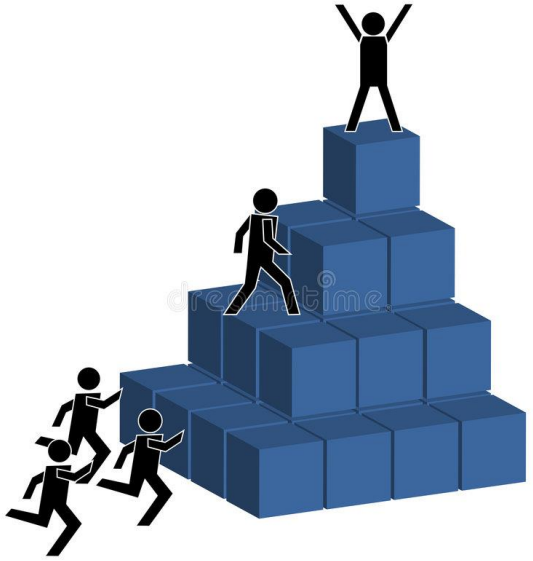
What is Aspiration?

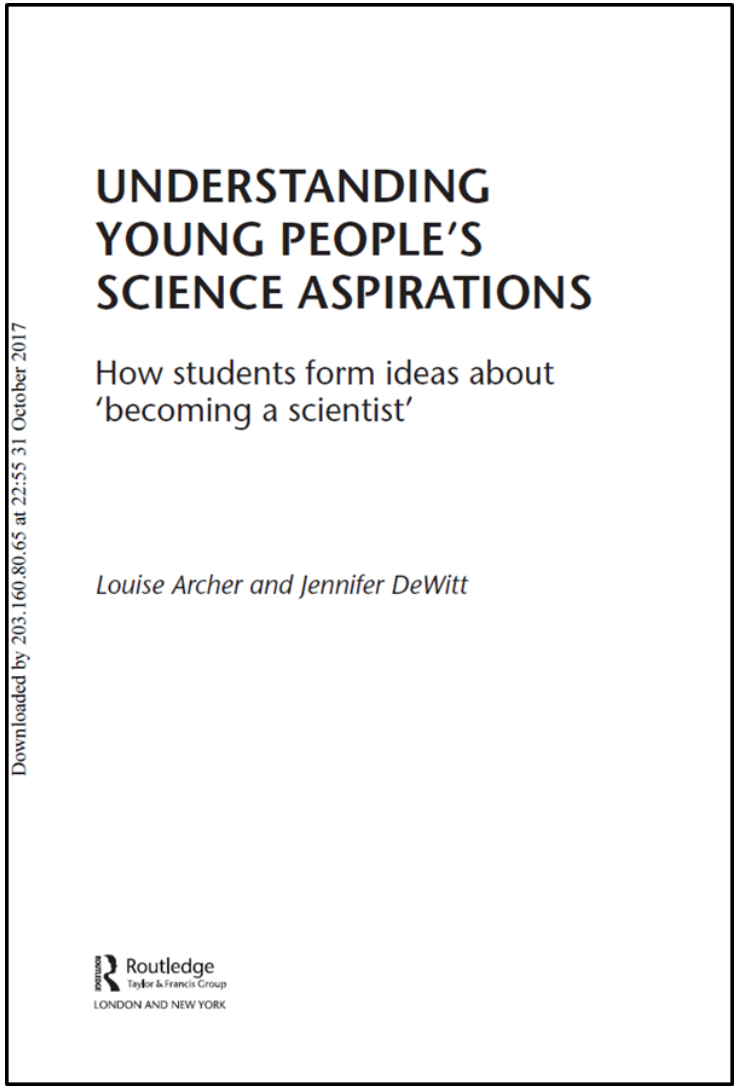
- Expressions of one's hopes or ambitions

L. Archer & J. DeWitt (2017),
Understanding Young People's Science Aspirations

- Aspirations can range from vague and uncertain ideas about the future through to 'more concrete and achievable' plans

Julia Brannen& Ann Nilsen, (2006) From Fatherhood to Fathering: Transmission and Change among British Fathers in Four-generation Families, *Sociology.*





Aspirations help to…

Predict the general type of career path young people may take

Provide a useful reference for policy makers to adjust education policies

L. Archer & J. DeWitt (2017), Understanding Young People's Science Aspirations

School-STEM Profession Collaboration

STEM Professions

Practical work experiences in authentic situations using **transdisciplinary knowledge** of S, T, E, M

Educators

Imparting STEM **knowledge** and **skills** with **relevant authentic resources** in designing STEM learning activities

Students

Reconcile students' interests to the contemporary world of science

STEM

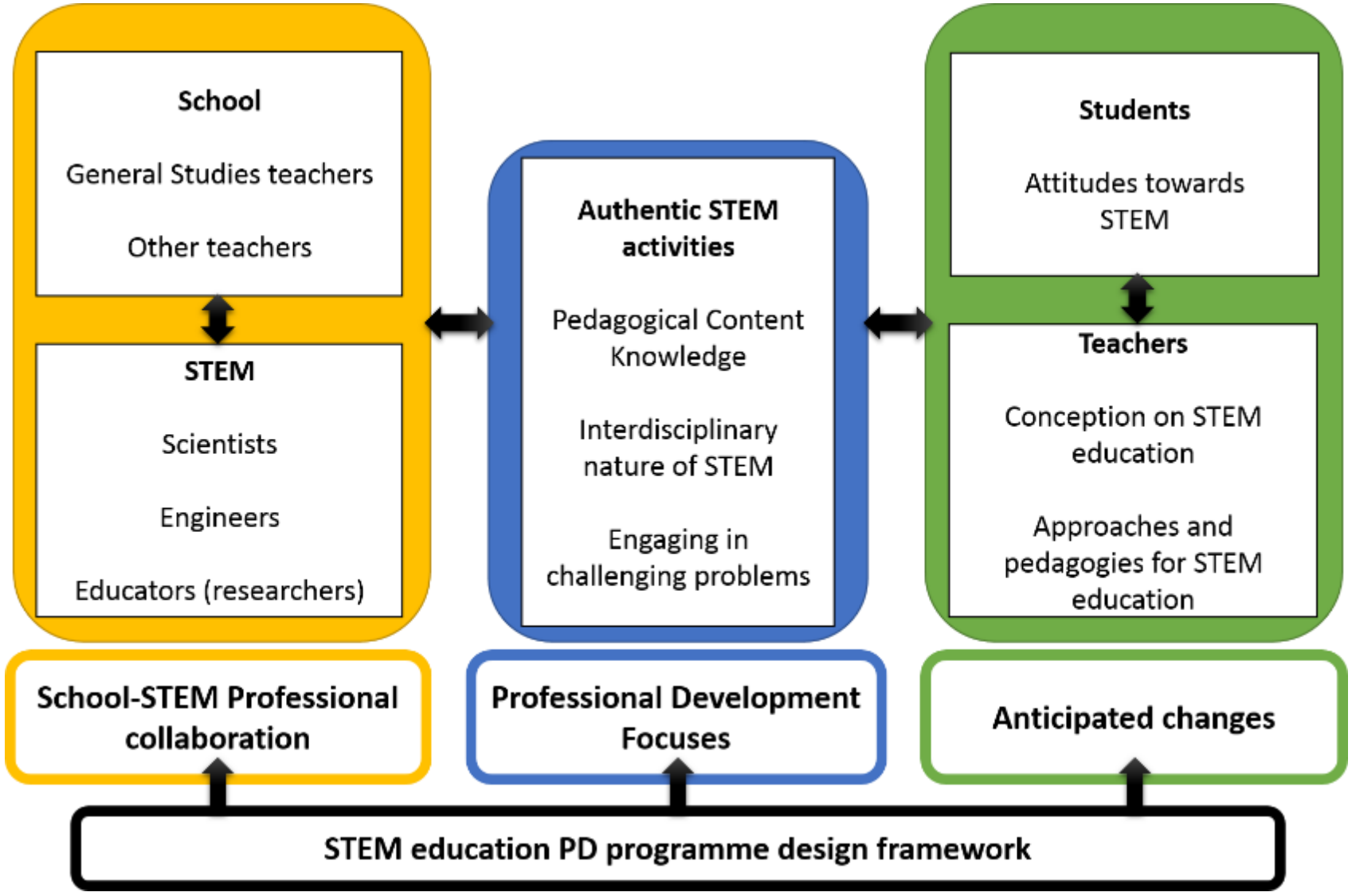
Watters and Diezmann (2013)

School-STEM Profession Collaboration

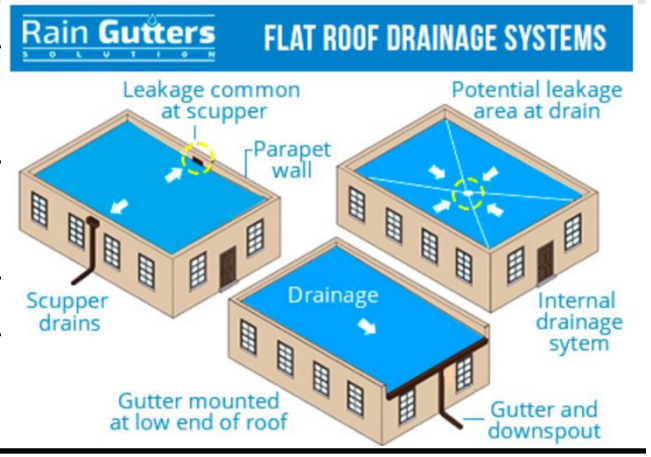
Research Project funded by

UGC 大學教育資助委員會 University Grants Committee

2018-2019



School-STEM Profession Collaboration

Core elements in school curriculum	Current issues	STEM professionals serving our community	Innovations
Landslides from hillside 	Landslides in rainy days 	Civic engineers 	
Energy saving with Green roof 	Collapse of green roof 	Landscape architect 	

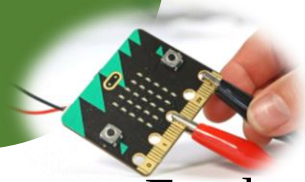
School-STEM Profession Collaboration

STEM Professionals serving our community

Environmental scientist

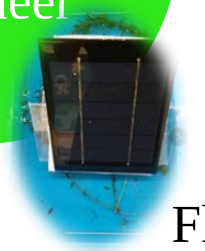
PM2.5 monitor

Food scientist



Food storage thermometer

Water service engineer



Floating solar power system

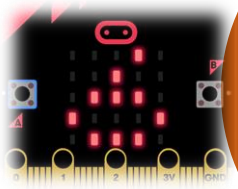
Software designer

VR tour App

Drainage engineer

Flood control reservoir

Chinese medical practitioner

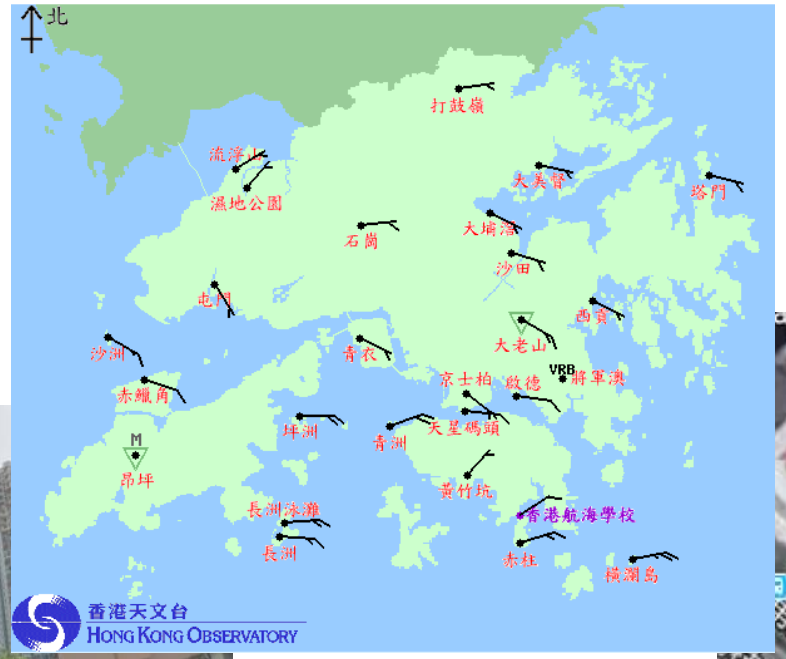


Cooking timer

Environmental Problem – Air Quality

Building ?

traffic ?



Wind ?

Work as an Environmental Scientist

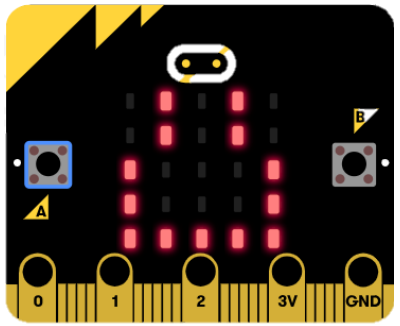




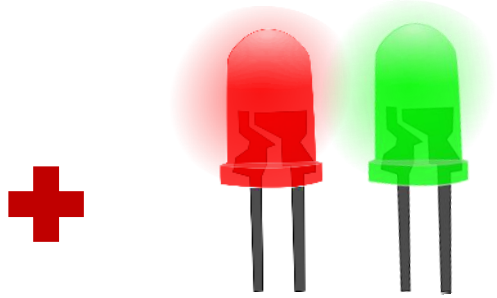

Introduce STEM professionals	Activity 1 Examine sources of indoor pm2.5	Activity 2 Enquiry about traffic and air quality	Activity 3 Enquiry about wind direction and pm 2.5	Activity 4 Field test on traffic flow and pm 2.5	Activity 5 Experiment air direction and pm 2.5

Innovative design - 「Air quality Alarm System」

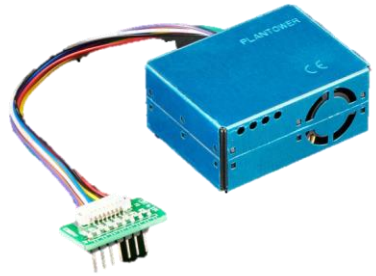
by students with intellectual disabilities



Microbit



LED

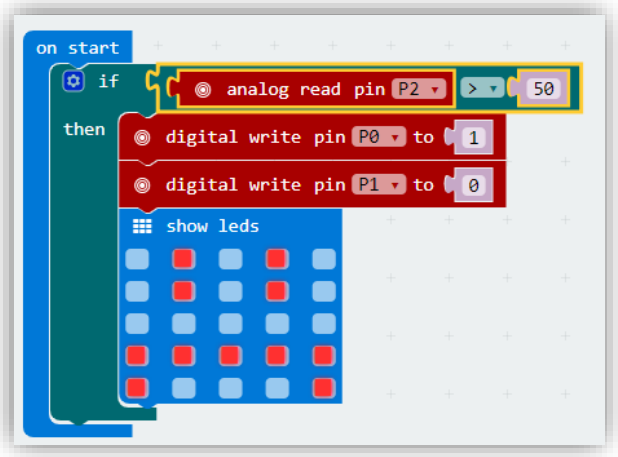


PM2.5 Sensor

「Air quality Alarm System」

Innovative design - 「Air quality Alarm System」

by students with intellectual disabilities



Coding:

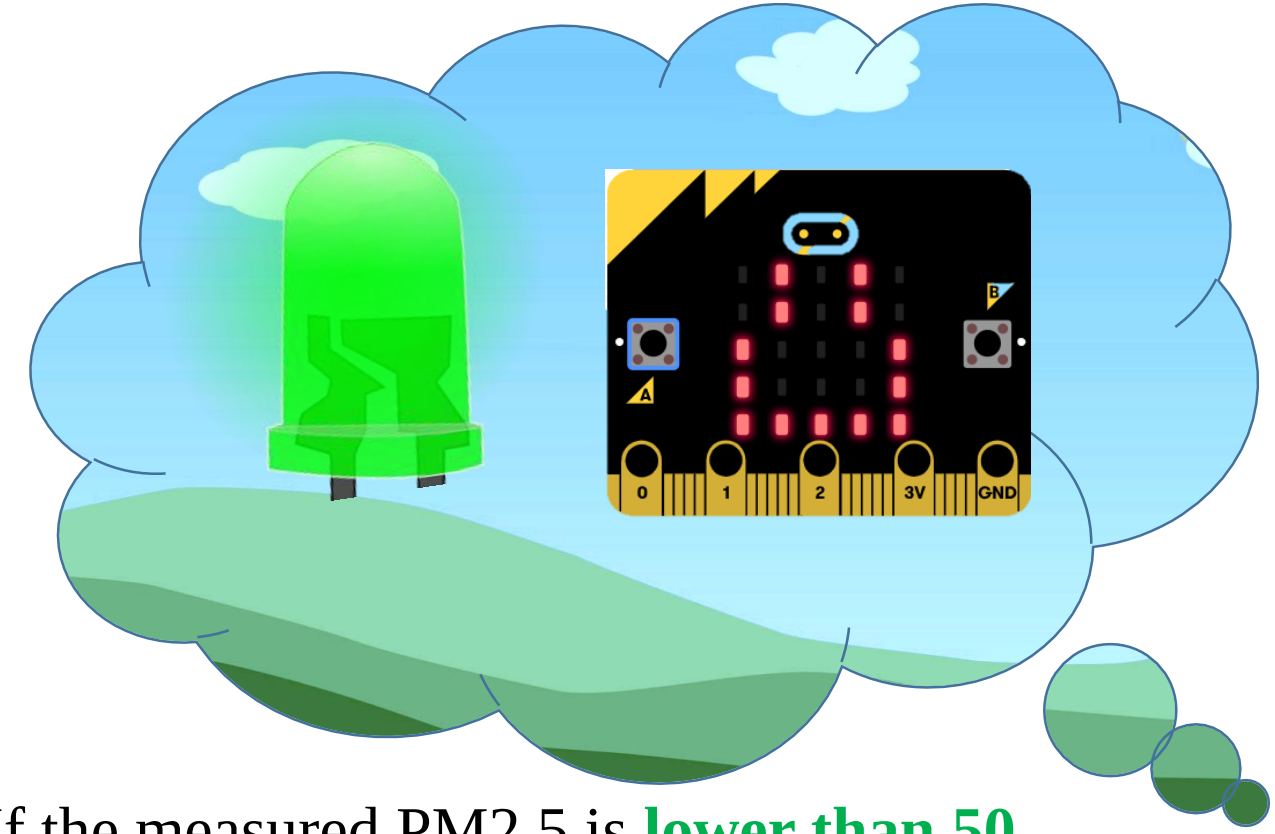
If the PM2.5 is **higher than 50** ,

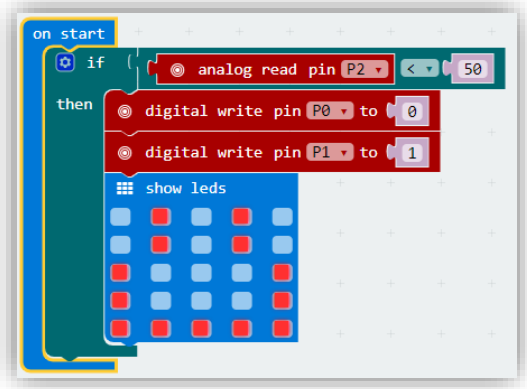
the red LED light is on and

the Microbit LEDs screen display **“Unhappy face”**

Innovative design - 「Air quality Alarm System」

by students with intellectual disabilities





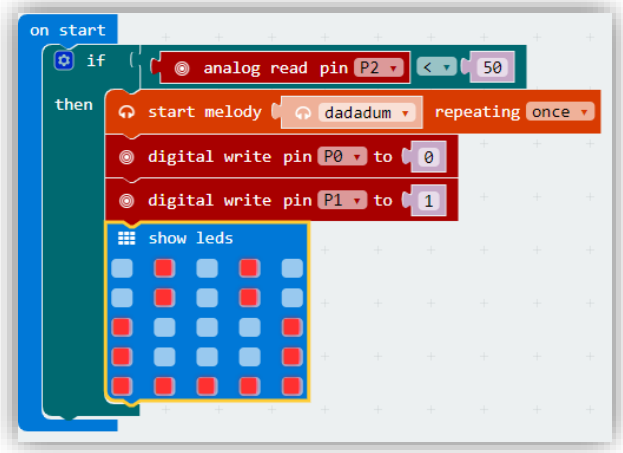
If the measured PM2.5 is **lower than 50**

green LED light is on and

Microbit LEDs screen display **"Smiling face"**

Innovative design - 「Air quality Alarm System」

by students with intellectual disabilities



If the PM2.5 is **lower than 50**

green LED light is on and

Microbit LEDs screen display**"Smiling face"** with

a nice music

Research on School-STEM Profession Collaboration

Research Methodology

Teachers

- Change of conception towards STEM education by writing/drawing
- Reflection on Lesson

Student

- Pre/post survey of attitude towards STEM education and STEM career

STEM professions

- Interview

Research on School-STEM Profession Collaboration

Research Methodology – Reflection on Lesson

A. Design
B. Implementation
C. STEM Content
D. Students' engagement in classes
E. Use of technology
F. Classroom Culture
G. Likely impact of Instructions on students' understanding of STEM

Research on School-STEM Profession Collaboration

Research Methodology – Student survey

A. **Perception Of STEM careers**
   - ***Science aspiration survey***
   - ***STEM stereotypes***
   - ***STEM career semantic survey***

B. **Personal and social implication of STEM**

C. **Use of the technology**

Research on School-STEM Profession Collaboration

STEM Professional Interview

- Background information
- How to equip youngsters for the STEM careers
  - Scenarios suitable for student inquiry
  - STEM practices (knowledge and skills required)
- Study pathways the professionals took that led to the current job
- Recommendations of steps to pursue if one is interested in this career field

Wyss, V. L., Heulskamp, D., & Siebert, C. J. (2012). Increasing middle school student interest in STEM careers with videos of scientists. International journal of environmental and science education, 7(4), 501-522

Research on School-STEM Profession Collaboration

Findings – Changes in teachers' conceptions

- Teachers' narrow views of STEM engagement
- Impact of the School-STEM Professionals collaboration on teachers' conception
  - Scientific enterprise
  - Human endeavor in engineering and human benefit with technology
  - Problem solving with mathematics
  - More emphasis on student learning
  - Role of STEM professionals

Research on School-STEM Profession Collaboration

Findings – Students' attitude

Increase on most of the four constructs in the post-survey
Students develop more views of STEM professionals after the STEM programme

Constructs		School A	School B	School C
Interests in STEM careers	Pre	3.89 (0.96)	4.03 (0.88)	4.08 (0.85)
	Post	3.96 (0.89)	4.02 (1.00)	4.26 (0.82)
Views on STEM implications	Pre	3.63 (0.76)	3.70 (0.82)	3.85 (0.78)
	Post	4.01 (0.75)	3.61 (0.89)	4.01 (0.83)
Positive images of STEM professionals	Pre	3.52 (0.77)	3.50 (0.78)	3.67 (0.70)
	Post	3.86 (0.65)	3.51 (0.82)	3.78 (0.73)
Stereotypes of STEM professionals	Pre	3.93 (0.99)	4.00 (0.89)	3.99 (0.83)
	Post	3.88 (1.07)	4.05 (0.93)	3.99 (1.05)

Note:
Scores are on a five-point scale of 1 to 5, with 5 being the most favoured attitudes toward STEM careers and images of STEM professionals
Pre = pre-survey, Post = post-survey

Research on School-STEM Profession Collaboration

Findings – Students' attitude

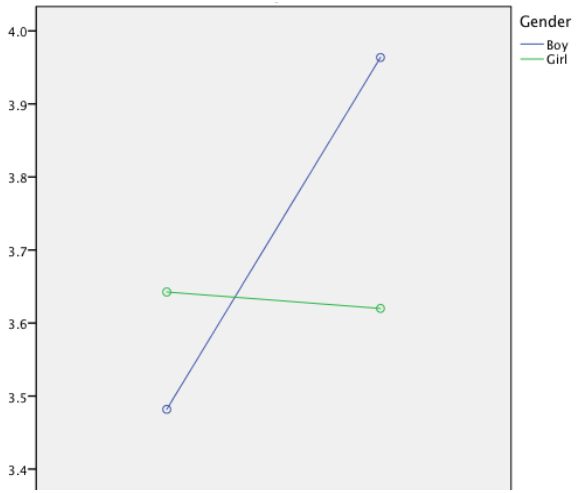
School A (Water Engineering Service)

- Significantly main effect of the programme on "Implications" and "Positive images" was found, indicating that the students **significantly improved** their views of STEM occupations' social implications, and **developed** more positive images of STEM professionals after the STEM programme
- Significant STEM programme * gender effects were found on "Implications". Boys' images improved more significantly compared to girls'

Results of Mixed ANOVA

Construct	Source	*F*	ηp^2
Interests	STEM programme	0.414	0.010
	STEM programme *Gender	2.349	0.055
Implications	STEM programme	**5.121***	0.113
	STEM programme *Gender	3.435	0.079
Positive images	STEM programme	**4.916***	0.109
	STEM programme *Gender	**5.926***	0.129
Stereotypes	STEM programme	0.112	0.003
	STEM programme *Gender	1.675	0.040

Significant differences at p≤ .05 are in bold. *$p < 0.05$



Positive images of STEM professionals

Gender effect on the impacts of the STEM programme
(1 = Pre-survey, 2 = Post-survey)

Research on School-STEM Profession Collaboration

Findings – Students' attitude

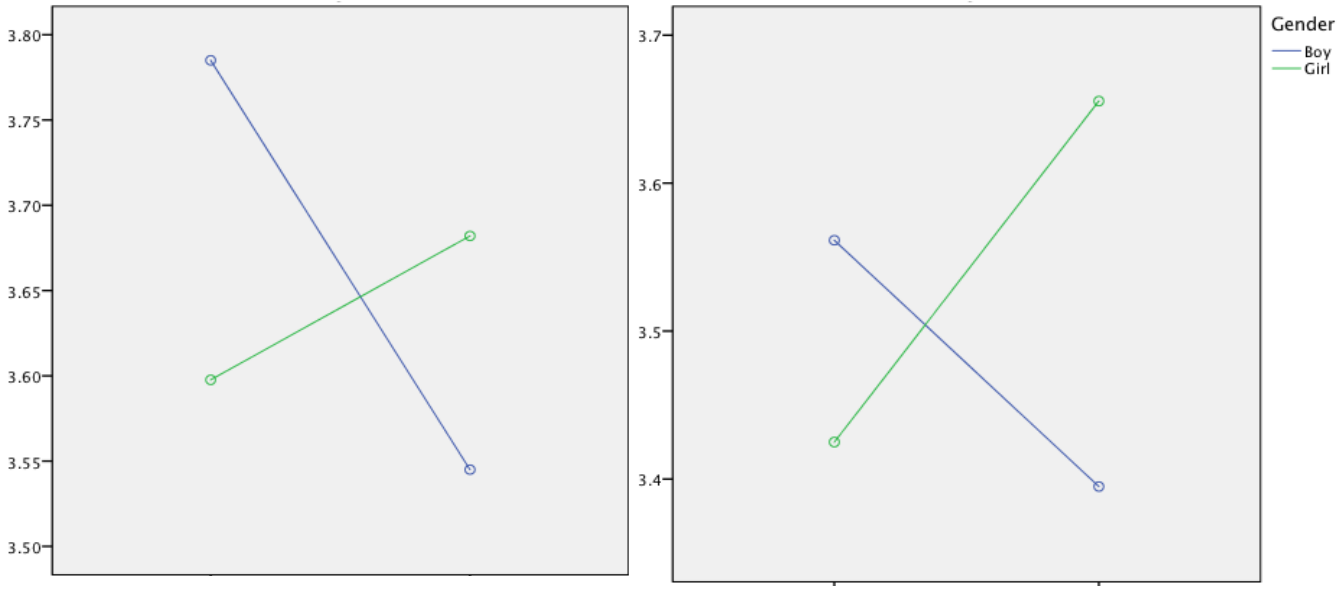
School B (Environmental Scientist)

- Significant interactions between the STEM programme and gender on "Implications" and "Positive images". Effect sizes were medium
- STEM programme was significantly **more pronounced among girls** than boys

Results of Mixed ANOVA

Construct	Source	F	ηp^2
Interests	STEM programme	1.191	0.001
	STEM programme *Gender	2.515	0.017
Implications	STEM programme	1.105	0.008
	STEM programme *Gender	**4.800***	0.033
Positive images	STEM programme	0.166	0.001
	STEM programme *Gender	**6.379***	0.043
Stereotypes	STEM programme	0.824	0.006
	STEM programme *Gender	1.257	0.009

Significant differences at p≤ .05 are in bold. *$p < 0.05$.



Views on STEM Implications

Positive images of STEM professionals

Gender effect on the impacts of the STEM programme
(1 = Pre-survey, 2 = Post-survey)

Research on School-STEM Profession Collaboration

Findings – Students' attitude

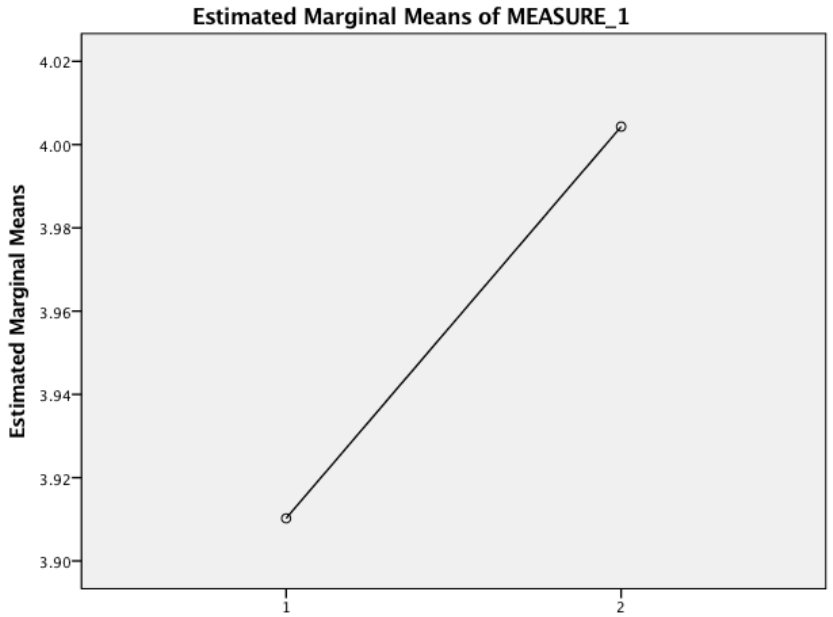
School C (Food Scientist)

- Students' interests in STEM careers significantly increased after the STEM programme
- No significant gender effect on the impacts of the STEM programme

Results of Mixed ANOVA

Construct	Source	F	ηp^2
Interests	STEM programme	**6.130***	0.065
	STEM programme *Gender	0.006	0.000
Implications	STEM programme	1.691	0.020
	STEM programme *Gender	0.043	0.001
Positive images	STEM programme	2.752	0.101
	STEM programme *Gender	0.504	0.006
Stereotypes	STEM programme	0.011	0.000
	STEM programme *Gender	0.025	0.000

Significant differences at p≤ .05 are in bold. *$p < 0.05$



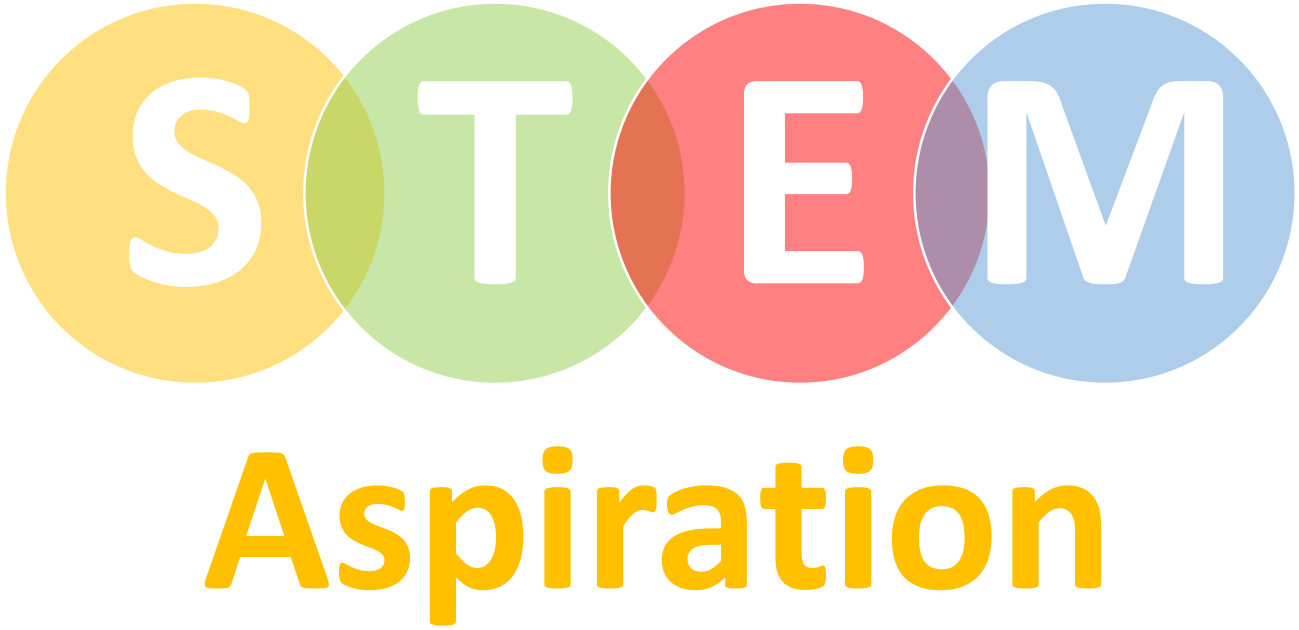
the STEM programme

Impacts of the STEM programme on students' interests in STEM careers
(1 = pre-survey, 2 = post-survey)

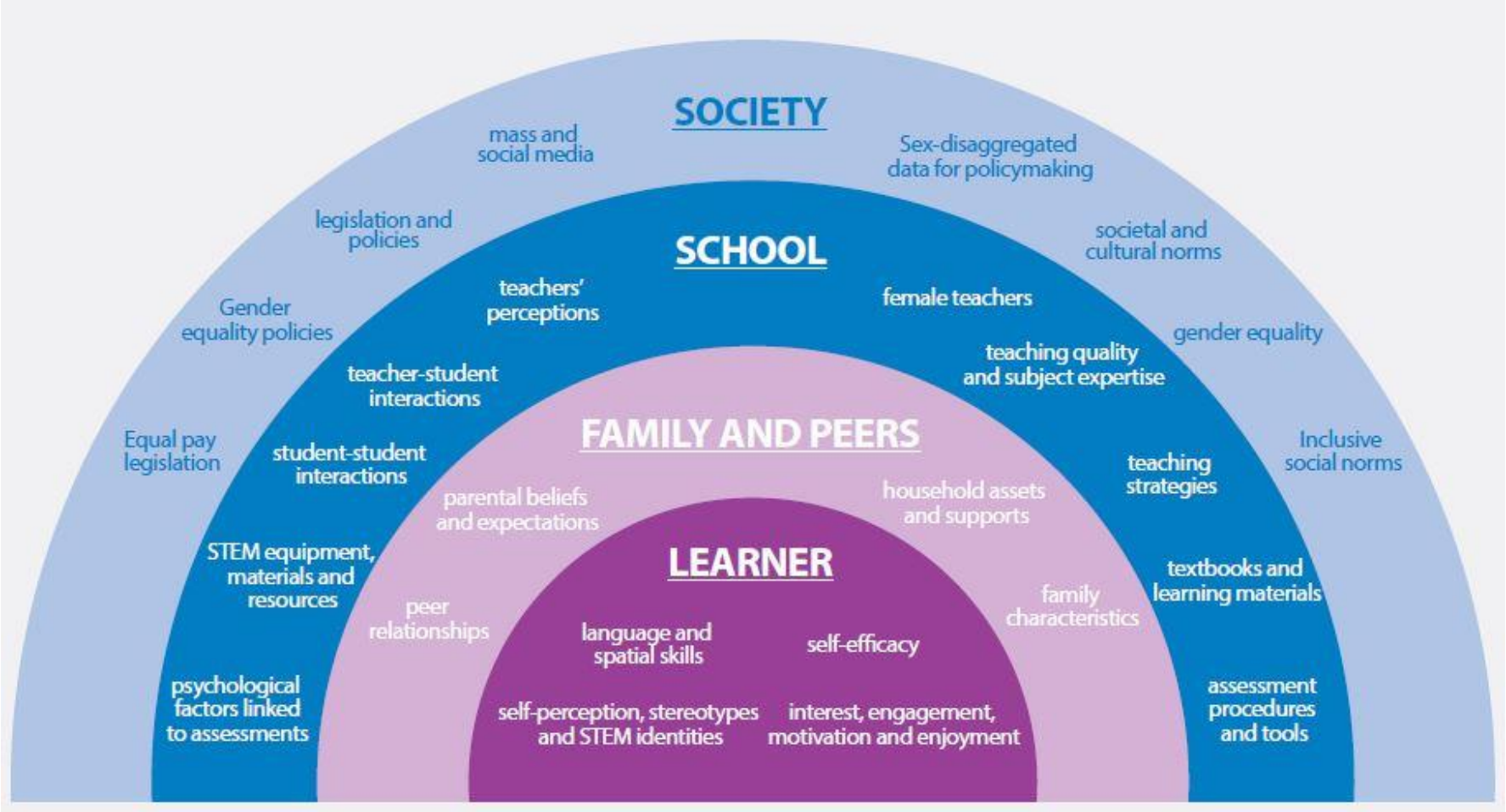
More Research on STEM Education

Public Policy Research Funding Scheme 2018-19

Hong Kong students' STEM aspirations



Various factors contributing to STEM Aspiration

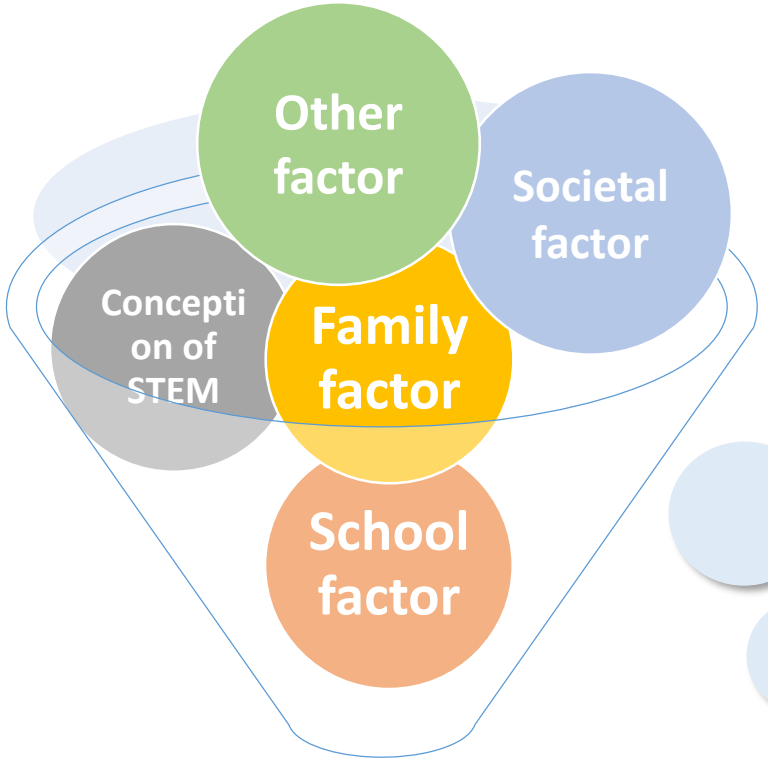


UNESCO (2017). *Cracking the code: Girls' and women's education in STEM*

Croucher Foundation (2017). *The Out-of-School STEM Ecosystem in Hong Kong.*

What is STEM Aspiration?

Hopes or ambitions of pursuing education attainment or careers in STEM fields



STEM Aspiration

- Opportunities
- Participation
- Achievement
- Progression

Conception of STEM
- Self-perception
- Self-efficacy

Family factor
- Family habitus
- Parental beliefs & expectations
- Capital
- Parents' education & professions
- Peers

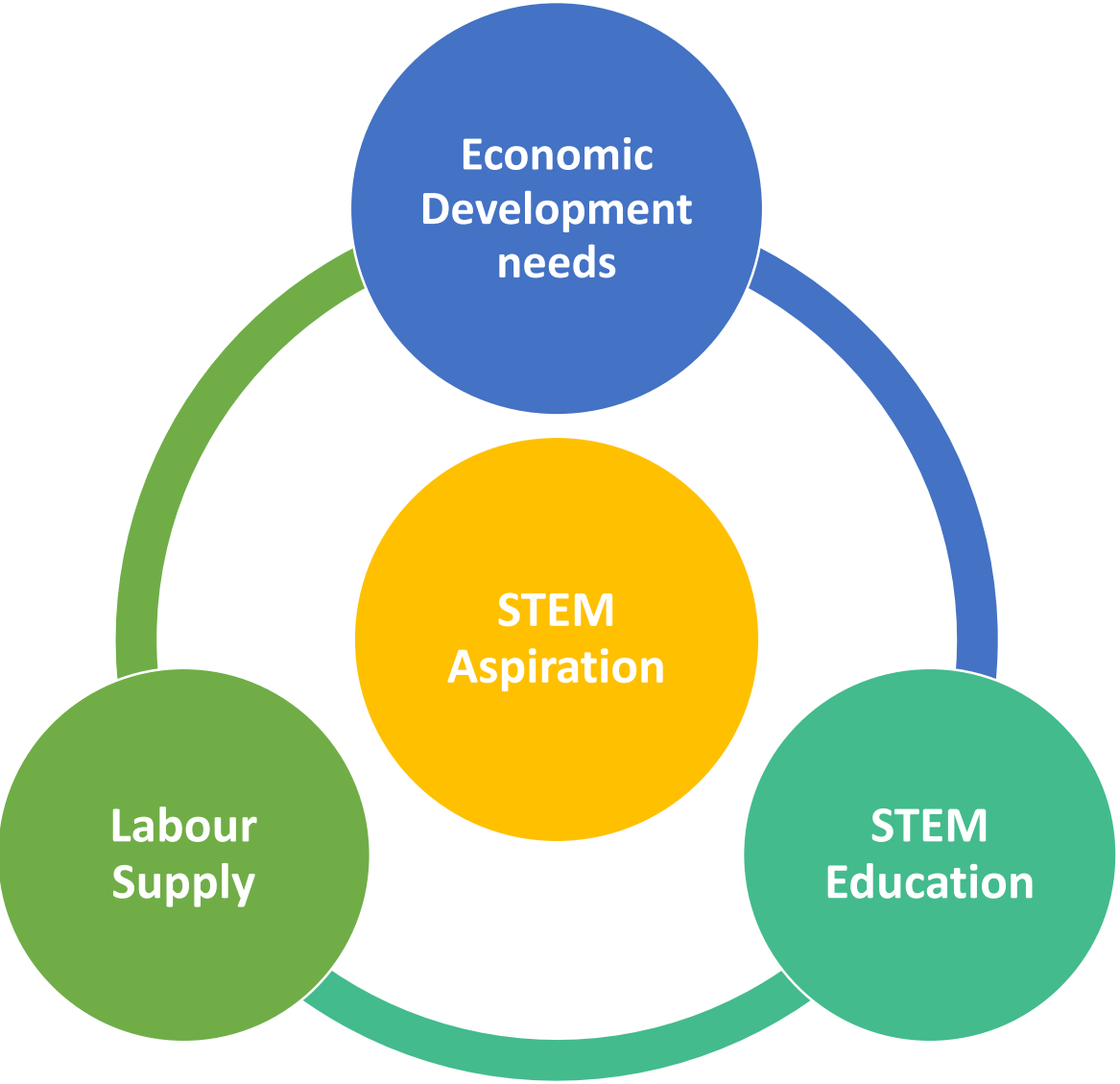
School Factor
- Teaching quality and expertise
- Teacher-student relations
- Curriculum and learning materials
- Assessment

Societal Factor
- Societal and cultural norms
- Gender equality
- Media

Reference:

Archer, L., & DeWitt, J. (2017), *Understanding young people's science aspirations : how students form ideas about "becoming a scientist*. New York: Routledge

UNESCO. (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM).* Paris, UNESCO



Quantitative survey

5800 students from 3 key learning stages

- Senior primary (age 10-11)
- Junior secondary (age 13-14)
- Senior secondary (age 15-16)

+

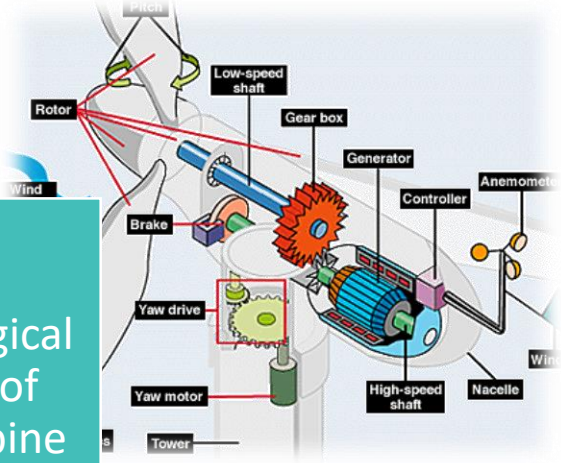
In-depth Interview

Parents + Students

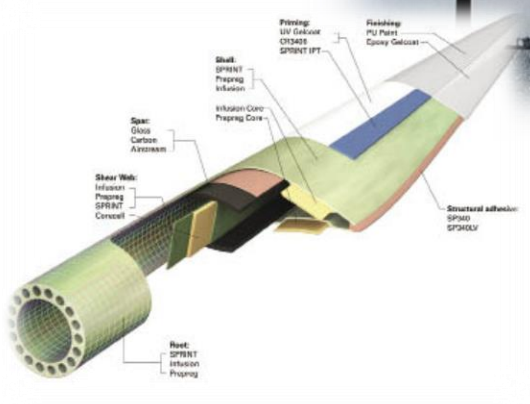
Disciplines are closely intertwined in the real world

S
Wind movement

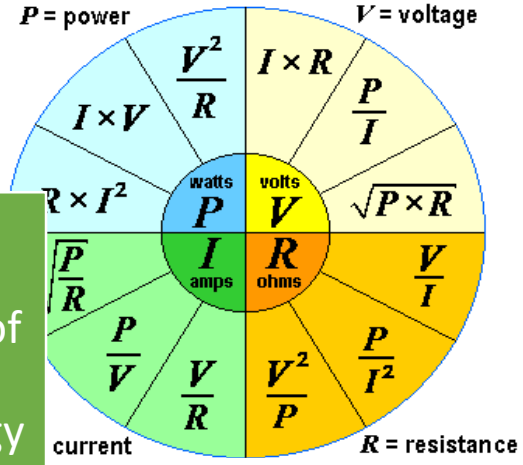
T
Technological literacy of wind turbine



E
Engineering design of blades



M
Calculation of power and kinetic energy



From Learning to Aspirations

Subject disciplines of Science and Mathematics in Schools

Textbook lectures

Hands-on connecting learning

Notion of Integration in STEM

A conceptual framework for integrated STEM education

- ***Science inquiry*** and ***engineering design*** as the basis
- ***Technological literacy*** and ***mathematical thinking*** as the auxiliary
- The integrity of the system is connected by the ***authentic context***

Kelley & Knowles (2016) A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3(11)*

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Thank you!

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