Innovation Technology for Interactive Renewable and Green Energy Education

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Renewable energy education

Energy Sources

- Solar
- Wind
- Tidal / Wave
- Fossil fuels
- Nuclear
- Parasitic energy

Illustration Credit: http://discourse112.blogspot.com/2015/05/the-use-of-renewable-and-nonrenewable.html

WiFi

Body heat

Parasitic Energy

Energy Conversion Devices

- Solar panel
- Wind turbine
- Vibration & thermal converters
- PV site survey & shading analysis

Energy/Power Conditioning

- Inverter
- Surge Protection
- Harmonic filter

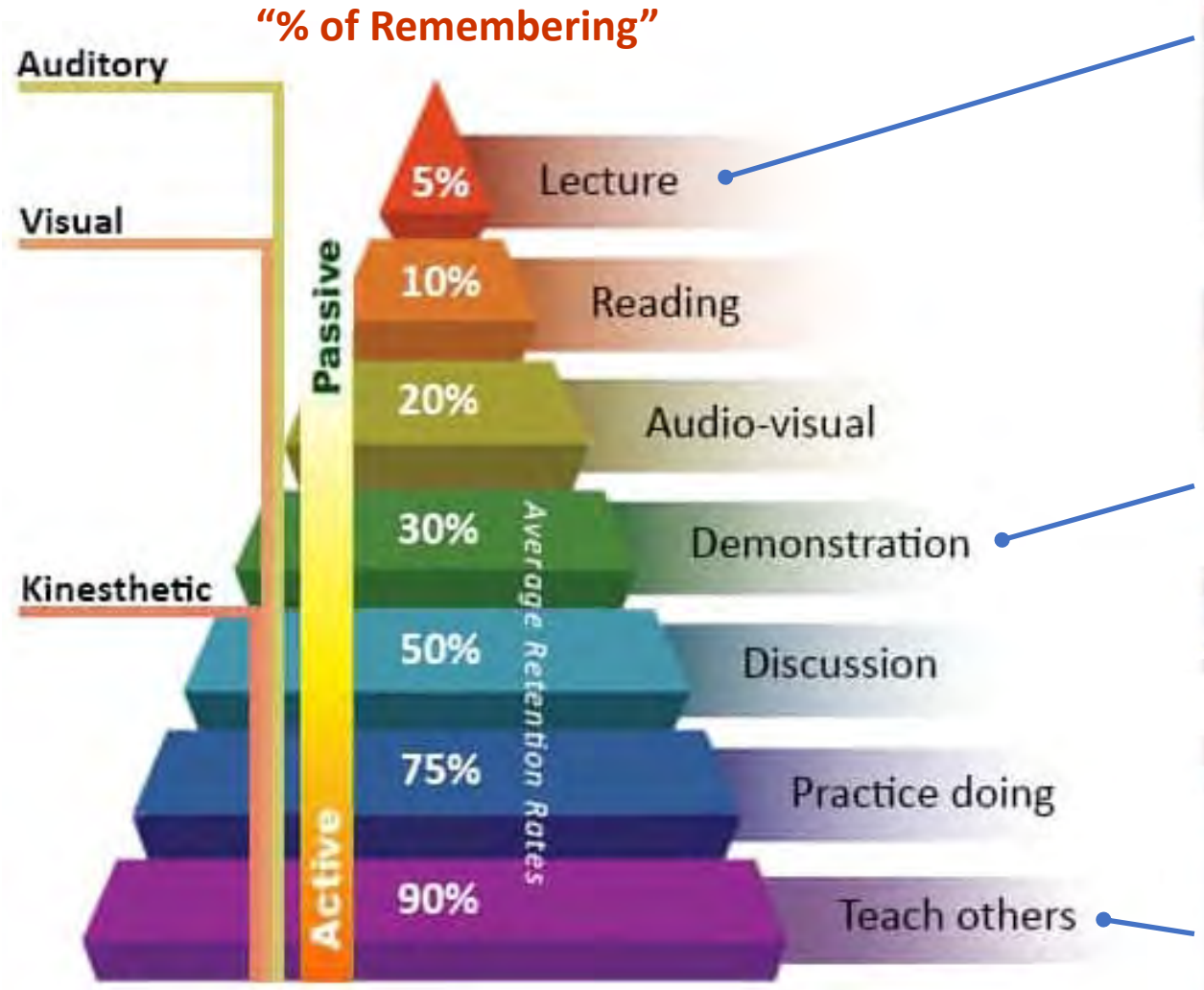
IT & Interaction between PV and human

- Innovation and smart technology
- Personal mobile devices + Mobile Apps
- Real-time data (date/time, power delivery, energy collection)
- Verbal communication
- Weather/Meteorological information
- Engagement
- Education

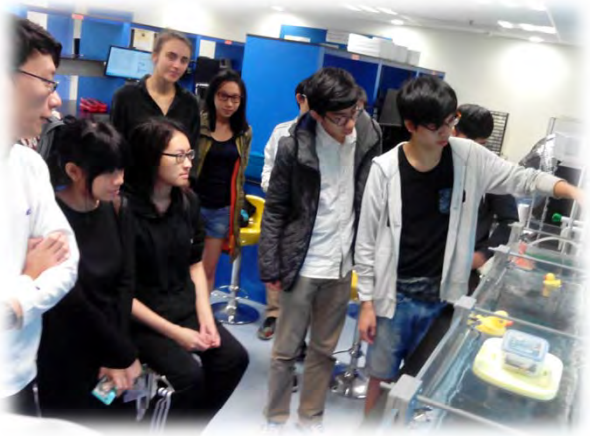
Components of interactive teaching and smart/innovative technology

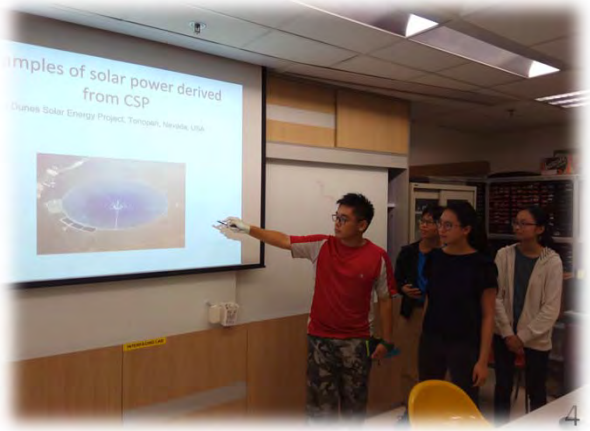
- Interactive demonstrations
- Microcontrollers
- Internet, WIFI, Bluetooth, BLE modules
- Sensors (eg., environmental and orientation sensors)
- Smartphones
- Mobile Apps
- Augmented Reality (AR) and Virtual Reality (VR)

Traditional RE education

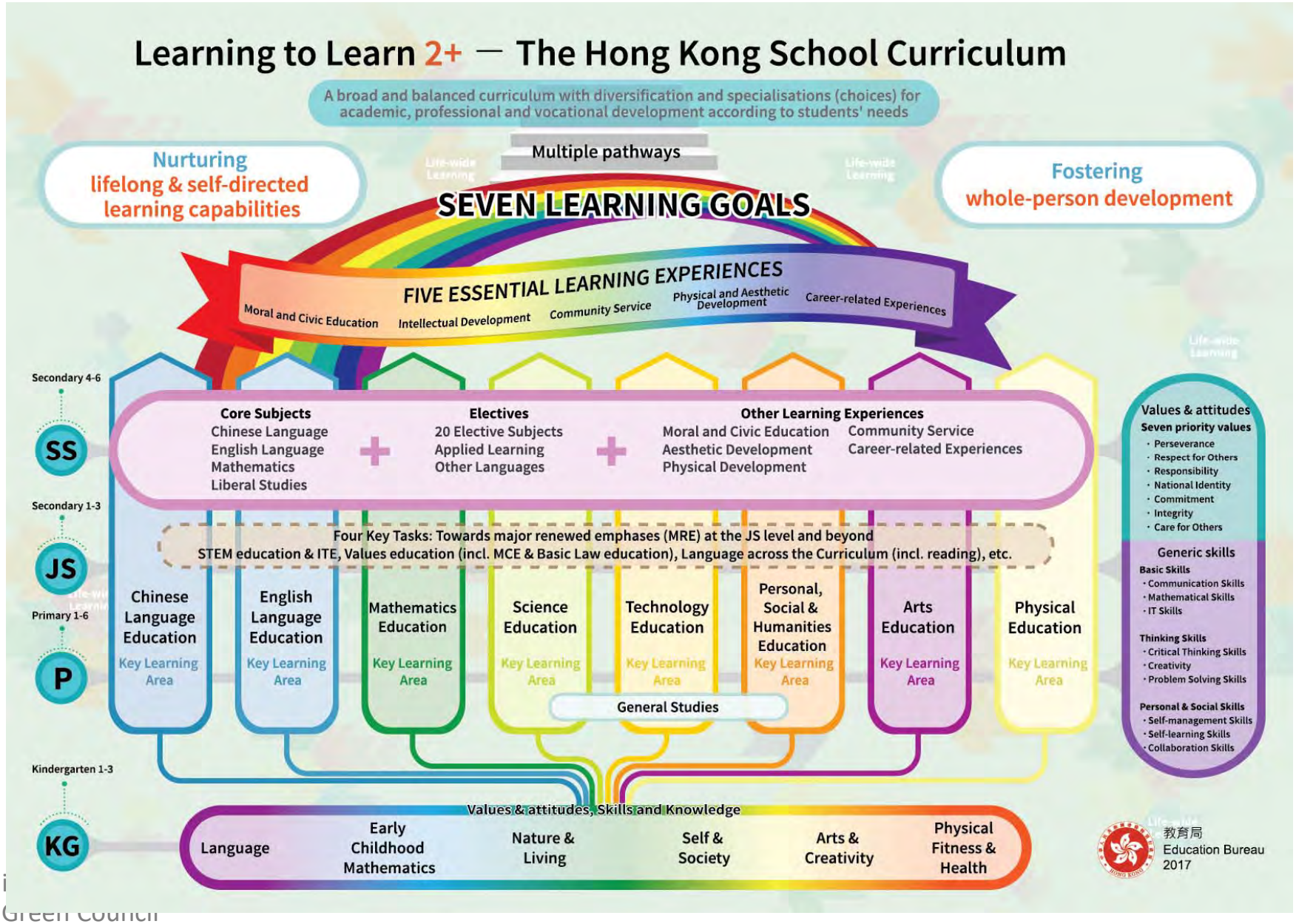


The Learning Pyramid
https://www.educationcorner.com/the-learning-pyramid.html



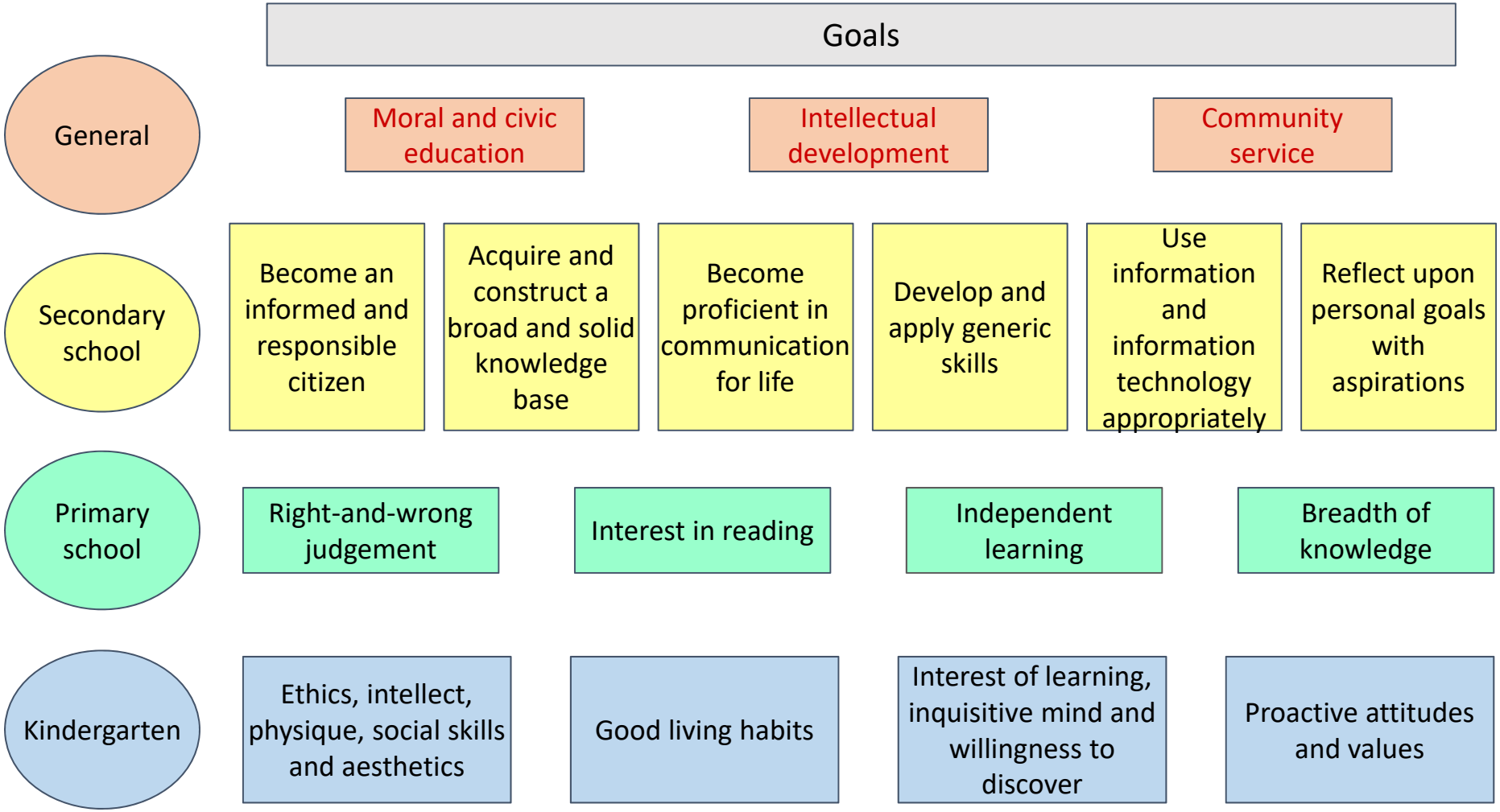


Learning Outcomes - Hong Kong School Curriculum



Learning Outcomes: RE and GE Education

(Renewable Energy and Green Energy Education)



https://www.edb.gov.hk/attachment/en/curriculum-development/major-level-of-edu/preprimary/ENG_KGECG_2017.pdf

https://www.edb.gov.hk/mobile/en/curriculum-development/7-learning-goals/about-7-learning-goals/primary.html

https://www.edb.gov.hk/attachment/en/curriculum-development/renewal/Guides/SECG%20booklet%202_en_20180831.pdf

Adapted from the EDB school curriculum

Solar community engagement

Our daily experience:

Usual practice to engage people

RE education objectives: Secondary school

Teaching and learning directions:

- Enhance students' knowledge / experimental skills on solar energy and PV systems through conducting solar energy harvesting related experiments / scientific investigation;
- Provide students with hands-on experience to use green, innovative, and smart technology to conduct solar energy harvesting related experiments and scientific investigations;
- Applications of innovative and smart technology to engage people into RE projects / activities.

RE education objectives: Primary

Teaching and learning directions:

- Use solar energy harvesting as a teaching and learning platform to develop students' positive values and attitudes for life-long learning;
- Develop generic skills to acquire and construct knowledge of solar energy harvesting

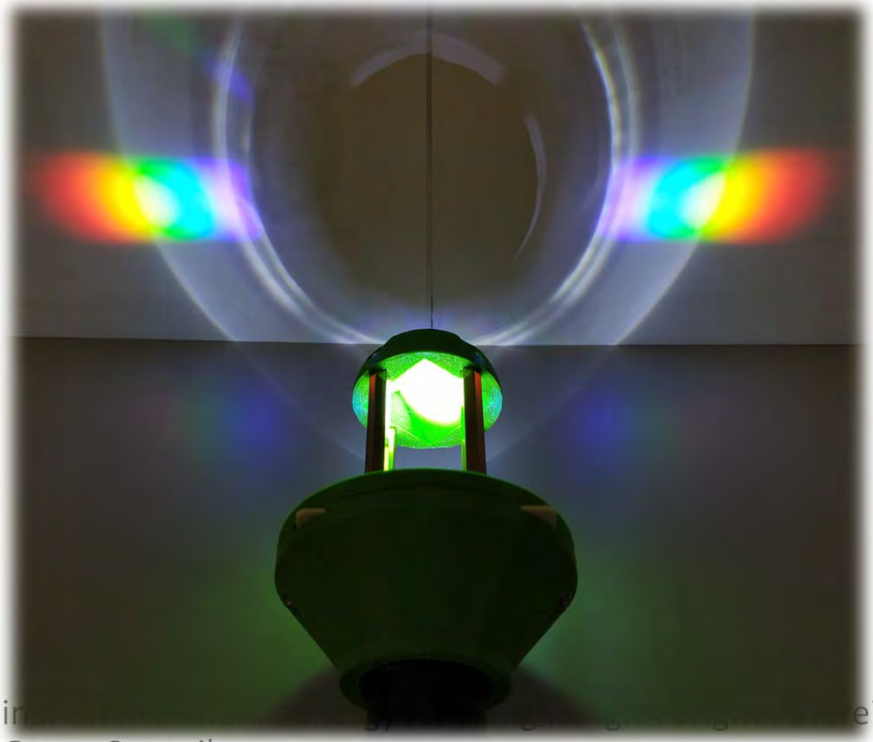
RE education objectives: kindergarten

“ Joyful Learning through Play

Balanced Development All the Way ”

“ 遊戲學習好開始

均衡發展樂成長 ”



RE Education: Secondary/primary students

Nature and Properties of Light and Sunlight

- *Light phenomenon and electromagnetic spectrum*
  - ➢ *Separation of different colors of light spatially*
- Photon energy
- Inverse square law and Lambert's cosine law

Astronomy and Space Science:

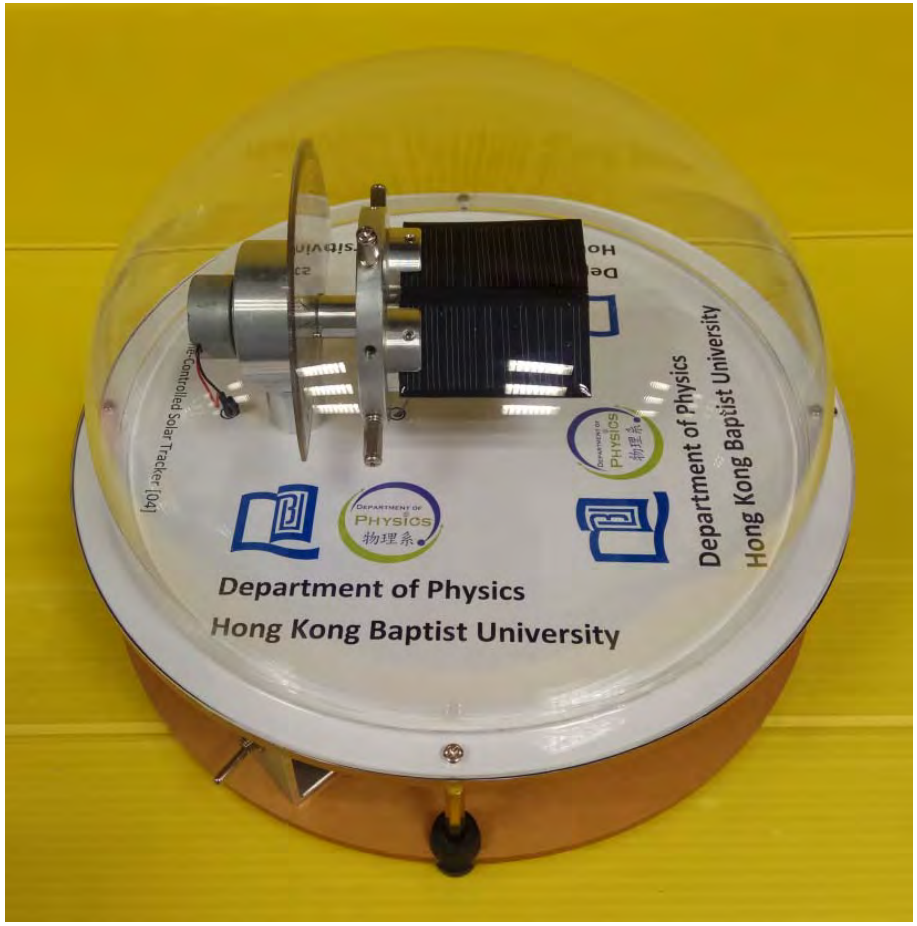
- *Seasonal and diurnal variation of the sun position*
- *Seasonal variation of the Sun trajectory*
- Seasonal and diurnal variation of solar radiation/irradiance

RE Education: Secondary/primary students

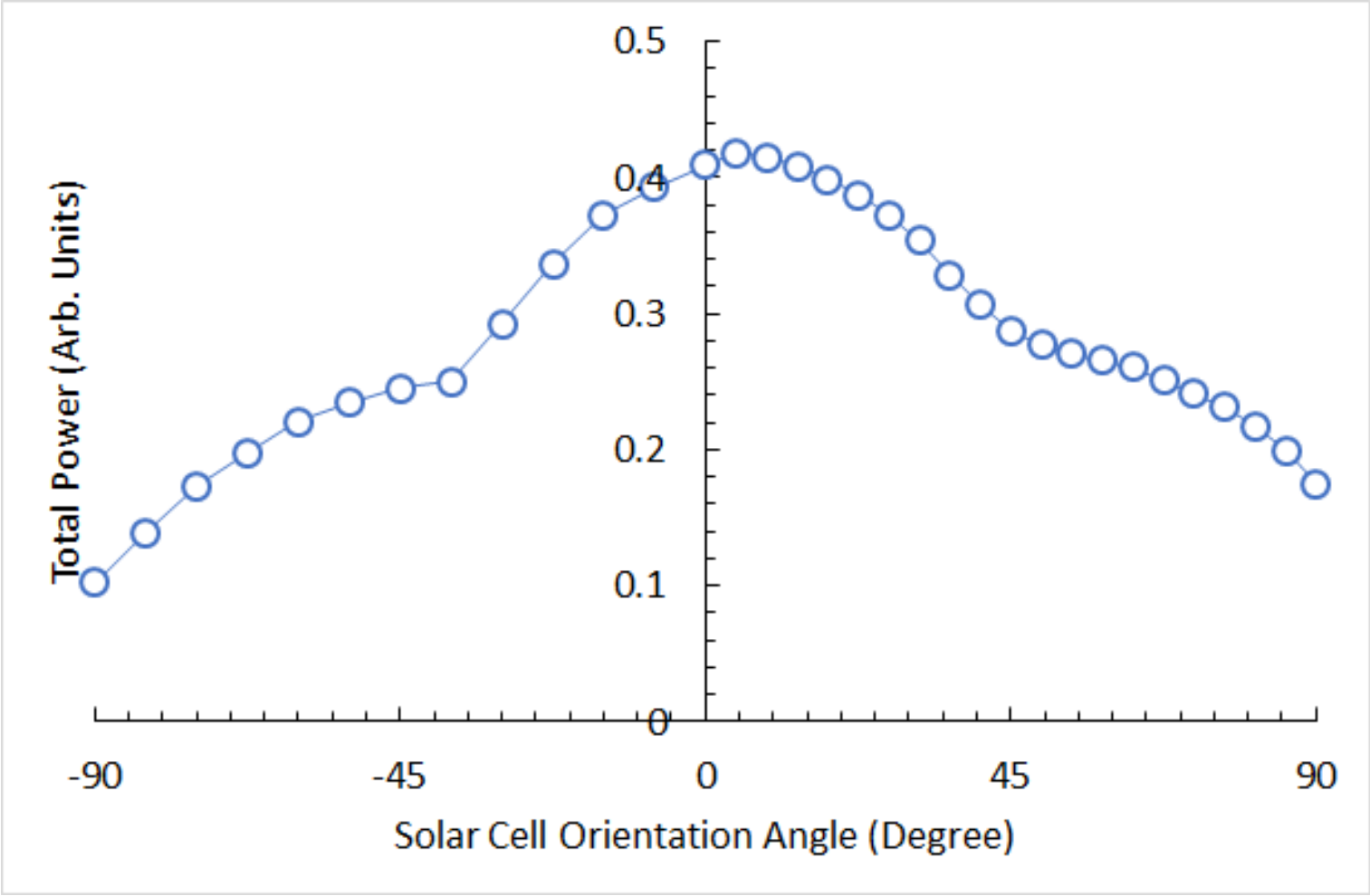
Renewable and Non-renewable Energy Sources

- Solar radiation and solar energy
- *Solar cell: Types and energy generation*
- Principles & applications of solar cells
- Energy transfer and energy conversion efficiency
- Performance evaluation (eg., temperature coefficient, NMOT).
- Pros and Cons: Alternative energy in Hong Kong
- Different energy sources and environmental impacts
- *Simulation of Solar Panel Orientation and Power Delivery with application of personal mobile device built-in sensors.*
- *Applications of smart and innovation technology in solar energy teaching activities (eg., Talking PV).*

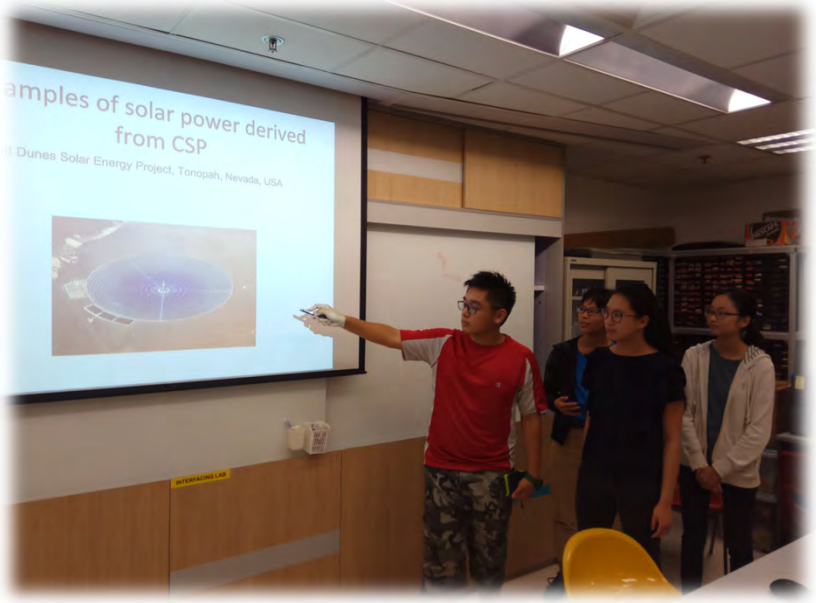
Example: Solar tracking platform with smartphone

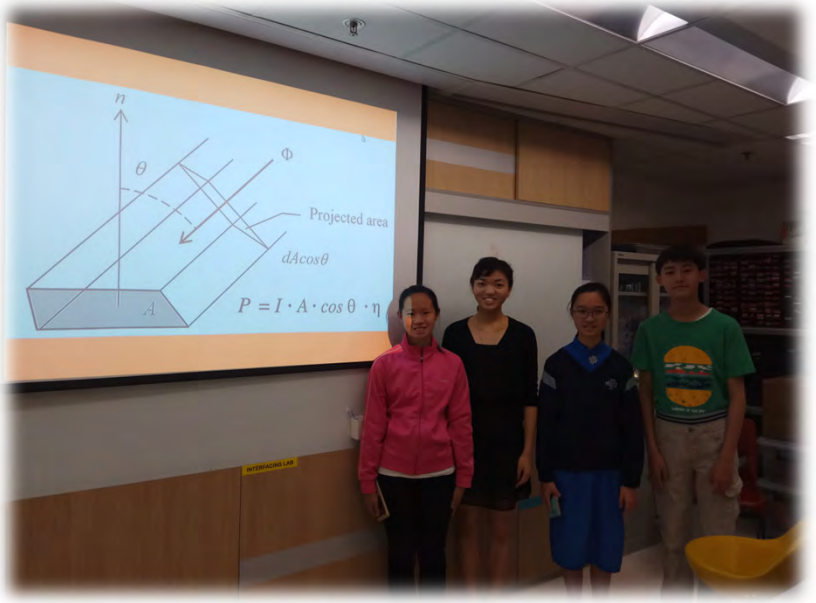


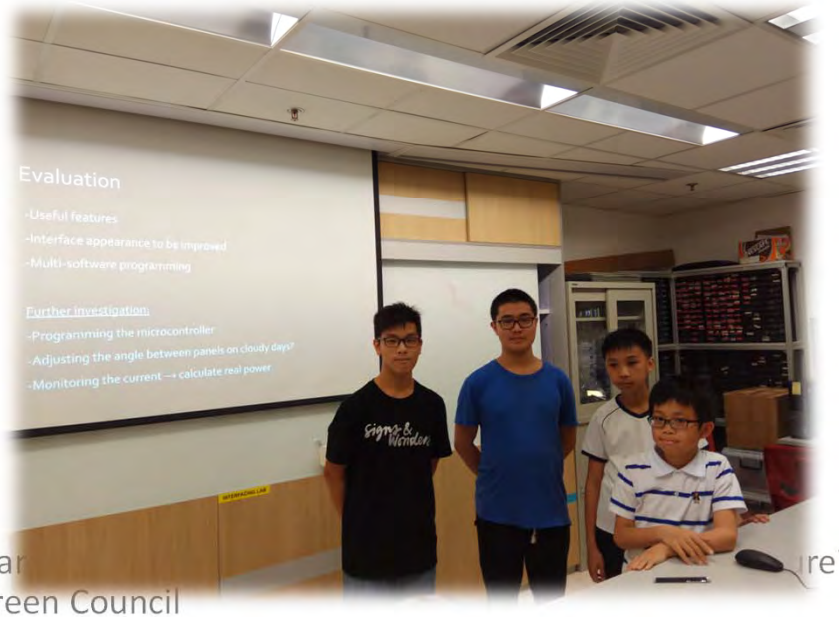
Solar tracking platform: Expected data measured by students

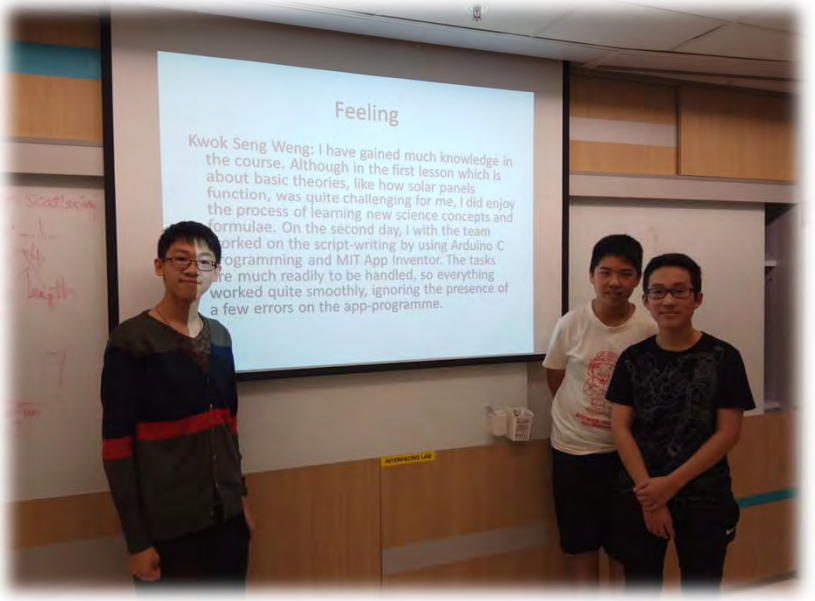


Solar tracking platform: Opportunity to teach others









RE Education: Kindergarten

Nature and Living, light and darkness

- Exploration of nature and living, light and darkness.
- Exploration of the physical world with multiple senses.
- The role of the sun in four seasons (eg., daily duration of sunshine, solar power)

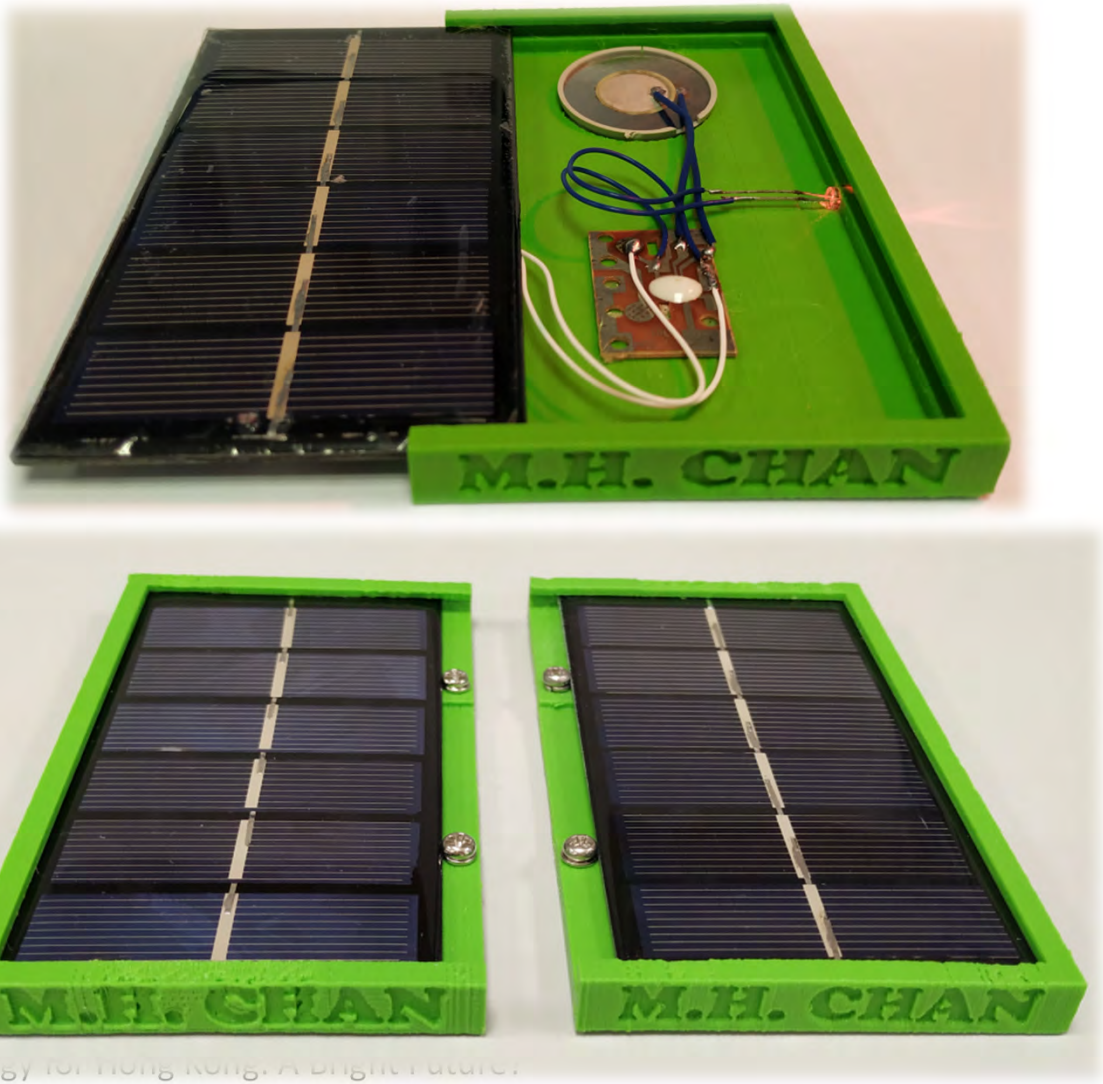
- *Sensing of visible light and colors*
- *Sensing the sunlight and light shadow*
- Theme-based learning
  - Real-life theme;
  - Story telling;
  - Alternation of seasons and the Sun;
  - Fun games, Board games; and Picture books.
- Project approach
  - *Shadow science: playing with shadow and time.*

RE Education: Kindergarten

Solar Energy

- Exploration of beauty of the Sun and its phenomena: solar light and solar energy
- Development of curiosity about the Sun and solar energy
- Solar powered toys for kindergarten sensory play.
  - *Solar music card (the higher the sunlight/light intensity, the higher the music volume.*
  - Solar water fountain (the higher the sunlight/light intensity, the higher the water column shooting up.
- Theme-based learning
  - Real-life theme, Story telling;
  - Sensation of solar thermal energy (eg., become warm under sunshine);
  - Fun games, Board games, Picture books
- Energy conservation in daily life and suggestions of smart tips
- Practice of green living and energy saving
- Project approach
  - Sun print with photosensitive paper (putting objects on photosensitive paper and allow sunlight to generate pattern of the objects)

Interactive demonstration:
Music Card. Energy harvesting from indoor light



Environmental awareness: Single-use batteries

Electronic devices to consume batteries

Remote Controllers: 5 – 50 mW

Calculator: 9 mW

Timer: 5 µW

Clocks: 1.2 and 0.5 mW, respectively

Solution to replace single-use batteries: Parasitic Energy

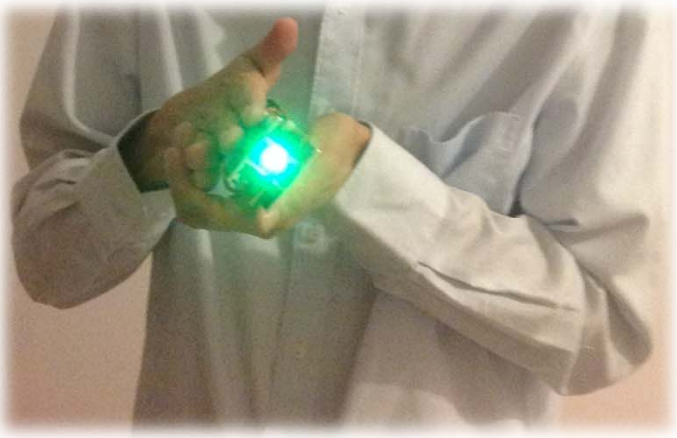
- Parasitic Energy:
  Tiny Energy Source, but High Environmental Conservation Value
  寄生能源：能量雖微小，但環保價值高

- Parasitic Energy
  - Energy harvesting and collection of energy from ambient sources.
  - Small-scale energy (usually μW – mW)

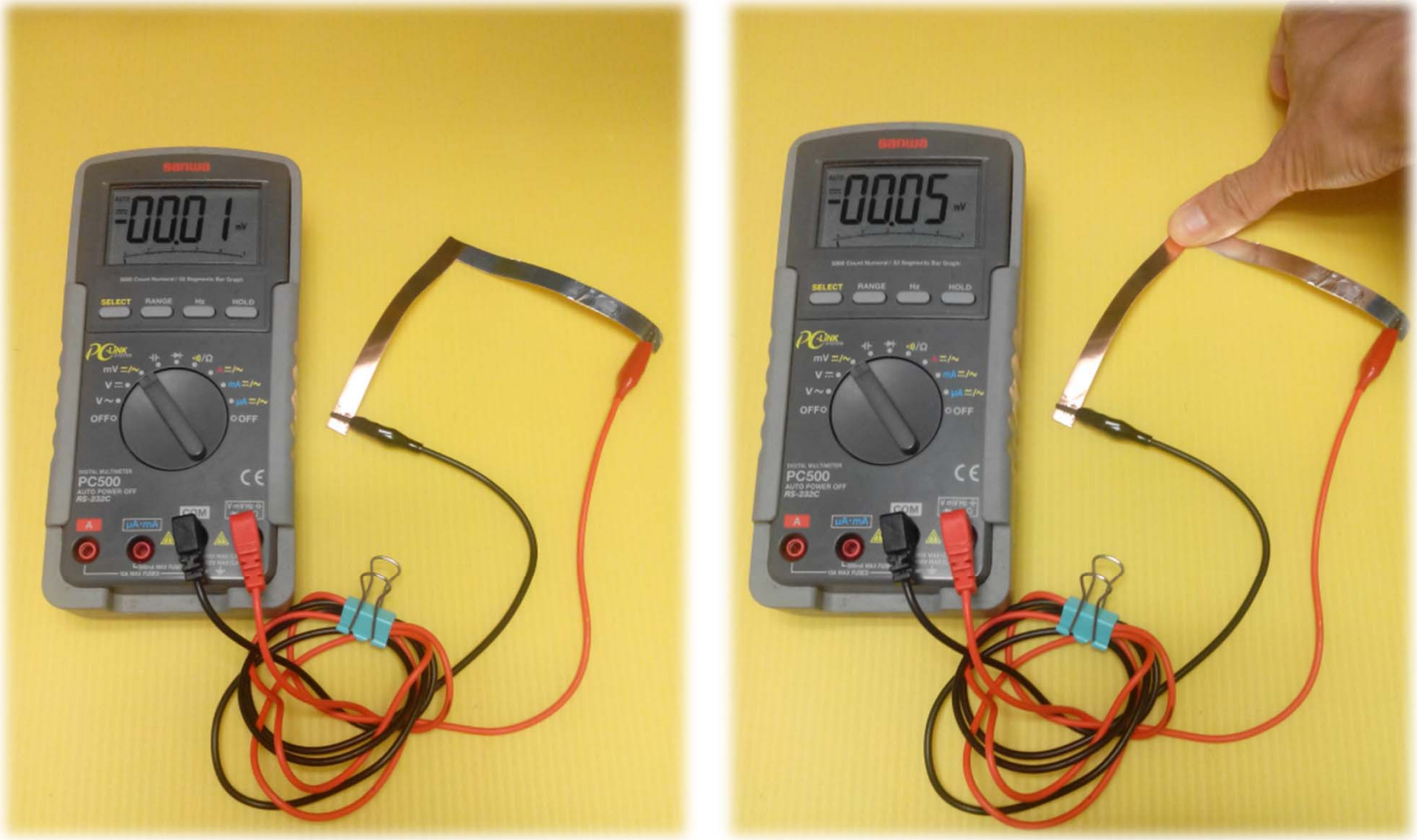
Alternative Power Source: Energy from RF

Parasitic Energy: Thermal Energy

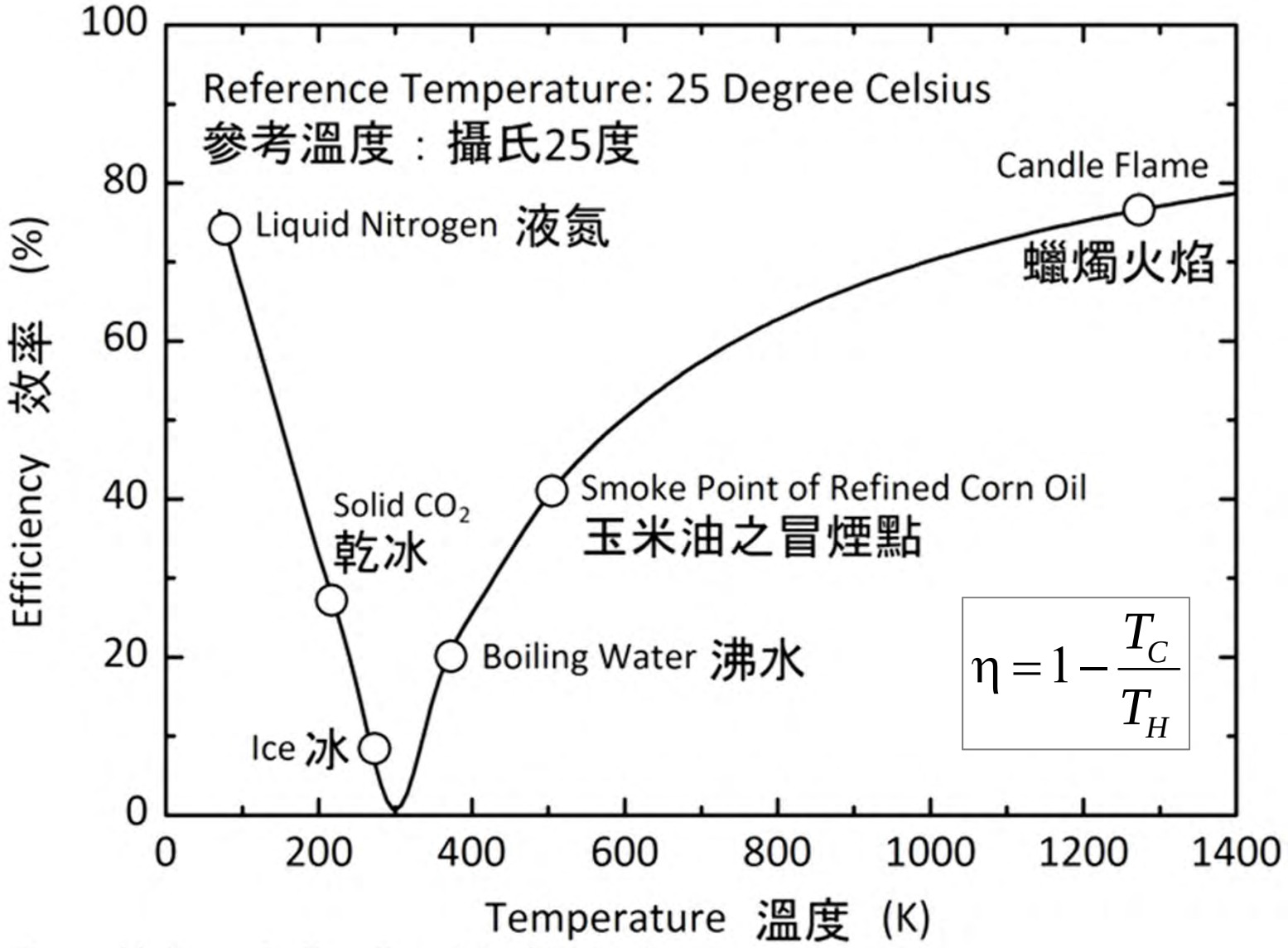
- Thermal Sources
  - Device: Thermoelectric Generator
  - Principle: Seebeck effect
  - Sources: Temperature gradients such as body heat to ambient



Example of Seebeck Effect: Copper and Aluminium



Thermodynamics: Efficiency of a Carnot Engine



Exhibition in HK Science Museum
Portable Energy Harvesting Devices
便攜式能量收集裝置

Science News Corner: An information center for exhibiting scientific research projects of local universities.

Exhibition Period: 13 January till 30 Aug 2017

Opening Ceremony on 13 Jan 2017

東方日報 (14 Jan 2017): 浸大研能量收集器環境及體溫差發電

881903.com 商業電台 (14 Jan 2017): 科學館今日起展出便攜式能量收集裝置

Video: Portable Energy Harvesting Devices

Portable Energy Harvesting Devices

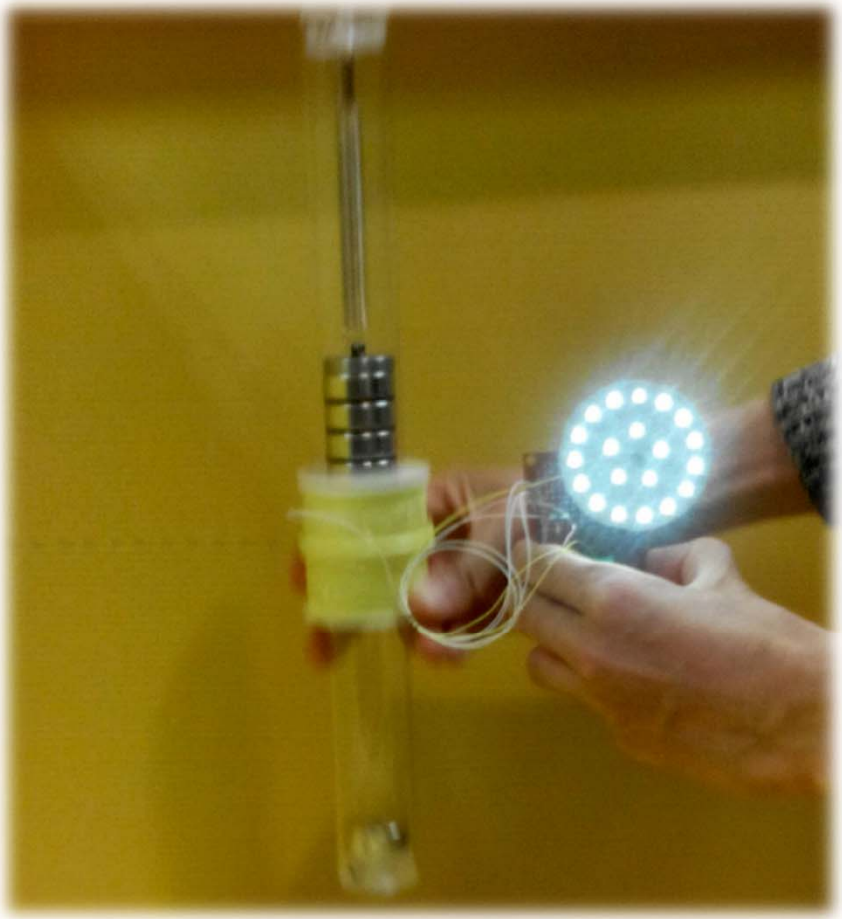
https://youtu.be/ZTU0pfXoC3Y

"Portable Energy Harvesting Devices" is a collaboration exhibition between Department of Physics, Hong Kong Baptist University and Science News Corner, Hong Kong Science Museum.

Exhibition Period: 13 January till 30 August 2017.

Devices to Capture Parasitic Energy

Vibrations and Accelerations



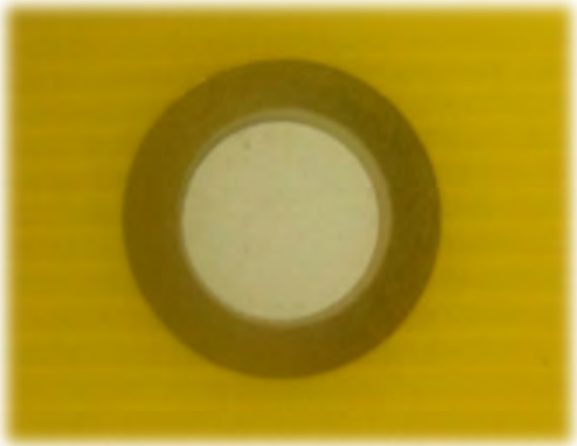
Homemade (~400 mW under 1 g acceleration)

Commercially available products

Devices to Capture Parasitic Energy

Vibrations and Accelerations

Piezoelectric Energy Converter

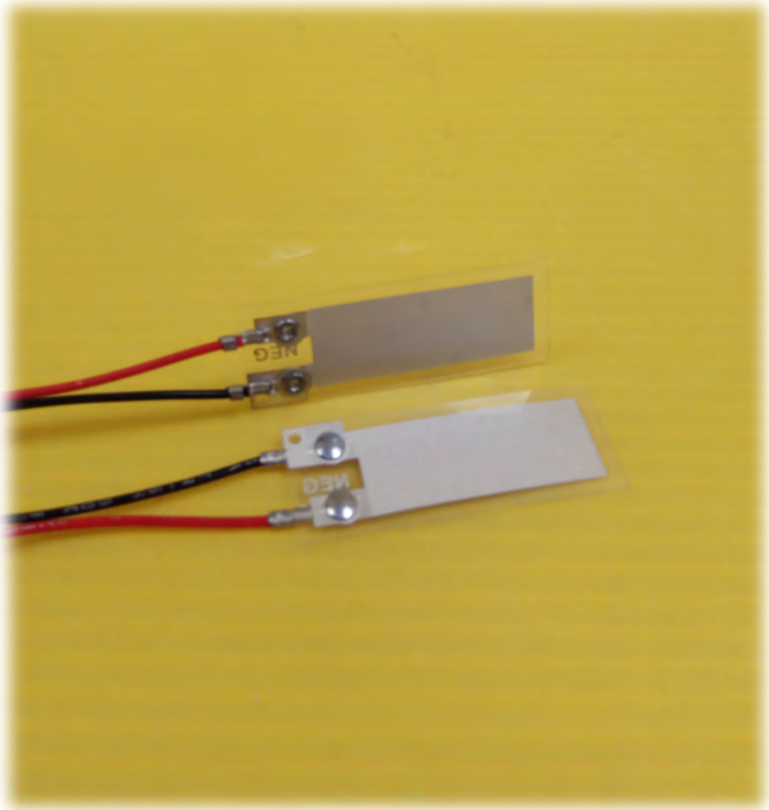


Piezoelectric
Buzzer

Parasitic Energy

Vibrations and Accelerations

"Pizeo Tree"



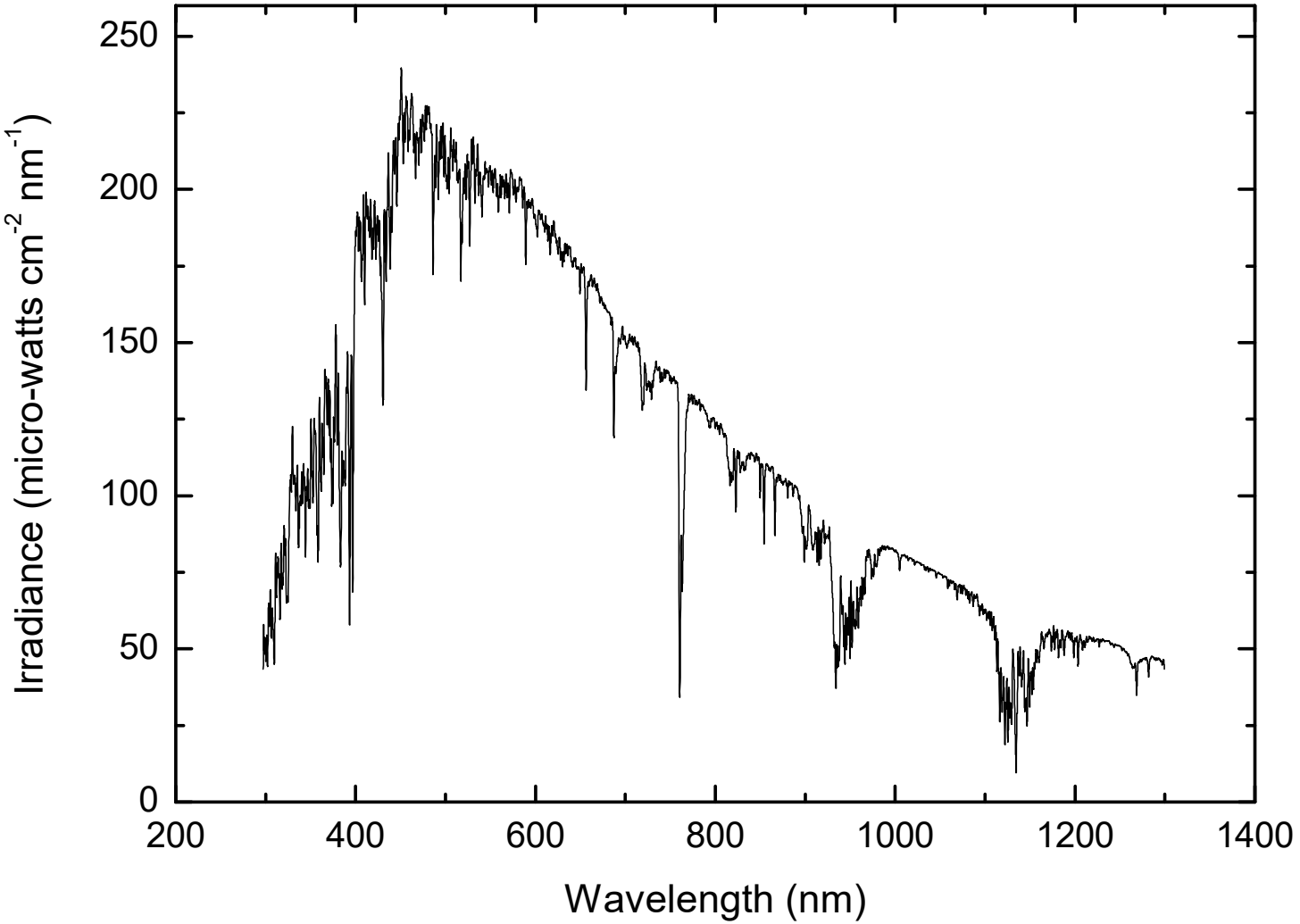
Commercial Pizeo Film (flexible)

For university students: Traditional teaching and learning activities in solar energy / PV system

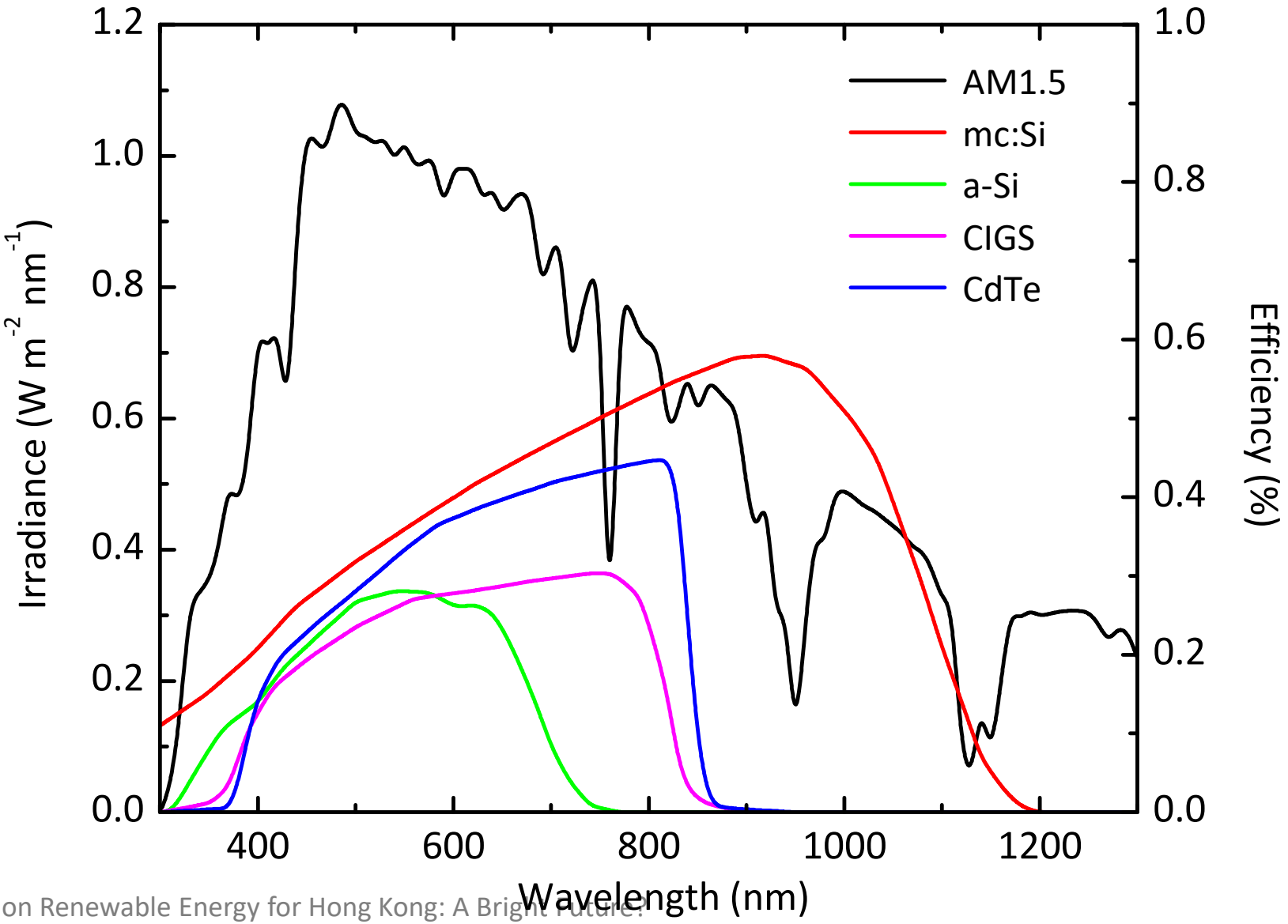
- Properties of sunlight
  - Irradiance (W/m^2)
  - Spectral information (intensity vs wavelength) in different meteorological conditions
- Solar position / sun trajectory
- Diurnal and seasonal variation of solar irradiance
- PV types, operation principles, PV performance evaluation
- PV mounting / orientation
- Characterization tools, components in PV system
- Engineering approaches

Properties of sunlight: solar spectrum

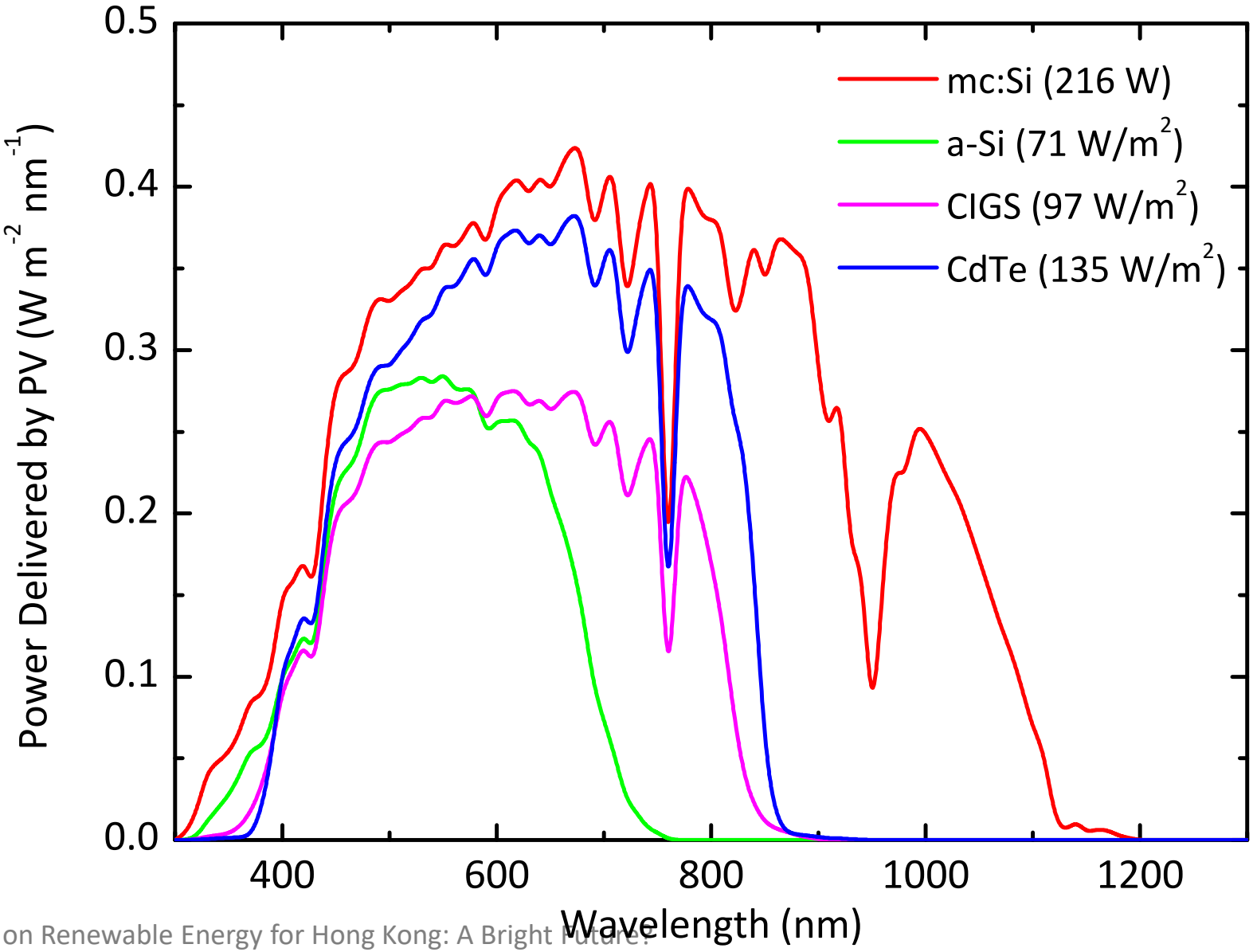
(1-nm spectral resolution spectrum)



Energy conversion efficiency



Power delivered by PV



Common types of solar cells

- Silicon Solar Cells
  - Monocrystalline Silicon
  - Polycrystalline Silicon
- Thin Film Solar Cells (nm to a few μm)
  - Amorphous Silicon (a-Si)
  - Cadmium Telluride (CdTe)
  - Copper Indium Gallium Selenide (CIGS)
  - Heterojunction with Intrinsic Thin-layer (HIT) Silicon

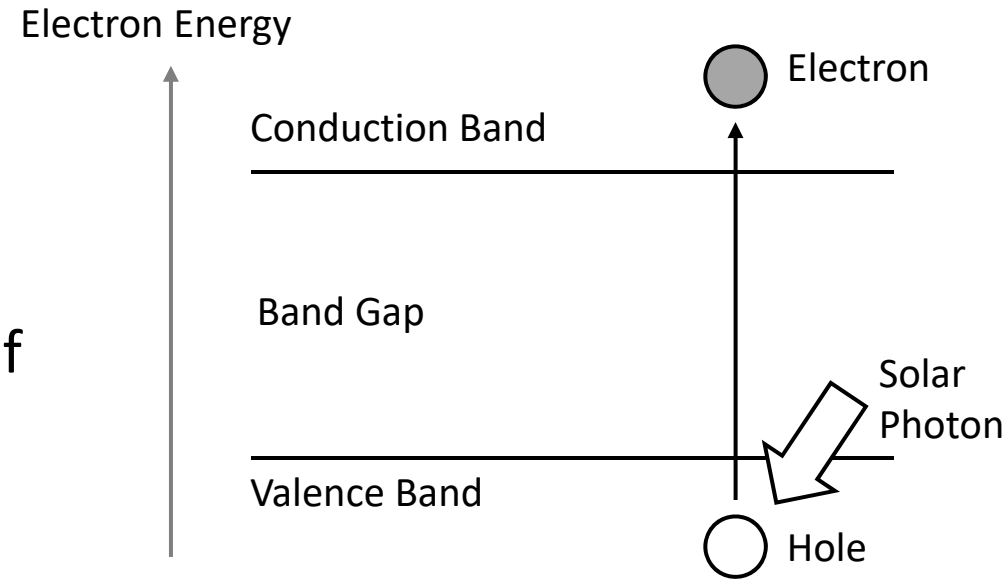
Commercial PV cells/panels

Fig 1. [LEFT] Commercial available solar cells. ① Amorphous silicon thin film, flexible; ② CIGS (Copper Indium Gallium Selenide), flexible; ③ amorphous silicon; and ④ polycrystalline silicon solar cells.
[RIGHT] Rollable solar cell

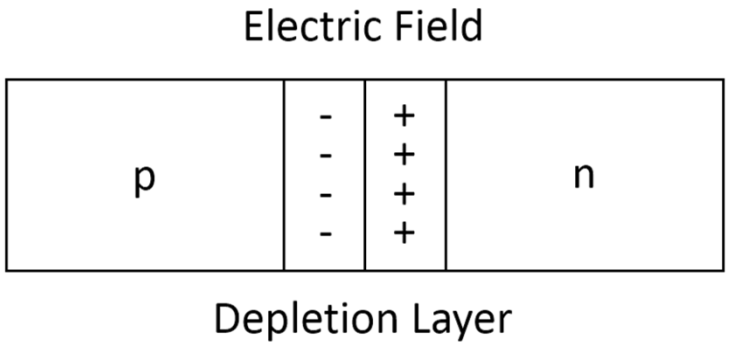
Background concepts: PV operation principle

Basic steps of energy conversion in a PV cell:

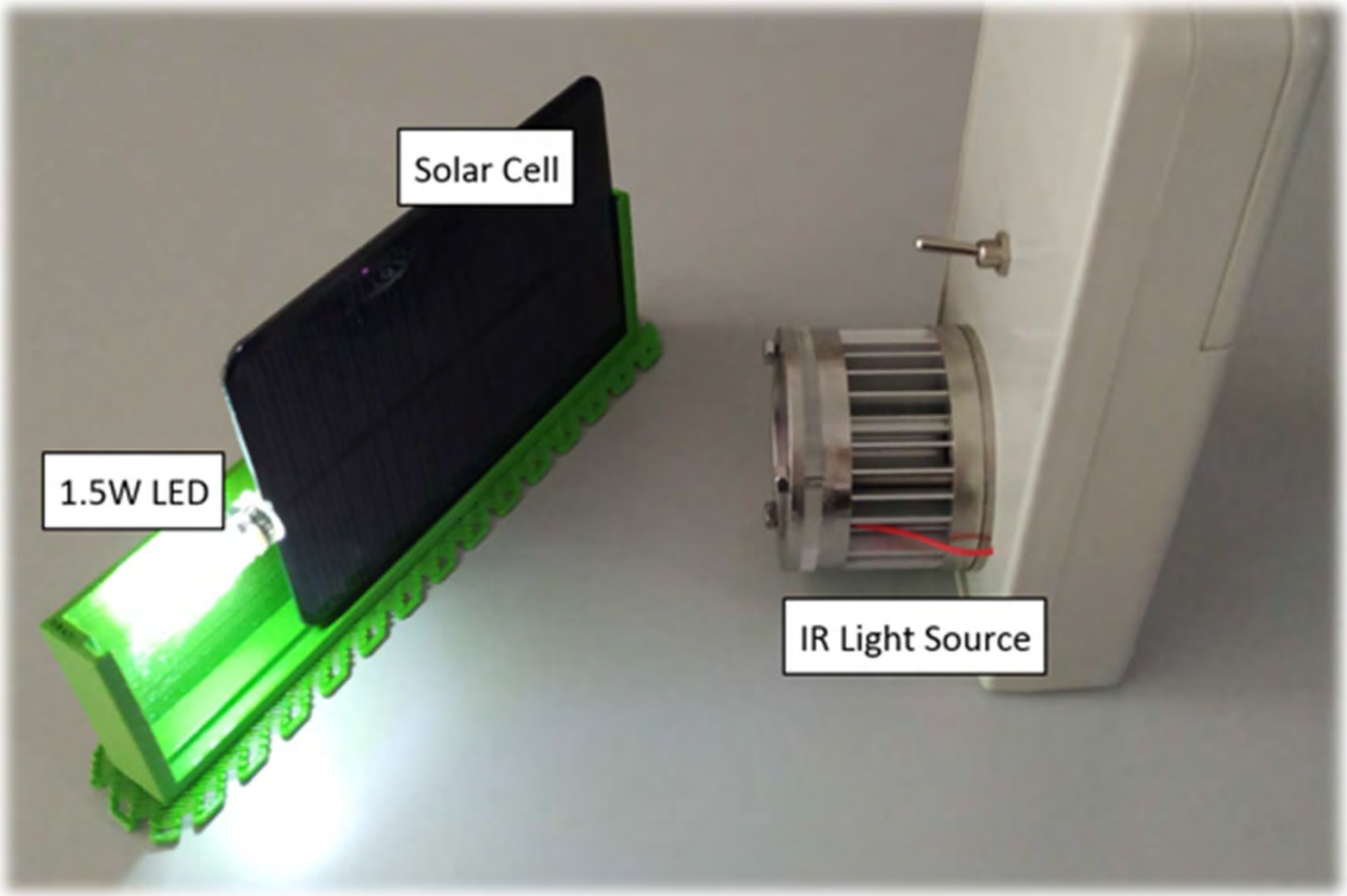
1. absorption of photons (light) and generation of electron-hole pairs,
2. separation of charges (electron-hole pairs in the depletion region), and
3. collection of charge.



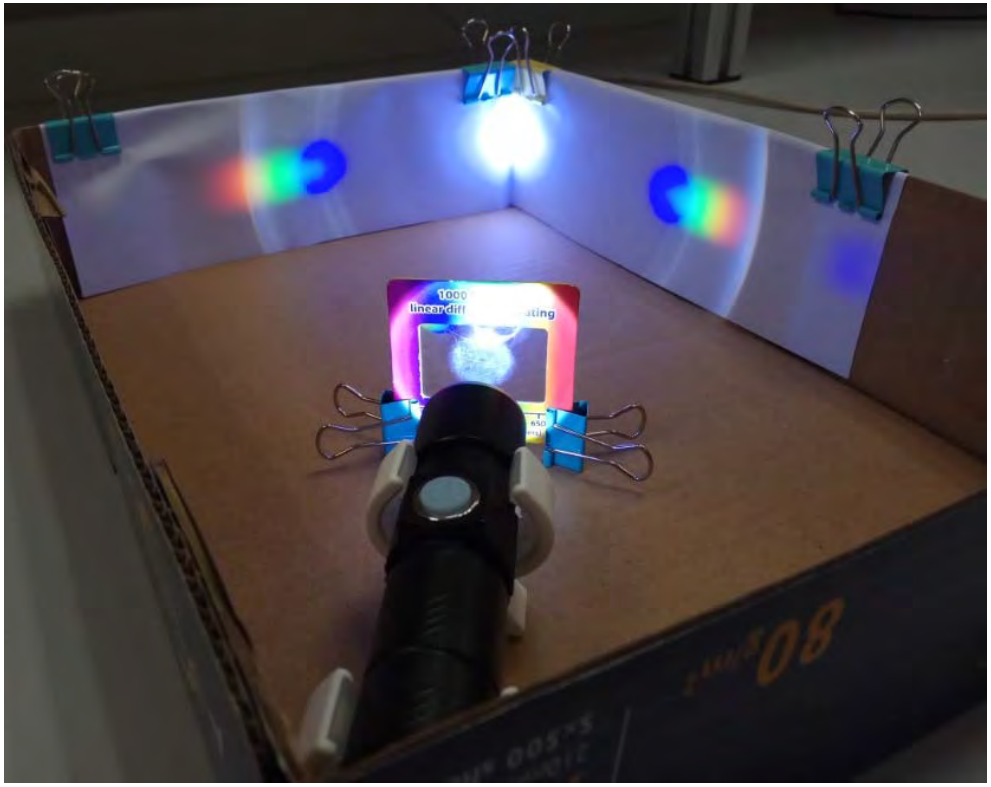
Basic steps of energy conversion in a PV cell.



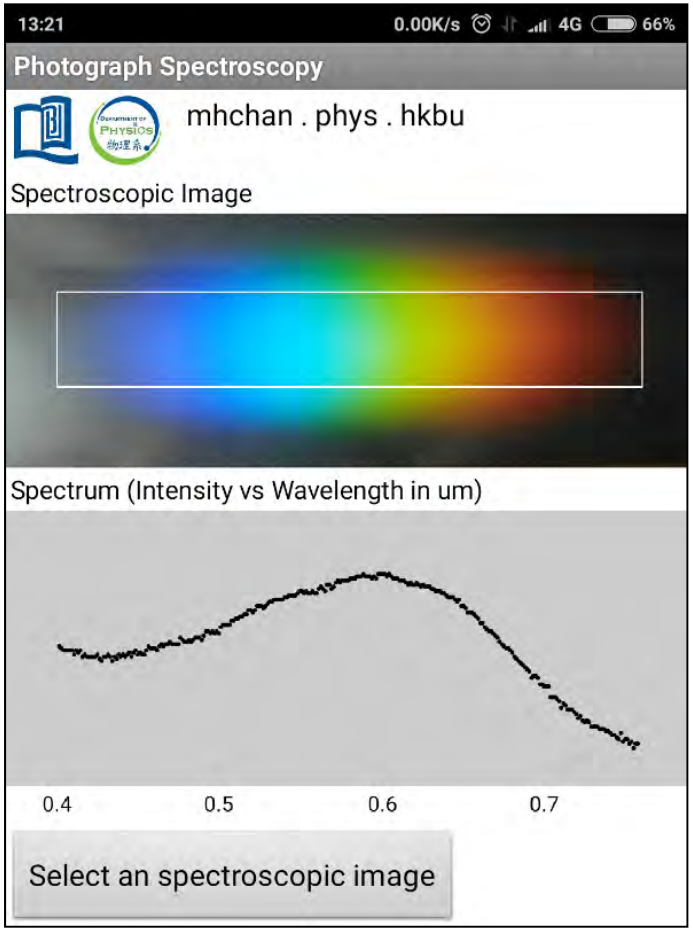
Energy source: Properties of light (IR)



Energy source: Properties of light (visible)



Homemade spectrometer



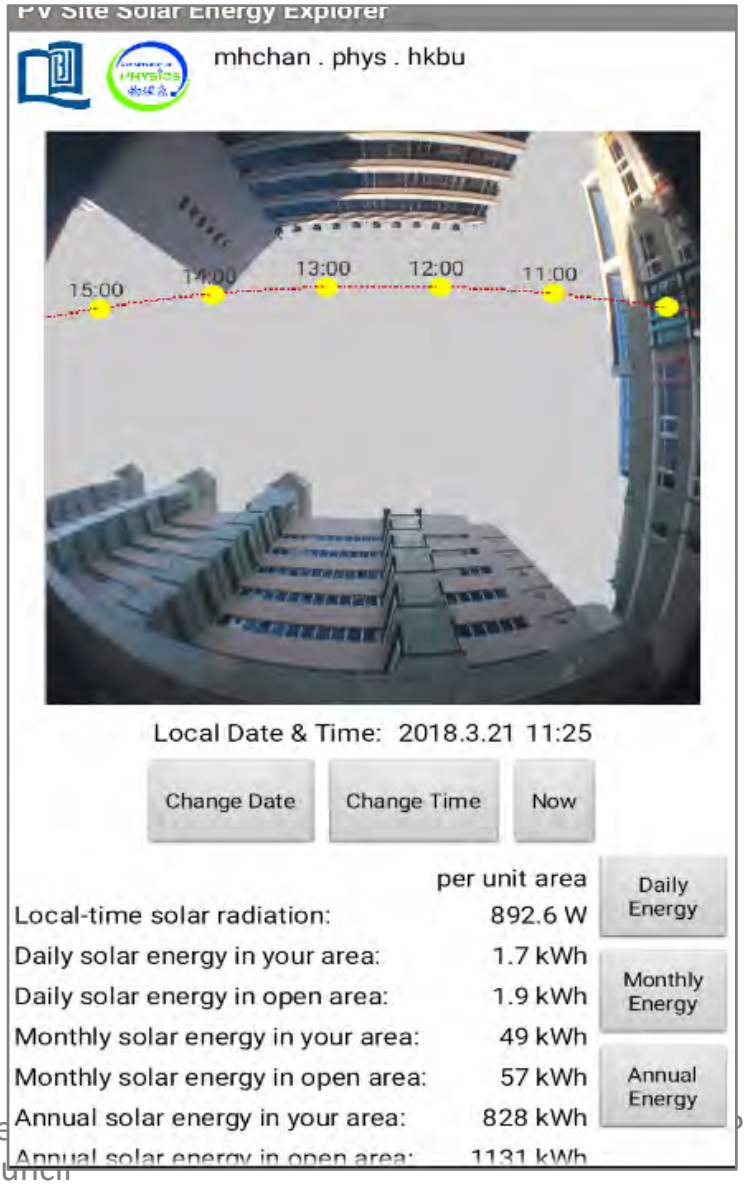
Introduction of innovation technology: mobile App

PV site survey and shading analysis (traditional method against innovation technology)

Traditional Method

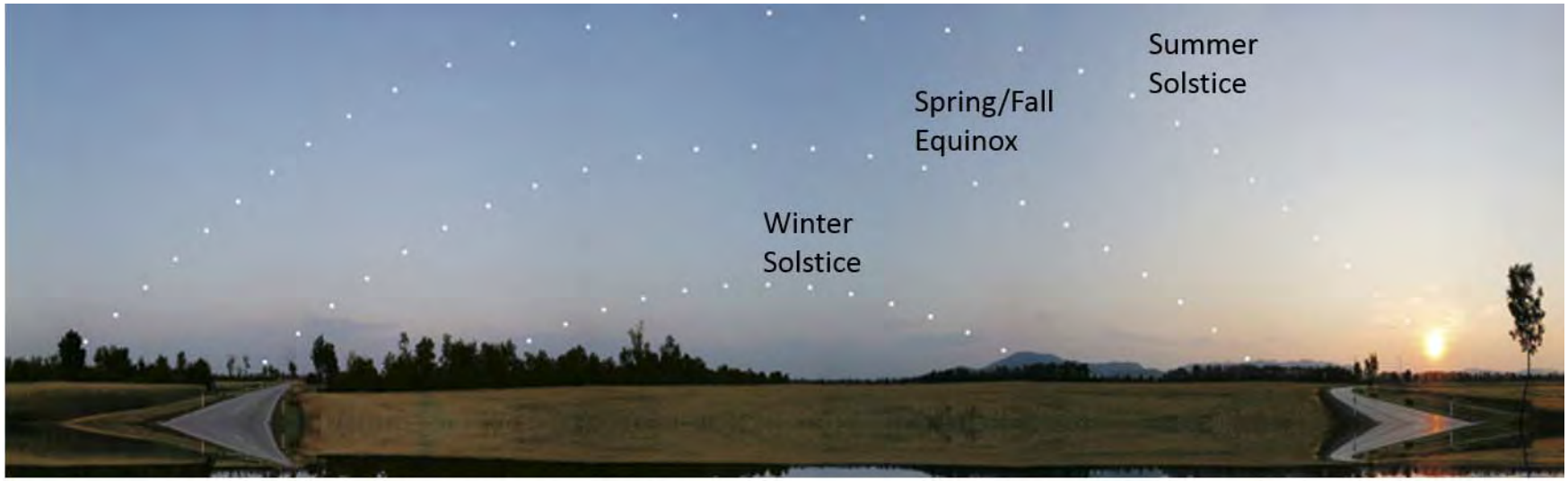
Shade analysis: Software tool

Self-development Apps



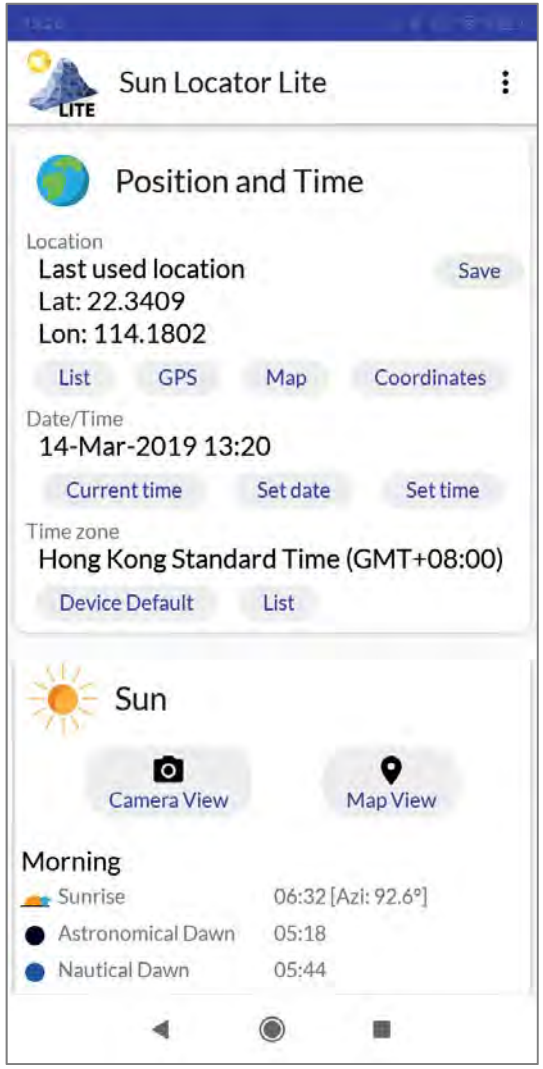
Sun position: Traditional tool

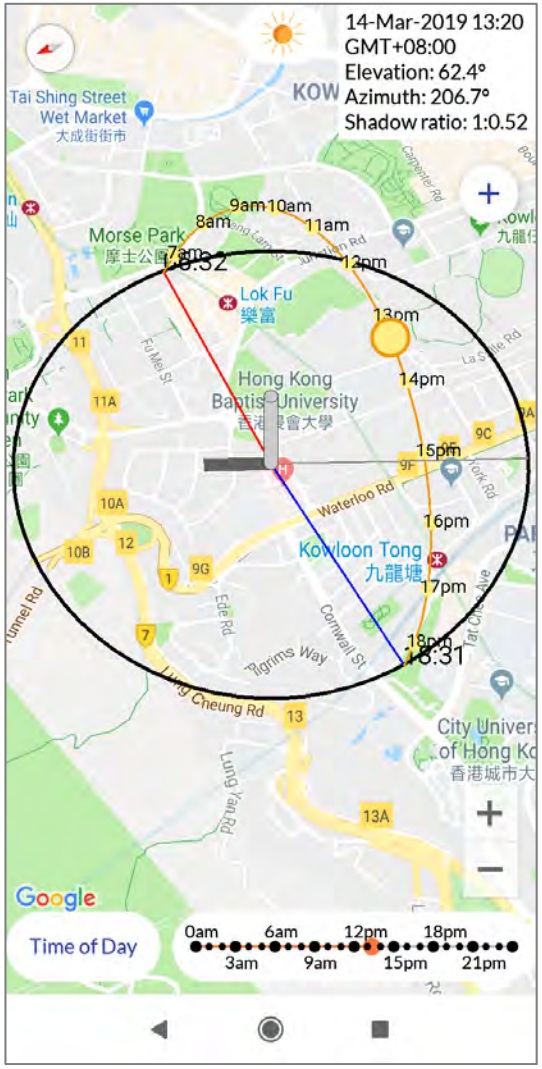
Sun trajectory: composition photo of solar positions in different seasons.

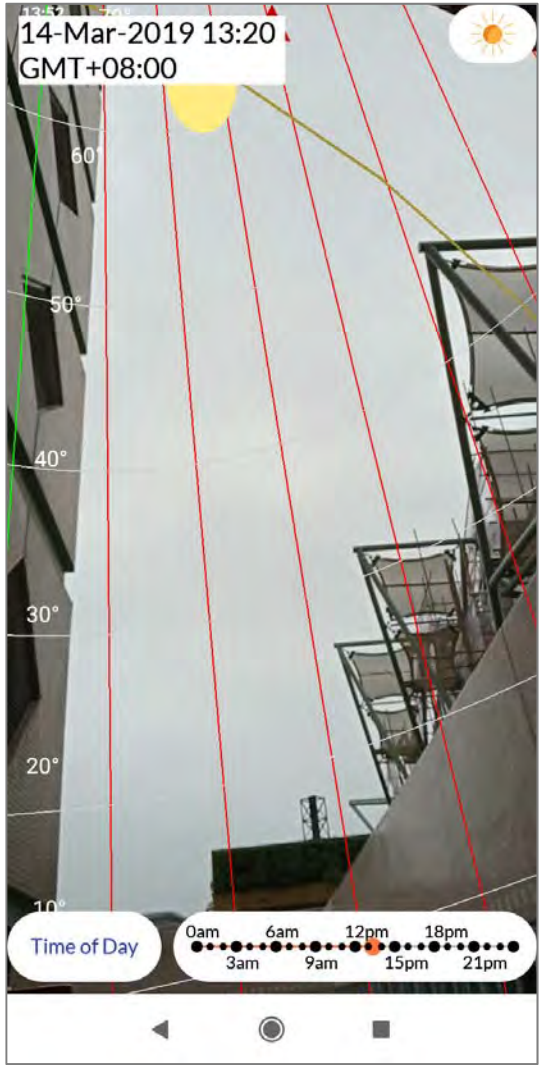


Source: APOD, looking down the Tyrrhenian Sea coast.

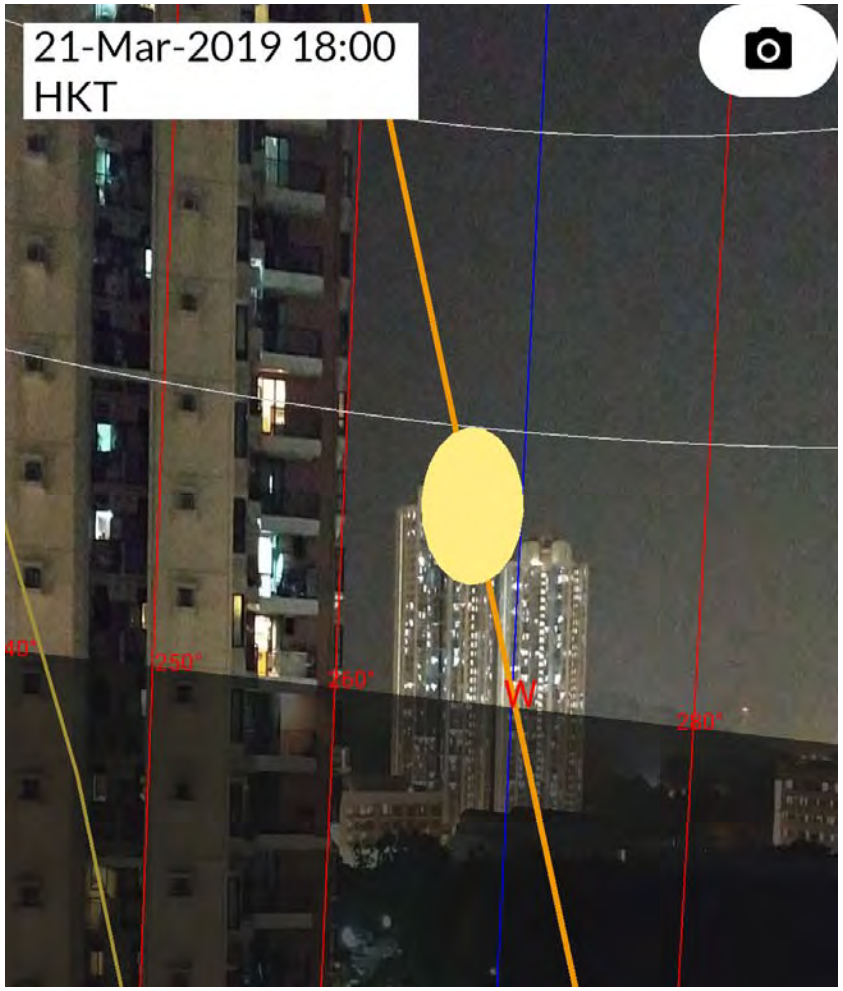
Sun position: Sun locator

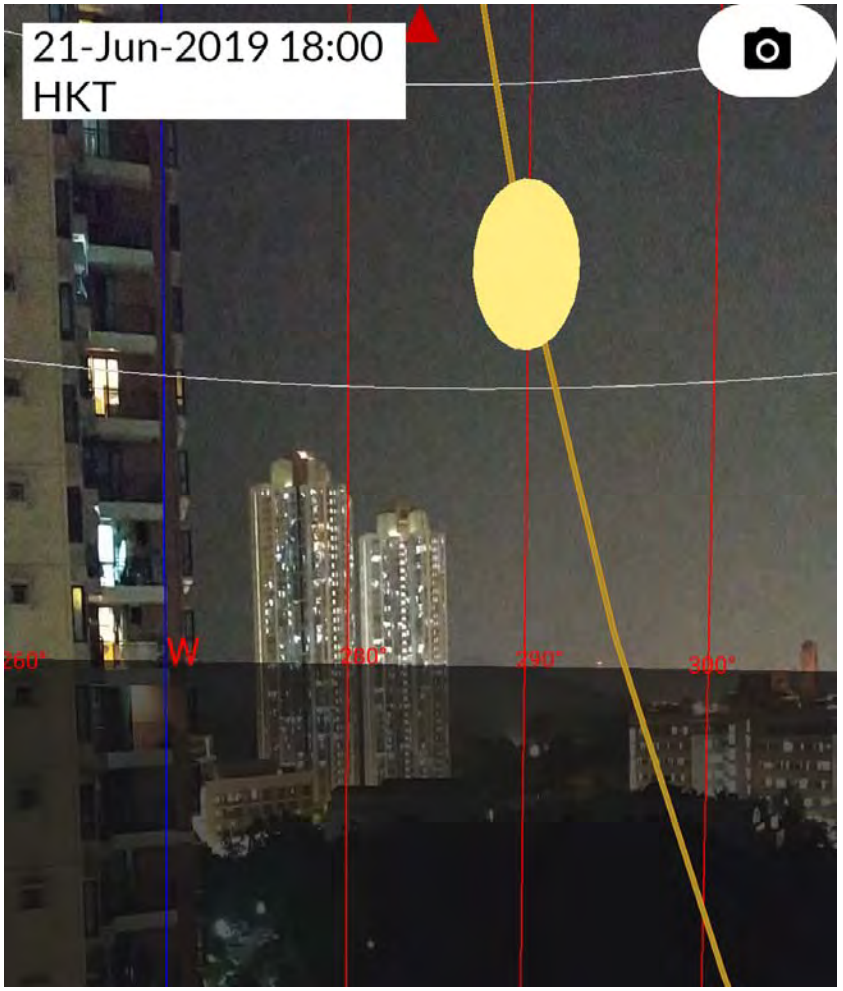






Sun position: Augmented reality





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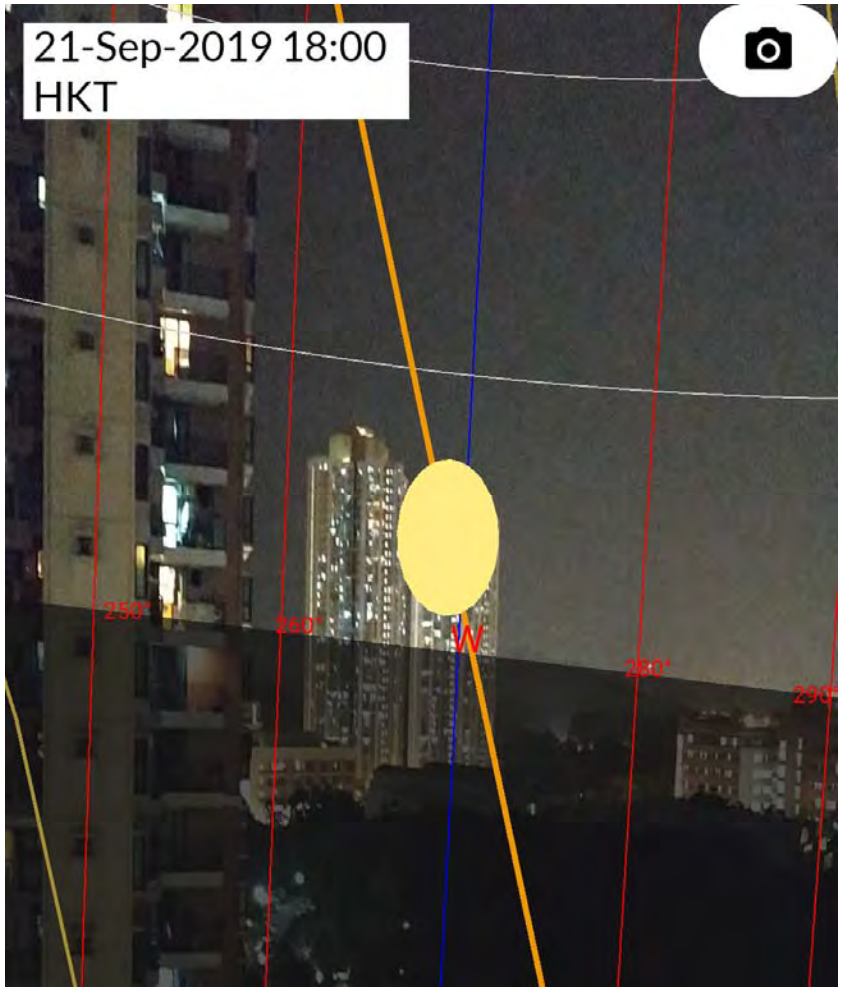
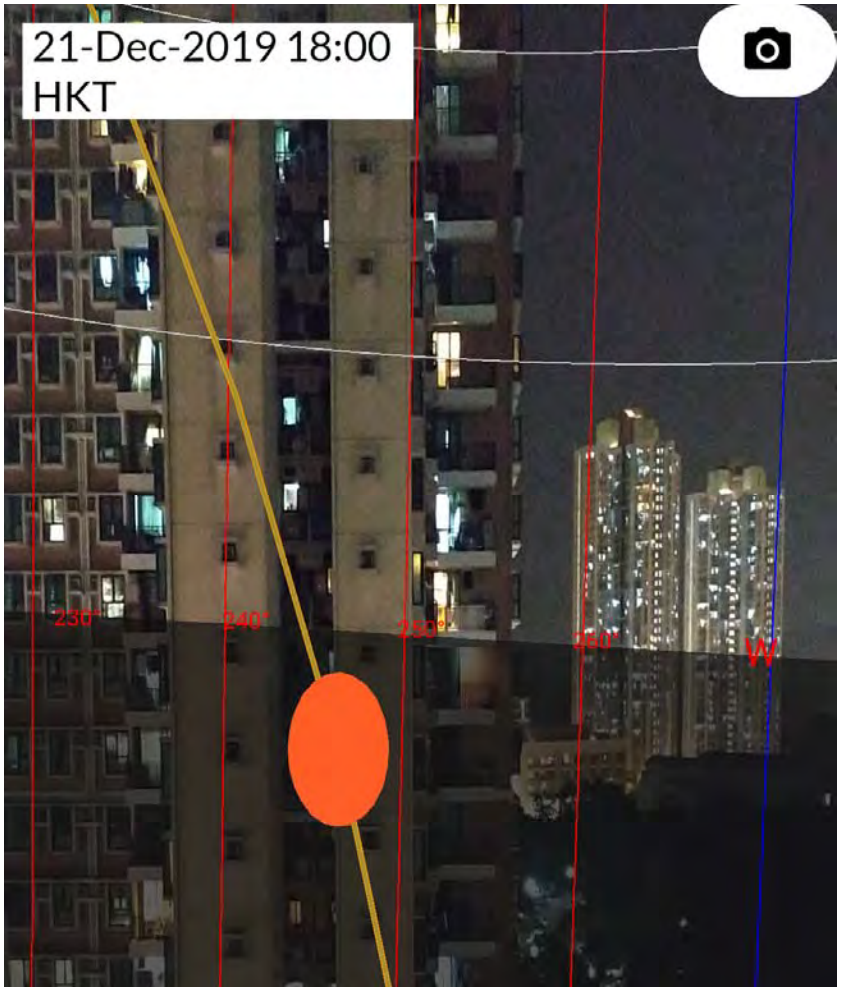
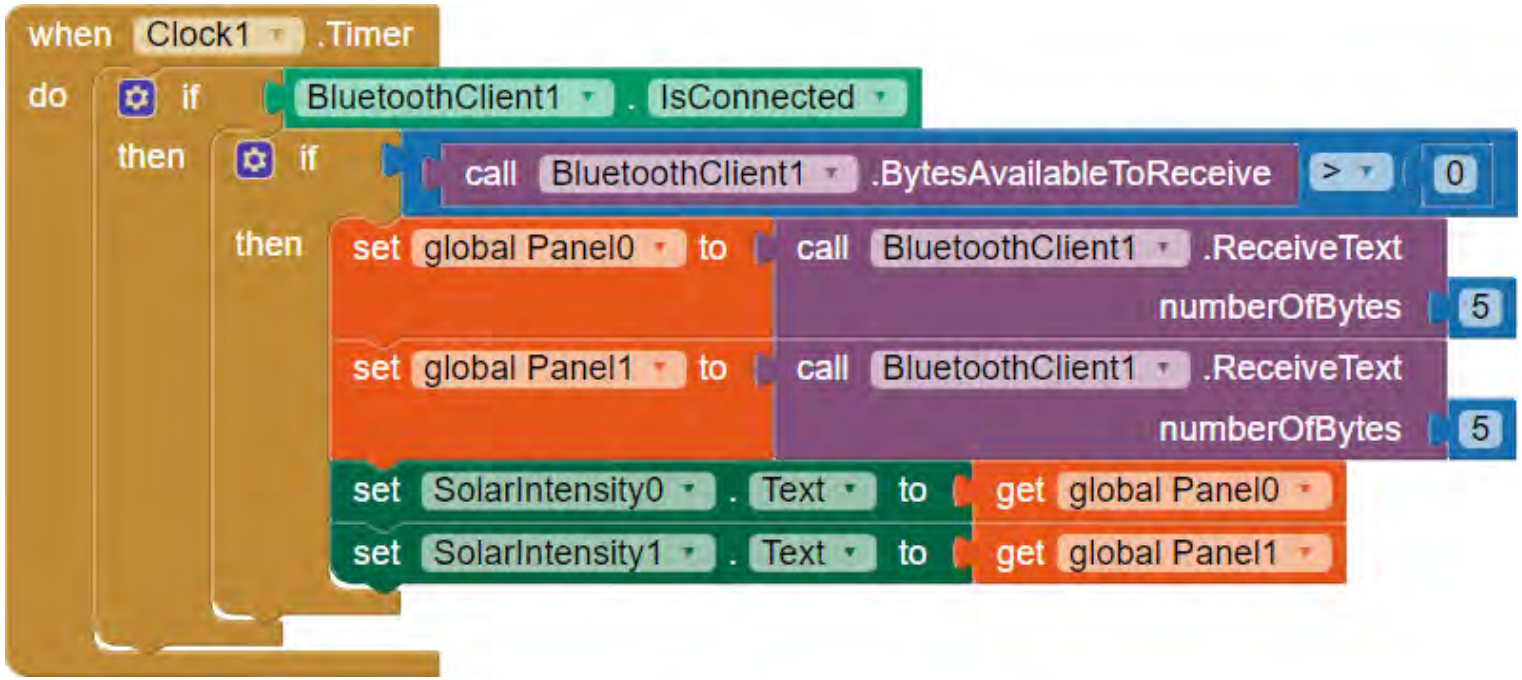




Smart and innovation technology: Mobile App development

Student groups: Secondary / university students

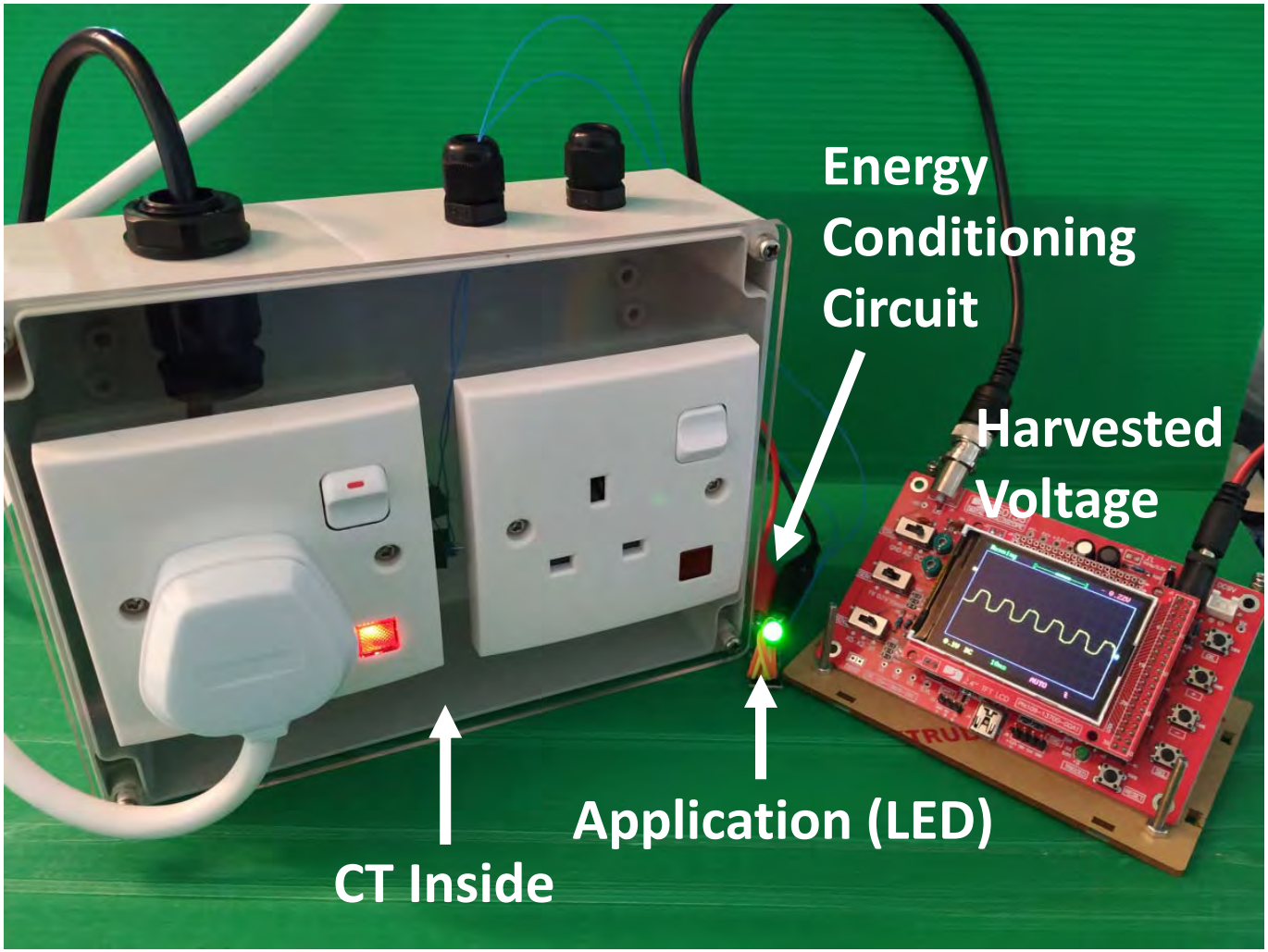


I&T enabled PV panels

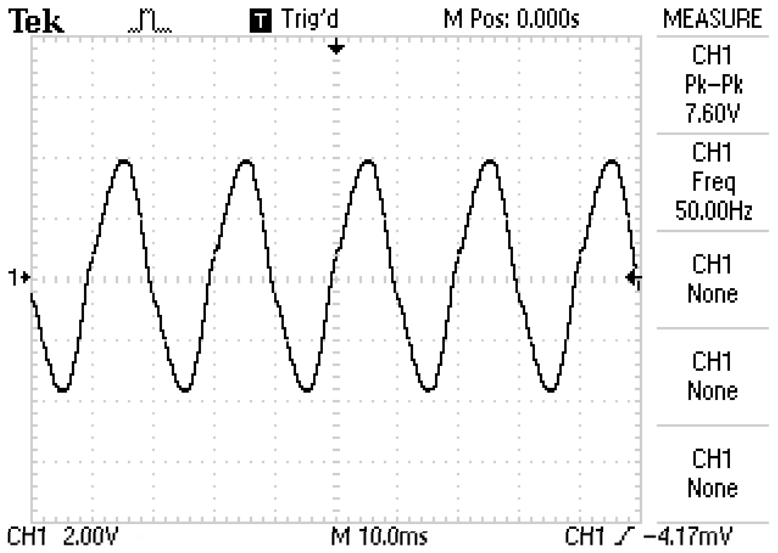
Study Directions:

- promotion of smart use of energy in smart Hong Kong city;
- raise public awareness in RE applications and energy conservation;
- engagement of all people into RE activities;
- delivery of education in I&T, RE and energy conservation, and STEM training.

Project for university students
Example: Energy Harvesting from AC Power Line



RE Project for university students
Example: Energy Harvesting from AC Power Line



<u>Parameters</u>:

AC Power: 1.5 kW

Number of CT turns: 5 × 500 = 2500

Loading: 50Ω

Peak-to-peak Voltage: 7.6 V

RMS voltage = 2.687 V

Mean Power: 0.1444 W

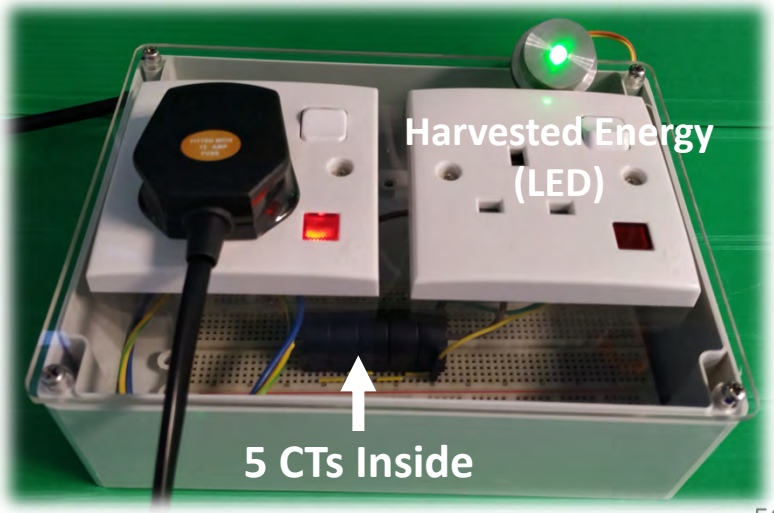
<u>Results (after normalization)</u>:

RMS Voltage:

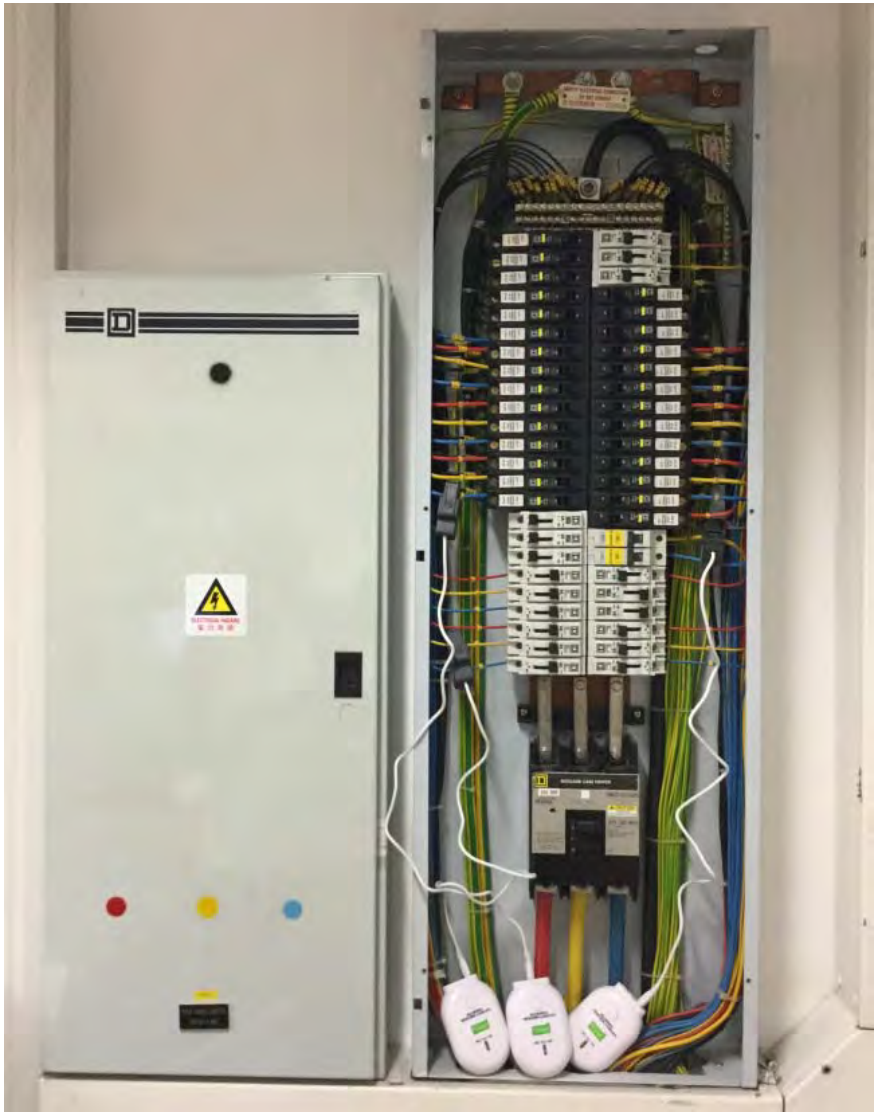
0.7165 μV / (CT Turn · AC W)

Mean Power:

0.0385 μW / (CT Turn · AC W)



Application of Energy Harvesting from AC Power Line



Teaching development project for university students

Project title:

Talking Measurement Devices for Student Question-Centered Pedagogy and Monitoring Students' Questioning Behaviors in Laboratory Classes

Objectives:

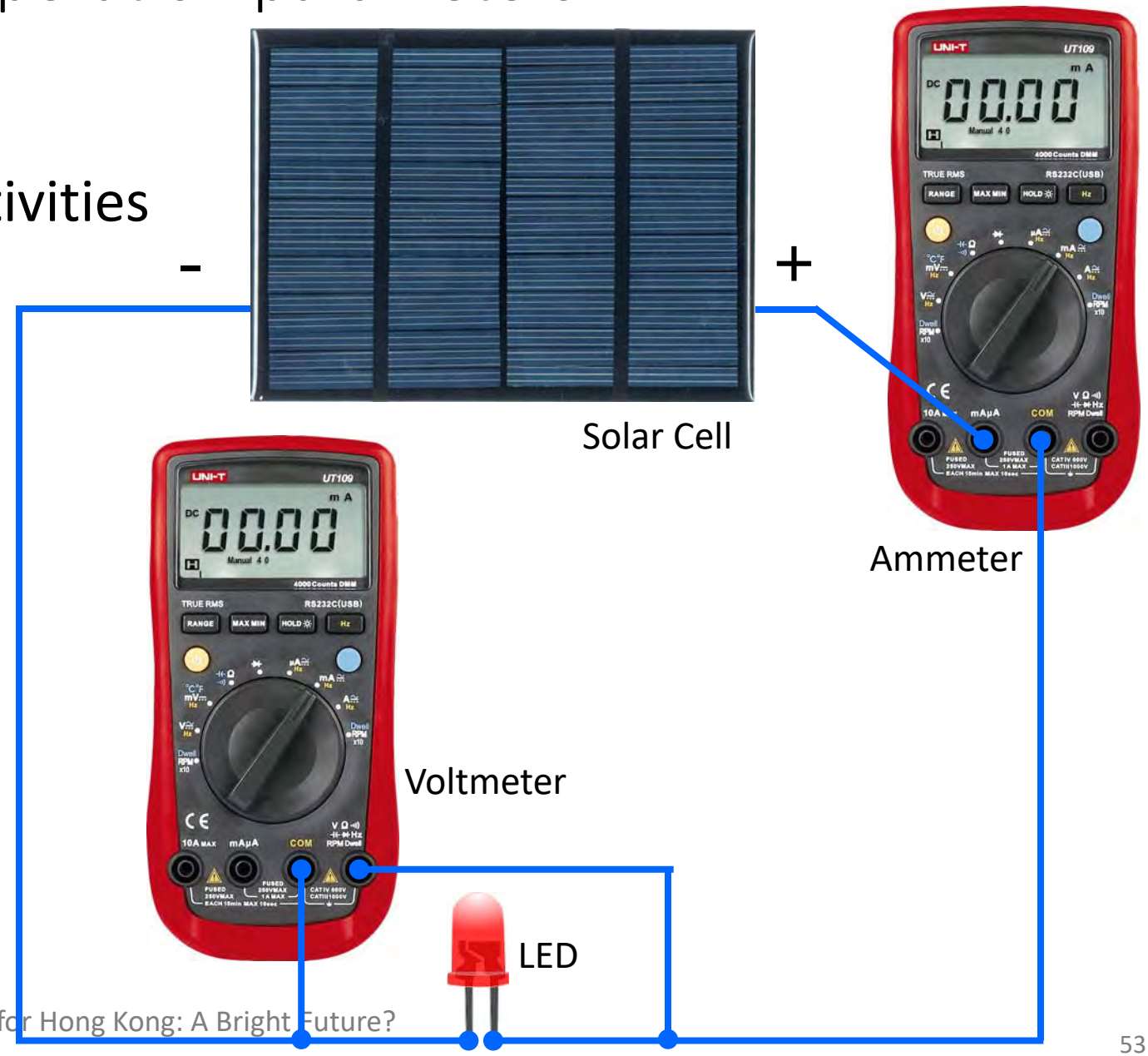
With applications of IT enabled PV panels,

i) to deliver student question-centered pedagogy, and

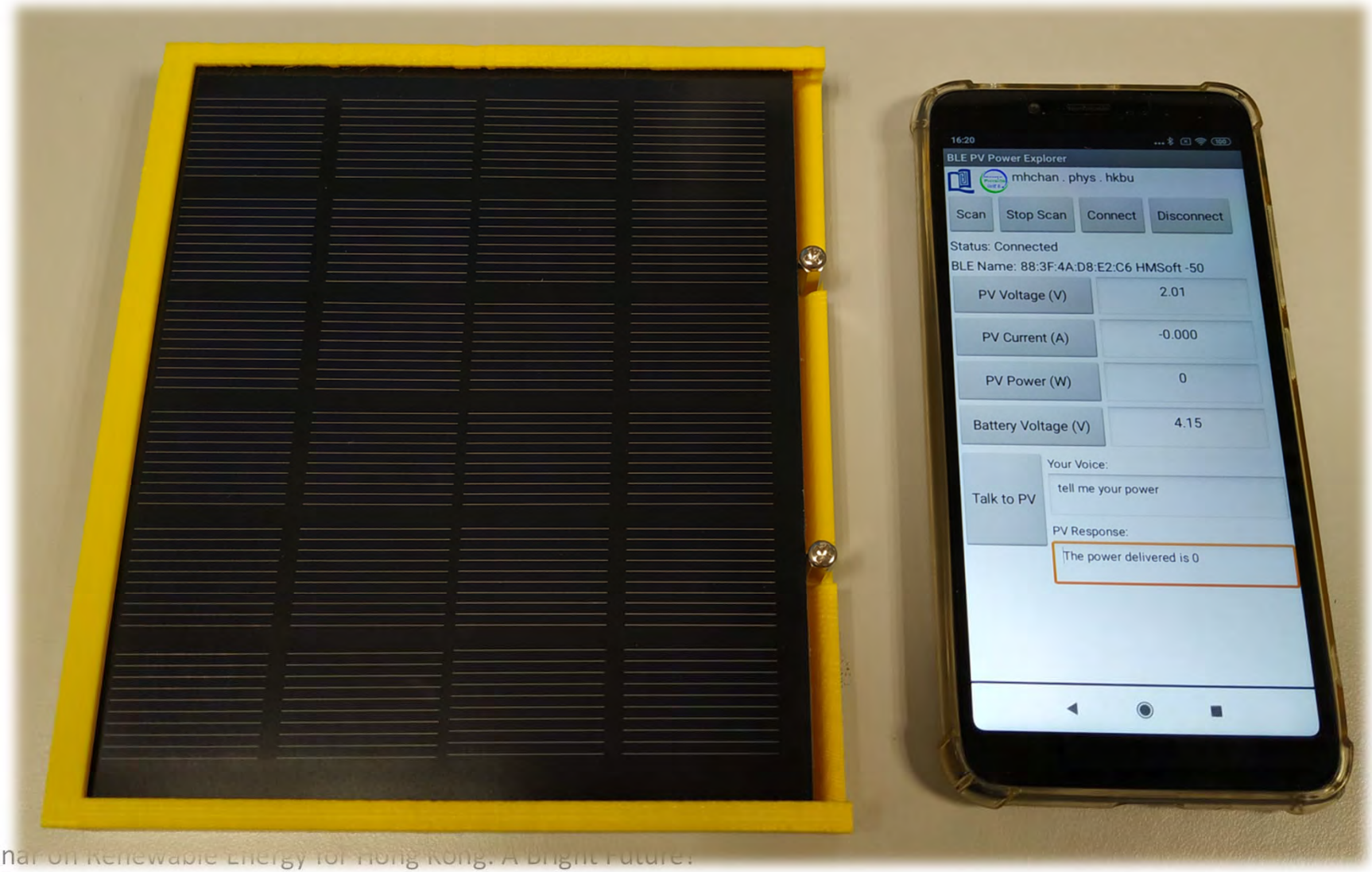
ii) to monitor students' asking questions behaviors

Solar cell operation parameters

Traditional
Teaching Activities



Solar cell operation parameters
Innovation technology: Talking to PV



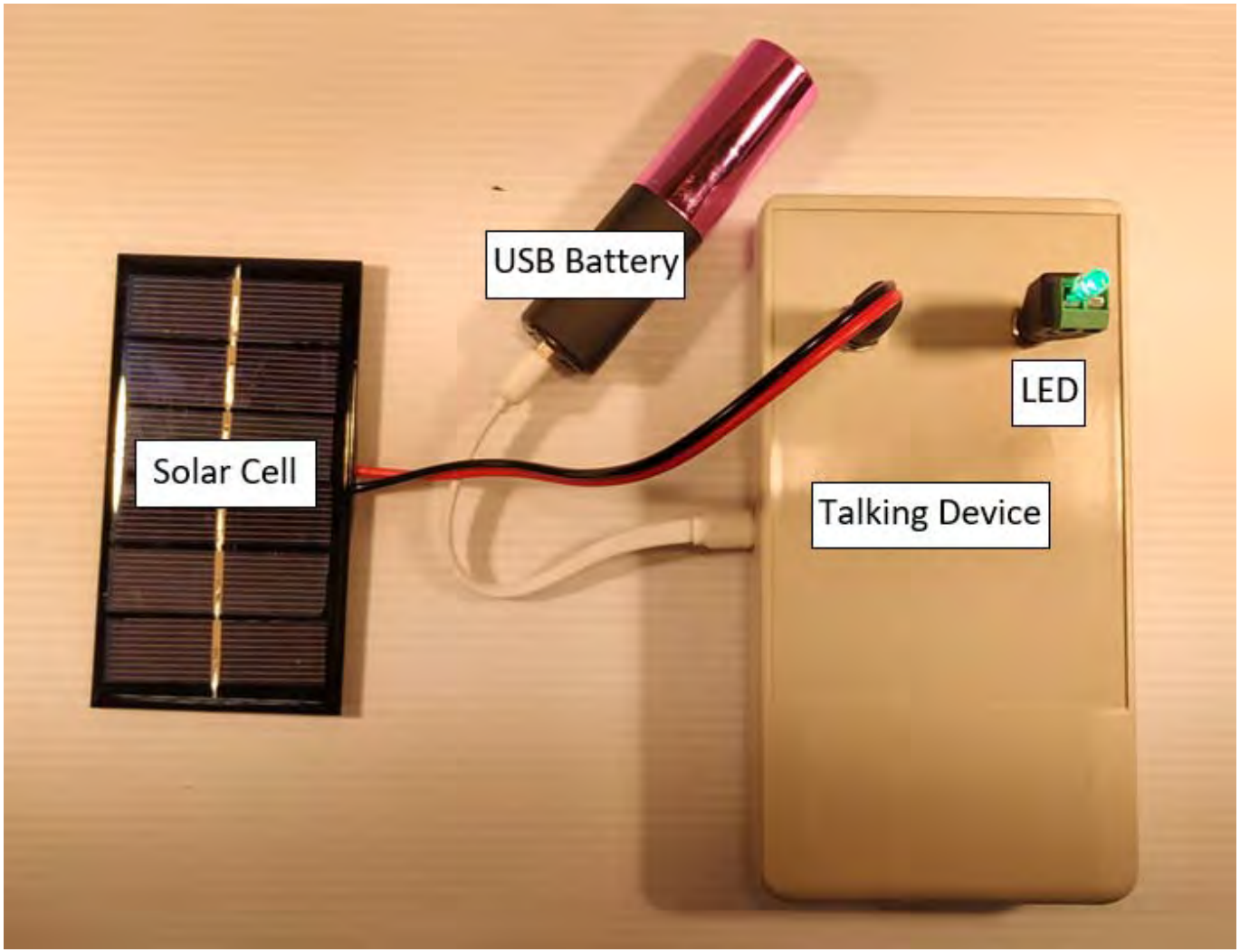
Solar cell operation parameters

I&T enabled STEM educational kit

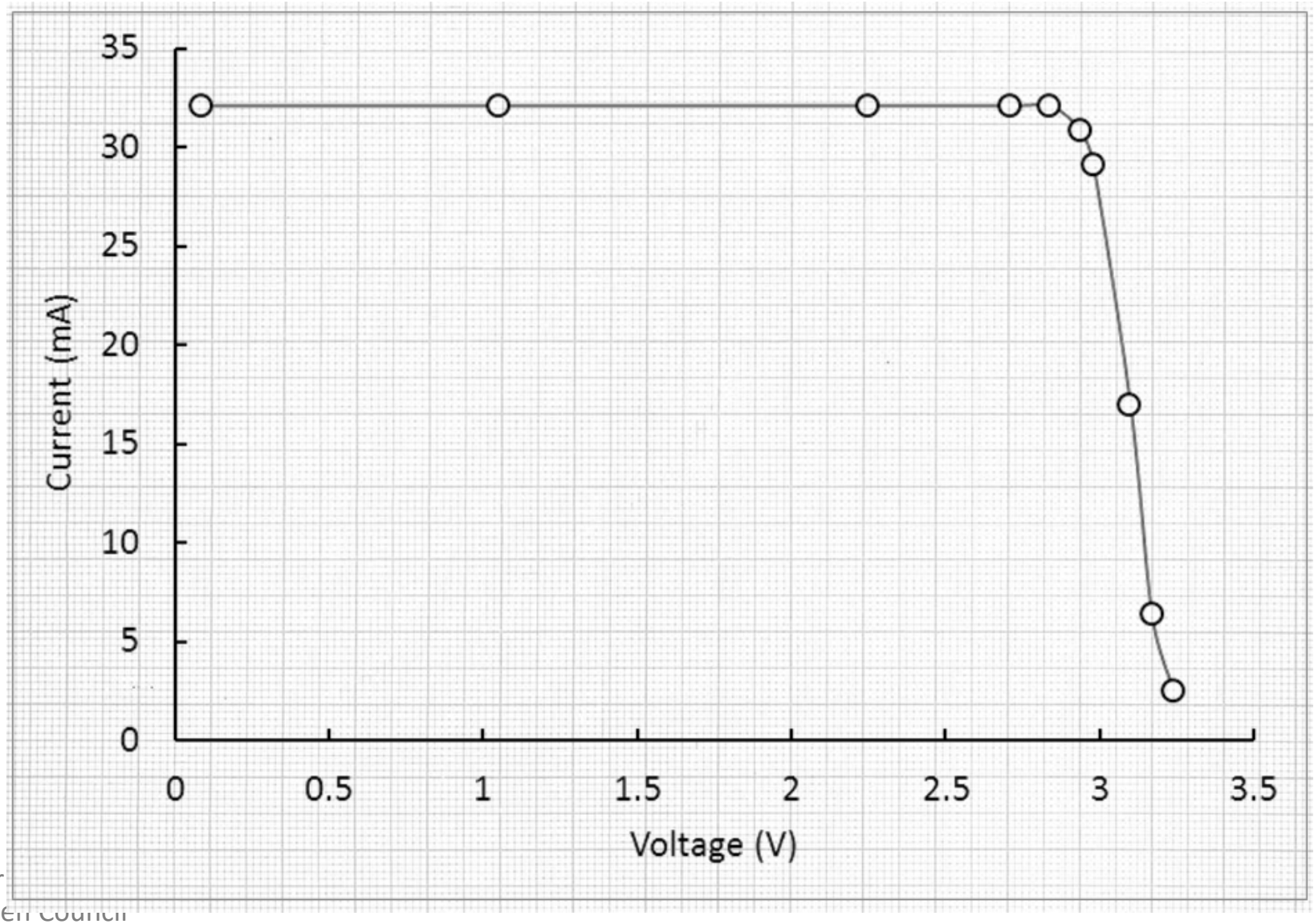
Students' teaching and learning activities

- Communication with the Talking Device
  - Making new friend
- Data and time
- Weather and meteorological information
  - Examples: temperature, humidity, atmospheric pressure, rainfall, UV index, visibility, air quality,
- Solar cell operation principle and technical terms
- Data measurements
- Hints on energy conservation
- Voice control

Lab teaching activities: PV data measurements with talking device



Lab teaching activities: PV data measurements with talking device



Talking device: Database development by university student

	A	B
21	electricity	Electricity is an intermediate form of energy.
22	iv curve	Characteristic current and voltage curve of a solar panel.
23	open circuit	Voltage of a solar panel measured without loading.
24	short circuit	Current supplied by the solar panel when it is short circuited.
25	operation point	Solar panel is operating at certain current and voltage values such that the
26	maximum power	Solar panel is operating at certain current and voltage values such that the
27	fill factor	It is the ratio of maximum obtainable power to the product of the open
28	solar spectrum	Characteristic irradiance against light wavelengths of sun.
29	air mass factor	It defines the direct optical path length through the Earth's atmosphere,
30	vernal equinox	An equinox is commonly regarded as the instant of time when the plane of
31	spring equinox	An equinox is commonly regarded as the instant of time when the plane of
32	summer solstice	The summer solstice occurs when one of the Earth's poles has its
33	fall equinox	An equinox is commonly regarded as the instant of time when the plane of
34	autumnal equinox	An equinox is commonly regarded as the instant of time when the plane of
35	winter solstice	The winter solstice occurs when one of the Earth's poles has its maximum
36	pv inverter	A PV inverter is a type of electrical converter which converts the variable
37	solar inverter	A solar inverter is a type of electrical converter which converts the variable
38	latitude	Latitude is a geographic coordinate that specifies the north south position
39	longitude	Longitude is a geographic coordinate that specifies the east west position
40	altitude	Altitude is commonly used to mean the height above sea level of a
41	azimuth	An azimuth is an angular measurement in a spherical coordinate system.
42	sun chart	Sun chart is a graph to illustrate the sun trajectory through the sky
43	super capacitor	Electric double layer capacitor with high value of capacitance and low
44	ultra capacitor	Electric double layer capacitor with high value of capacitance and low
45	mqt	Module quality test.
46	visual inspection	To detect any visual defects in the module.
47	maximum power	To determine the maximum power of the module.
48	insulation test	To determine whether or not the module is sufficiently well insulated
49	measurement of	Determine the temperature coefficients of current, voltage and peak power
50	nmot	NMOT is defined as the equilibrium mean solar cell junction temperature
51	performance at	To determine how the electrical performance of PV module varies with
52	outdoor exposure	To perform preliminary assessment of PV module to withstand exposure to

Overseas study: Environmental Technology and Green Culture Beijing Study Tour (23-27 December 2017)

Arrival: at the Beijing Capital International Airport.

Group photo in the Tiananmen Square.

Beijing Tianlang Cologne Ecological Technology Co. Ltd.
(北京天朗科隆生態科技有限公司)

Our Ten BSc and MSc HKBU Students.

Overseas study: Environmental Technology and Green Culture Beijing Study Tour (23-27 December 2017)

Photo with 國務院港澳事務辦公室交流司 張翼鵬 副司長 (the 5th from the right) at the Hong Kong and Macao Affairs Office of the State Council (國務院港澳事務辦公室).

Photo with 環保部 宣教司 何家振 副司長 (the 6th from the left) at the Ministry of Environmental Protection of the People's Republic of China (中華人民共和國環境保護部).

Group photo at Tsinghua University (清華大學).

Photo at SEE (Society, Entrepreneur, and Ecology), 中國企業家環保會：阿拉善 (SEE, China Entrepreneurs Environmental Protection Association)

RE Teaching and Learning Philosophy

We cannot create energy,

but we can renew the low-grade energy,

and we can even save energy for a sustainable future!

Thanks for attending my

RE teaching experience sharing!