香港城市大學
City University of Hong Kong

Sharing of an Advanced Learning and Teaching Experience to Gifted and Talented Secondary School Students of Hong Kong

Benny Hon @ LTExpo 2022 (HKCEC) on 8 December 2022
Professor
Department of Mathematics
City University of Hong Kong

專業 創新 胸懷全球
Professional · Creative
For The World

Acknowledgement

Gifted Education Fund
Off-school Advanced Learning Programmes for Gifted Students

Implementation Plan

Programme Number:	**2019-004 (For secondary levels)**
Title of Programme:	Advanced Talent Education Programmes for Gifted Students in Hong Kong (香港資優生才能培訓計劃)
Programme Provider:	City University of Hong Kong
Maximum Number of Participants and Class Level in the 2019/20 school year:	50 Secondary 3 to Secondary 5 students
Programme Duration:	12 months

Project Plan (Feb 2020 – Jan 2021)

Phase 1 (Preparation)

Briefing Seminar and Selection Test
(Written gifted quotient test, math subject test, strengths & difficulties questionnaire, children's hope scale and brief strengths scale):
30 May 2020

Announcement of Final Result: **10 June 2020**
(A total of 54 students were admitted)

Project Plan: Phase 2 (Mathematics/Psychology)

4 full-day lessons on mathematics related to STEM and
2 half-day lessons on psychology

4 July 2020	Sorting Algorithm-Sorting Machine
8 August 2020	Calculus Theory-Cycloid Curve, Square Wheel
15 August 2020	Probability & Statistic Theory-Galton Board
22 August 2020	Chaos & Fractals Theory-Double Pendulum
29 August 2020	Psychology
5 September 2020	Psychology

The STEM lessons included Mathematics theory/3D Modelling techniques to equip students with the ability to hands-on mathematical models from raw materials and 3D software "Tinkercad"

The Psychology lessons demonstrated the strengths of students through daily activities and how their talents could be used to cope with the adversity in the covid-19 pandemic.

Market products related to STEM

1. Mbot Mechanical, 4Wheel Driving
2. Mechanical robot - LEGO WeDo2.0 , Metas , LittleBits
3. Coding for AI and electronic devices
4. 3D printing

STEM with Mbot

Source pictures from ezone magazine

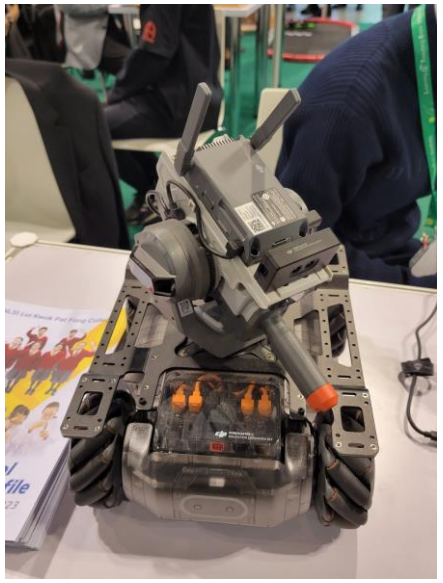
Video taken from LTExpo-2022

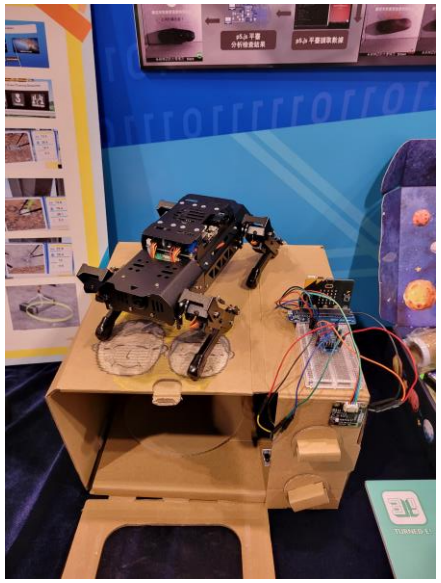
Mechanical Robot - LEGO

Source pictures from ezone magazine

Coding for AI and electronic devices


Source video from CocoRobot





Photos taken from LTExpo-2022

3D Printing

Photos taken from LTExpo-2022

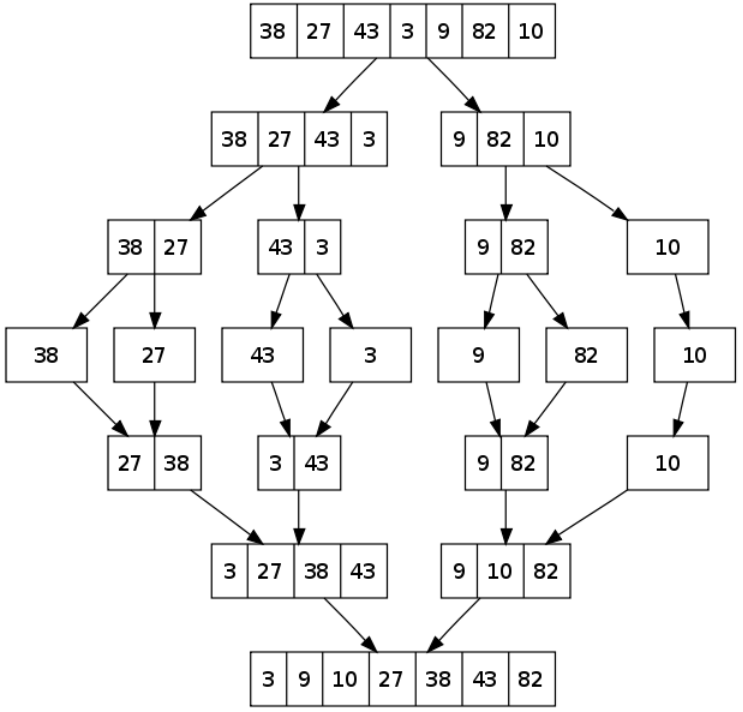
GEF Project: Aims and Objectives

- Experience mathematics
- Appreciate the beauty of mathematics
- Showcase the beauty of mathematics with hands-on model built from 3D printing or raw materials

How to experience Mathematics?

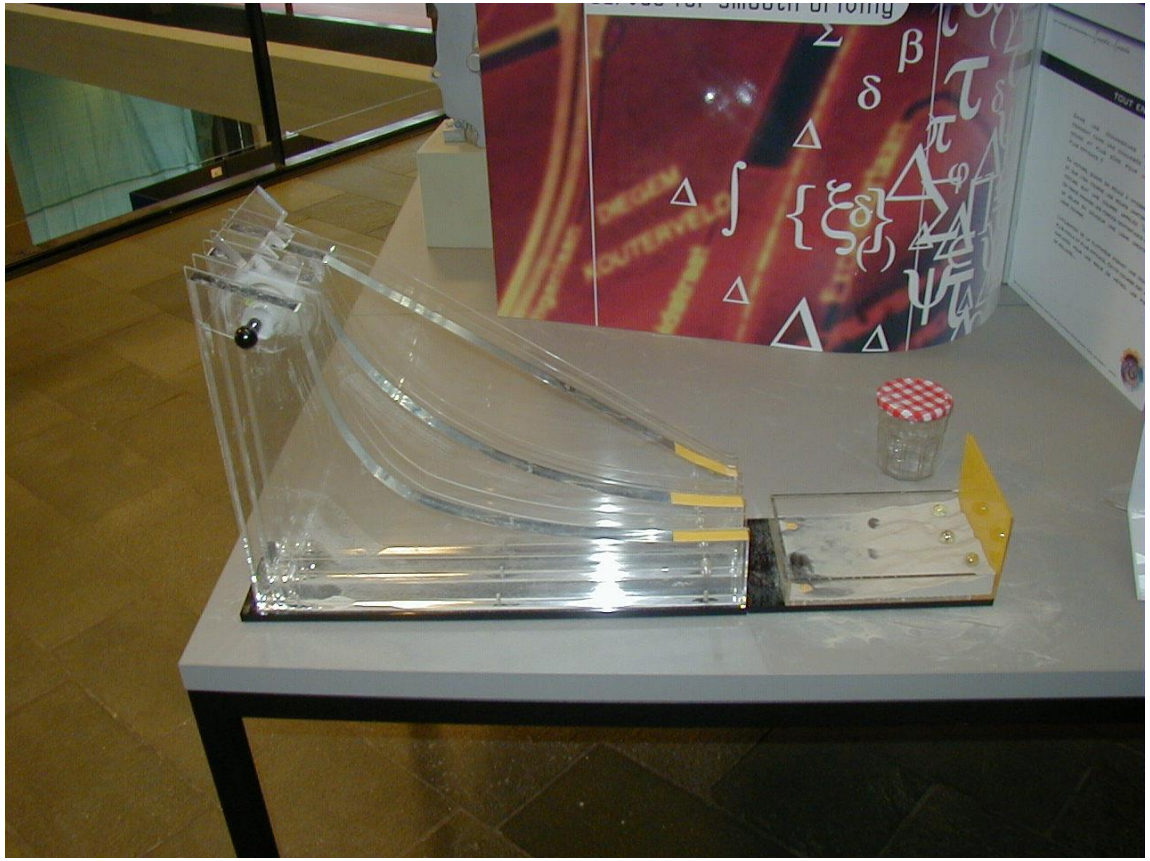
- Reproduction of models that have been exhibited
- Improvement on the “quality” of the models
- Creation of new model that has never been exhibited

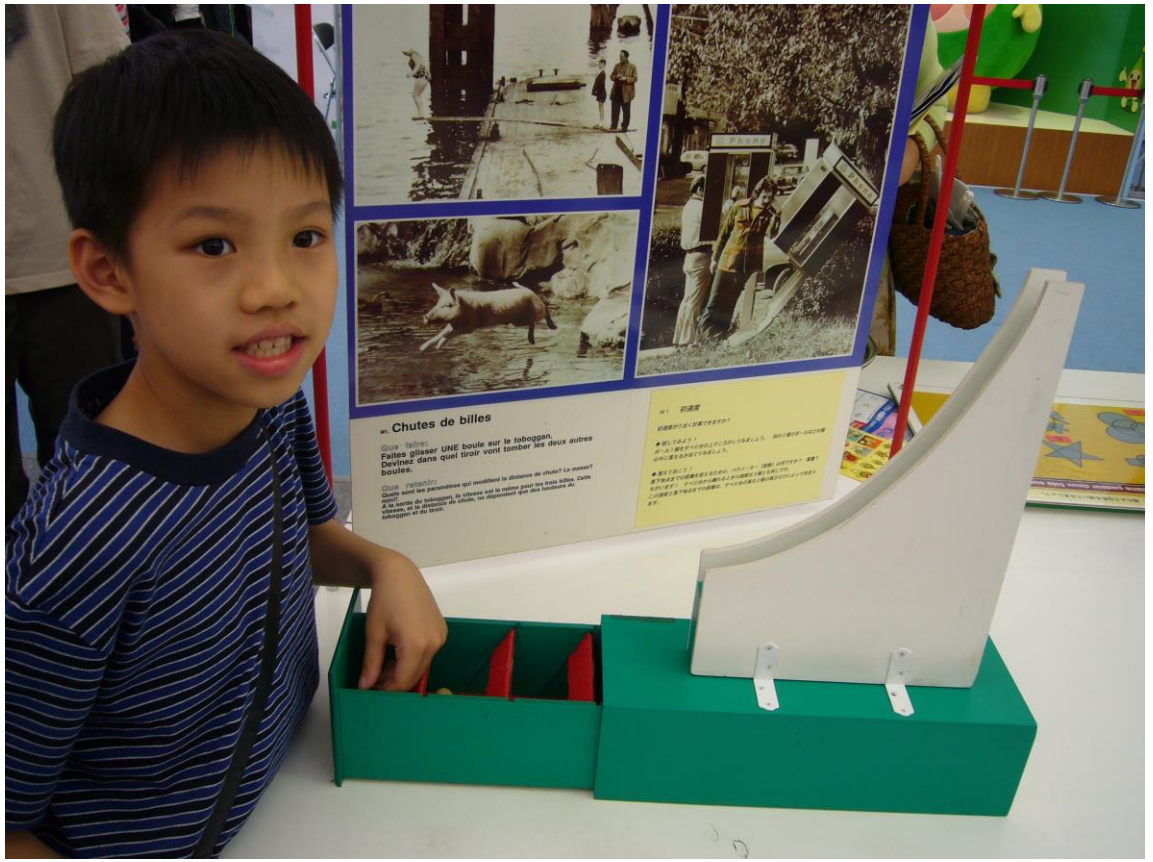
Phase 2-Sorting Algorithm: Sorting Machine



Source picture from Mr. Innovative

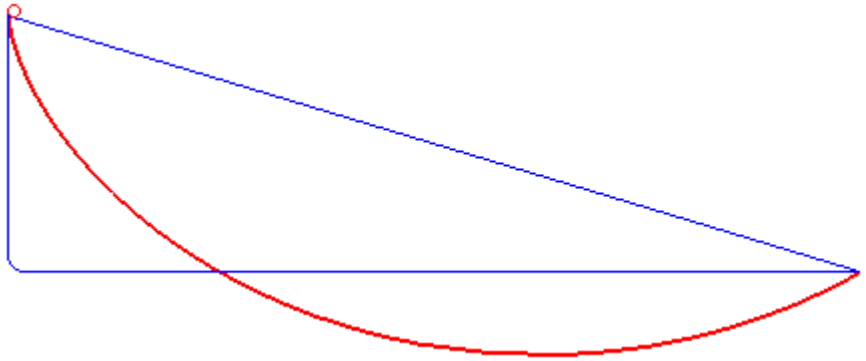
Phase 2-Calculus Theory: Cycloid Curve & Square wheel





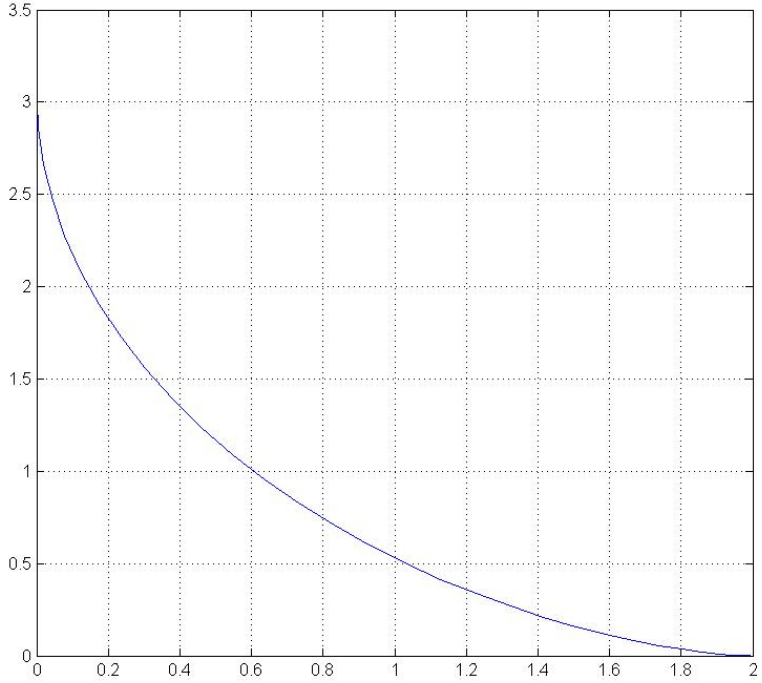
Photos taken from Museum of Mathematics in Hokkaido

What is a Cycloid Curve?



最速下降線

Steepest Descent Curve



$$x = a(\theta - \sin(\theta))$$

$$y = a(1 - \cos(\theta))$$

How to appreciate the beauty of Mathematics?

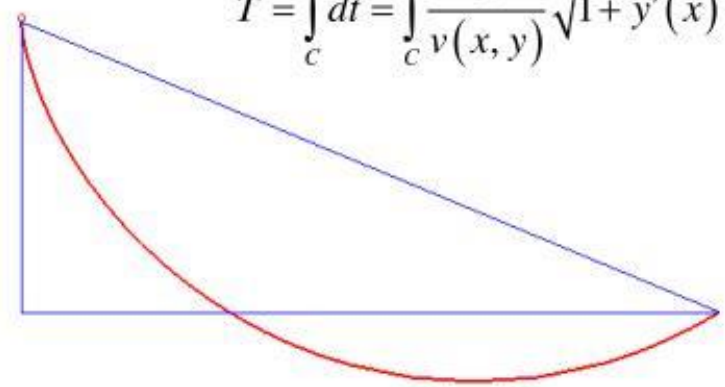
Brachistochrone Problem

Finding the shape of a wire joining two given points such that a bead will slide (frictionlessly) down due to gravity will result in finding the path that takes the shortest amount of time.

$$v = \frac{ds}{dt}$$

$$dt = \frac{ds}{v} = \frac{1}{v}\sqrt{1 + y'(x)^2}\,dx$$

$$T = \int_c dt = \int_c \frac{1}{v(x,y)}\sqrt{1 + y'(x)^2}\,dx$$



The shape of the wire will minimize time based on the most efficient use of kinetic and potential energy.

Fermat's Principle

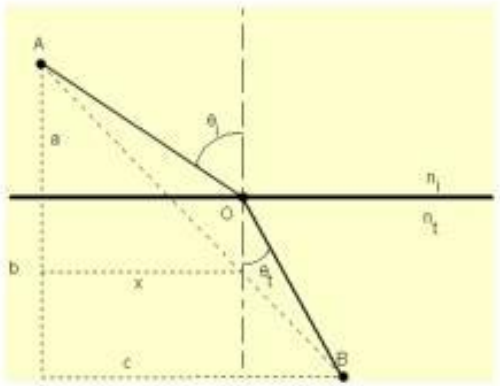
Refractive index of light in an inhomogeneous medium

$v = c/n$, where v = velocity in the medium and n = refractive index

Time of travel = $T = \int_C dt = \int_C \frac{ds}{v} = \frac{1}{c}\int_C n ds$

$$T = \int_C n(x,y)\sqrt{1+y'(x)^2}\,dx$$

Fermat's principle states that the path must minimize the time of travel.



Geodesics

A locally length-minimizing curve on a surface

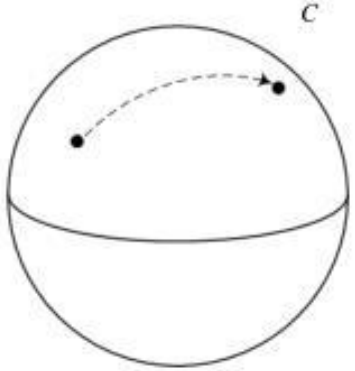
Find the equation $y = y(x)$ of a curve joining points (x_1, y_1) and (x_2, y_2) in order to minimize the arc length

$$ds = \sqrt{dx^2 + dy^2} \quad \text{and} \quad dy = \frac{dy}{dx}dx = y'(x)\,dx$$

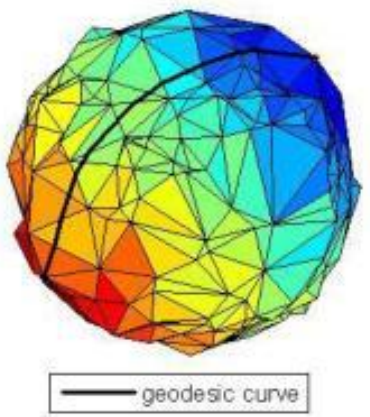
so

$$ds = \sqrt{1 + y'(x)^2}\,dx$$

$$L = \int_C ds = \int_C \sqrt{1 + y'(x)^2}\,dx$$

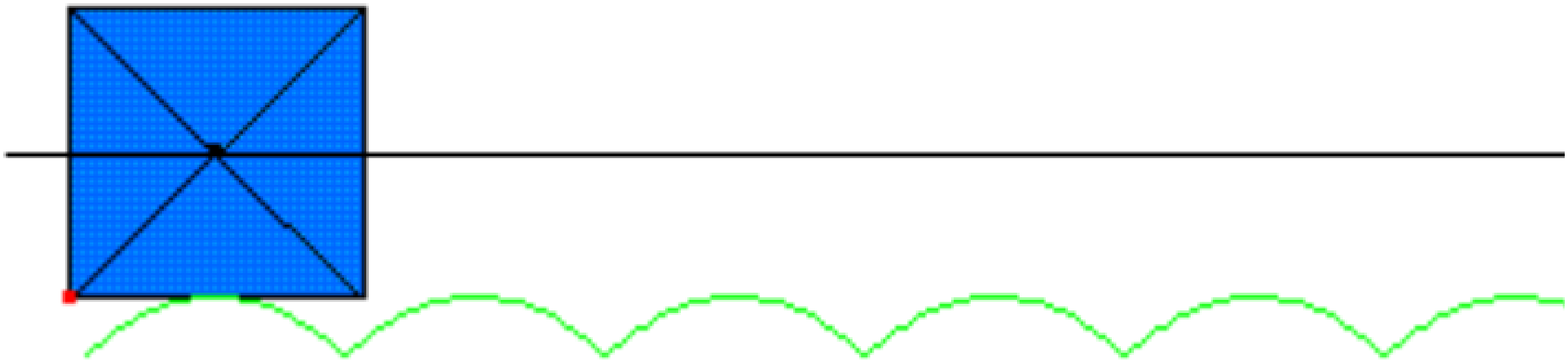


Geodesics minimize path length



How is square wheel be possible to move?

- It must move on a surface of inverted catenaries.
- Shape like cycloid curve.



A square rolling on a bed of inverted catenaries.

Square Wheels

Source picture from google search

How about this?

Source picture from google search

Phase 2-Probability & Statistics: Galton Board

1

1 ● 1

1 ● 2 ● 1

1 ● 3 ● 3 ● 1

1 ● 4 ● 6 ● 4 ● 1

Pascal's triangle

Binomial Distribution *B*(x; n, p)

x~B(x; n, p)
n trials each with p successful rate.
The total number of successes is a random variable, x

Photo taken from Museum of Mathematics in Hokkaido

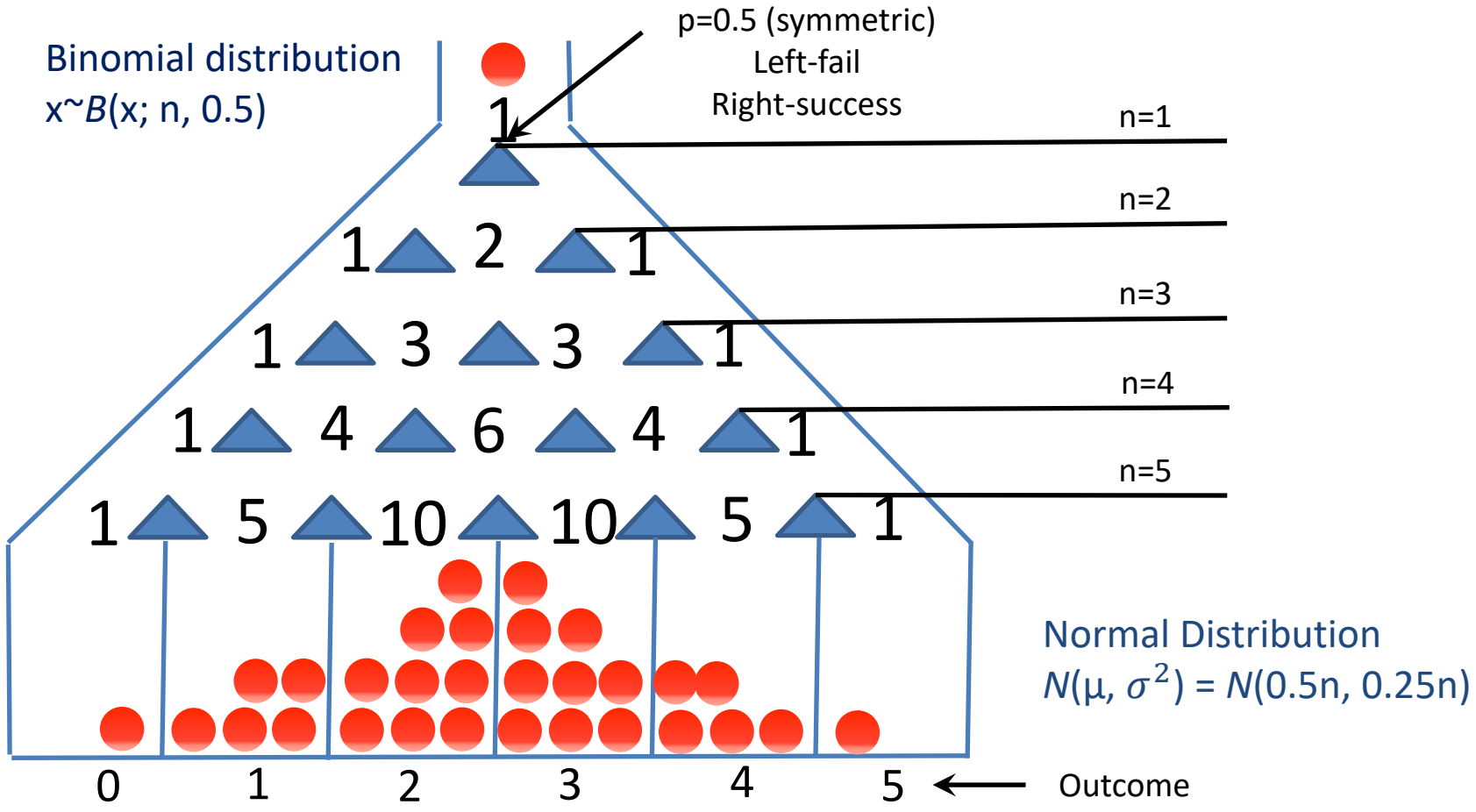
Normal Approximation to Binomial Distribution

Normal Distribution $N(\mu, \sigma^2)$

Source pictures from google search

Photo taken from Museum of Mathematics in Hokkaido

Galton board



Source picture from google search

Galton Board

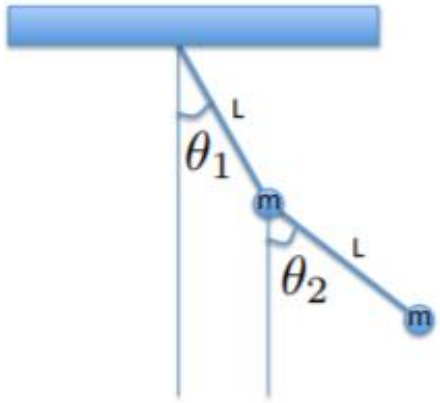
Source video from youTube

Phase 2-Chaos & Fractal: Double Pendulum

The equations of motion for a simplified model of a double pendulum are

$$2mL\frac{d^2\theta_1}{dt^2} - mL\left(\frac{d\theta_2}{dt}\right)^2 \sin(\theta_2 - \theta_1) + 2mg\sin\theta_1 = 0,$$

$$2mL\frac{d^2\theta_2}{dt^2} - mL\left(\frac{d\theta_1}{dt}\right)^2 \sin(\theta_2 - \theta_1) + 2mg\sin\theta_2 = 0.$$



The slightly change of values in the parameters L, θ_1, θ_2 gives very different chaotic patterns

How to showcase the hands-on math models?

Raw materials hands-on experience in a Summer math project at La Salle College in August 2006.

S3-S4 students:

8 boys from La Salle College

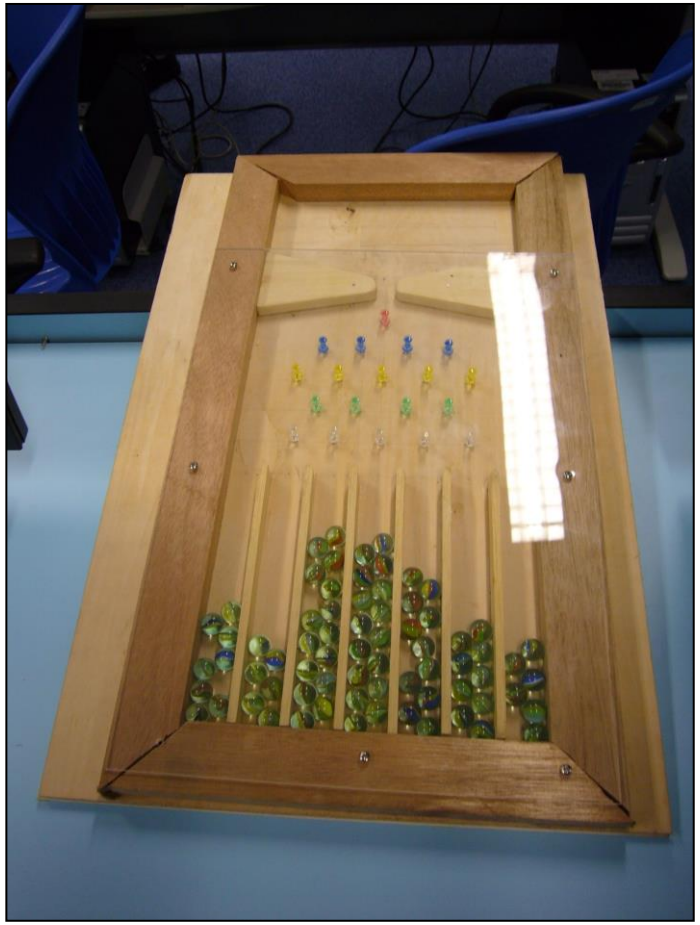
8 girls from Heep Yunn School

8 boys+girls from Pui Ching Middle School

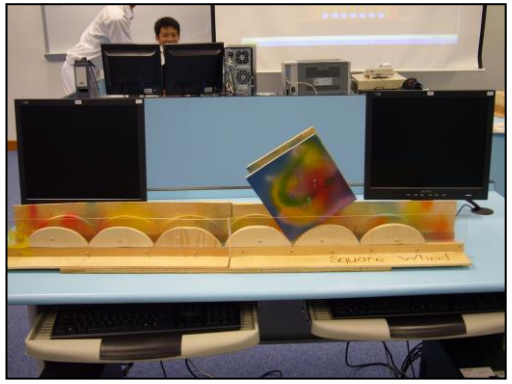
Mechanical Workshop @ La Salle College

Binary Sorting Machine

Galton Board



Square Wheel & Steepest descent curve



Information Session – A brief introduction of the courses

3D MODEL FOR REVEALING THE BEAUTY OF MATHEMATICS

3D 模型展示數學之美

APPLICATION CLOSED

Schedule

8 July 2017	9:00a.m. – 5:00p.m.
15 July 2017	9:00a.m. – 5:00p.m.
29 July 2017	9:30a.m. – 11:30a.m.

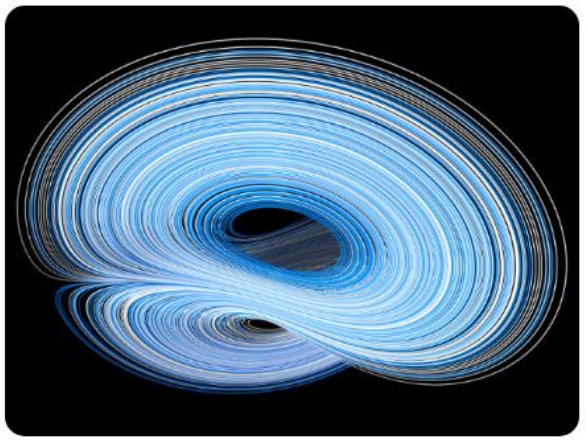
Instructor Prof. Benny Hon (Department of Mathematics)

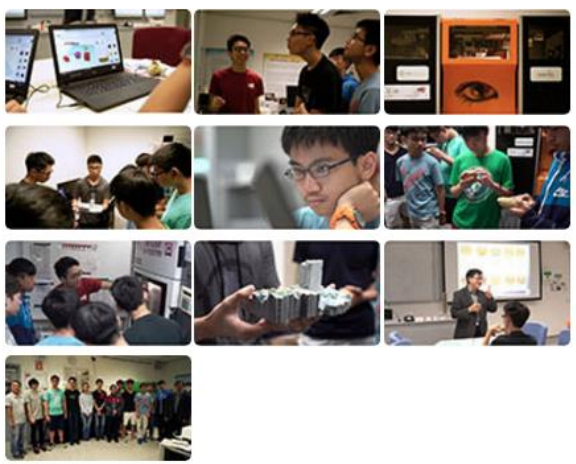
Target Participant HKAGE student members

Medium of Instruction Cantonese

Downlaod PDF for more details

DOWNLOAD PDF (ENGLISH VERSION) | 下載PDF (中文版)

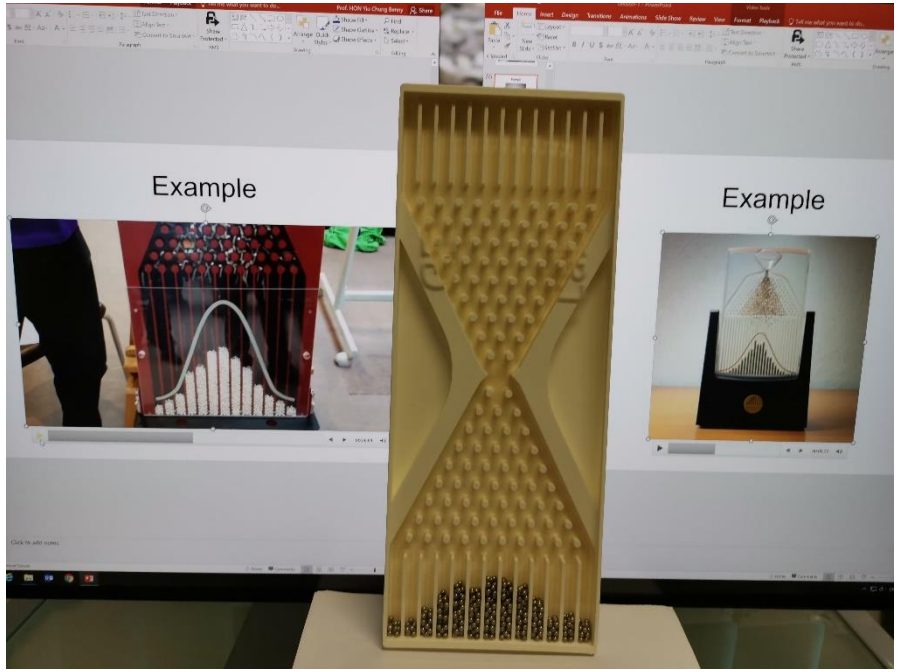




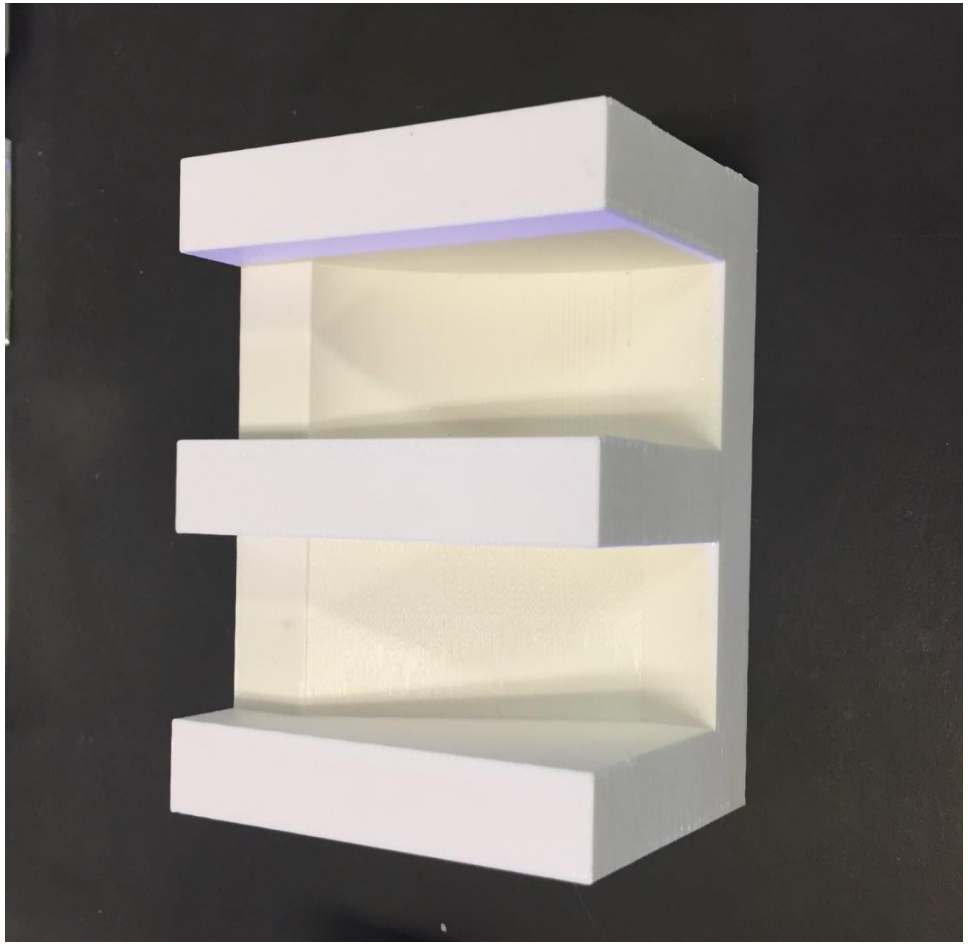
Showcase hands-on models by 3D printing

Galton Board

Bought from Amazon @US$40



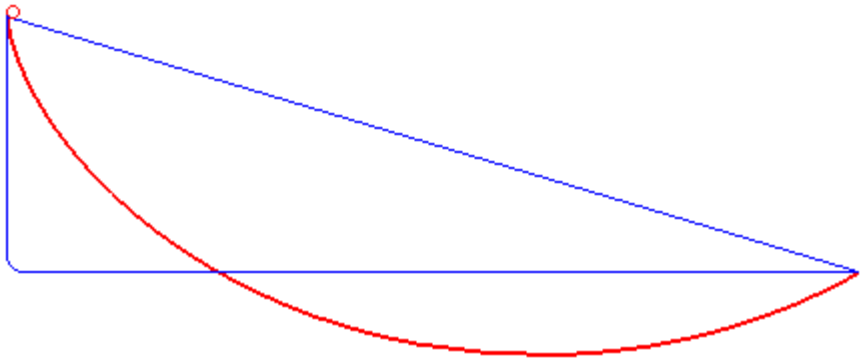
3D printing from the GEF project with 3D software Tinkercad



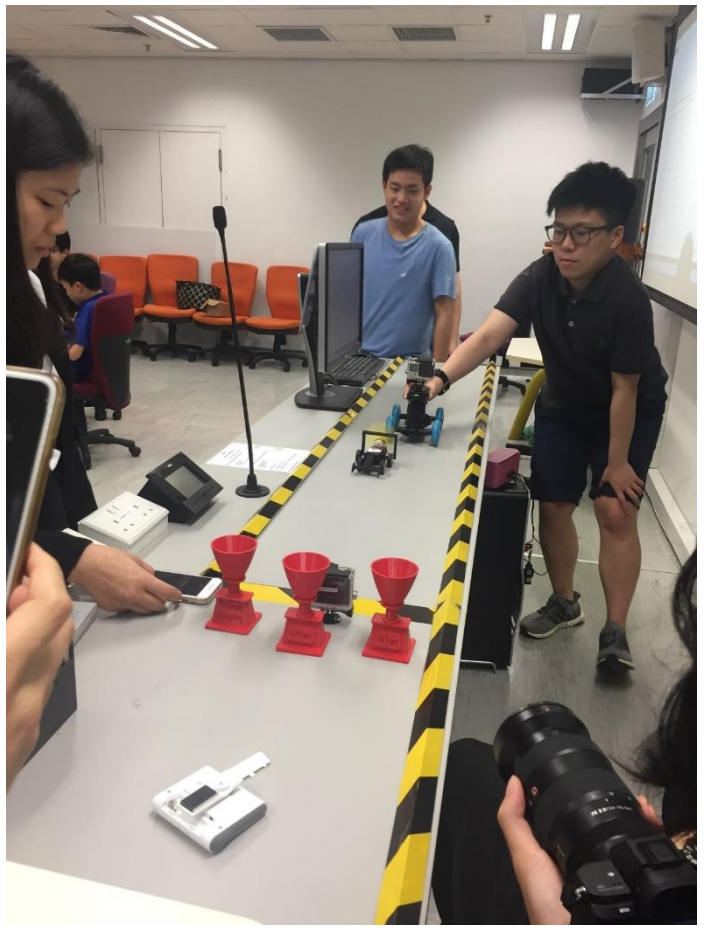
3D printing by a student during one morning session of the 3D modelling project

最速下降線

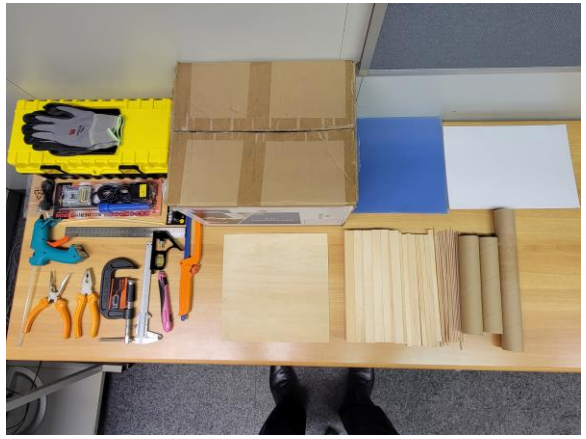
Steepest Descent Curve

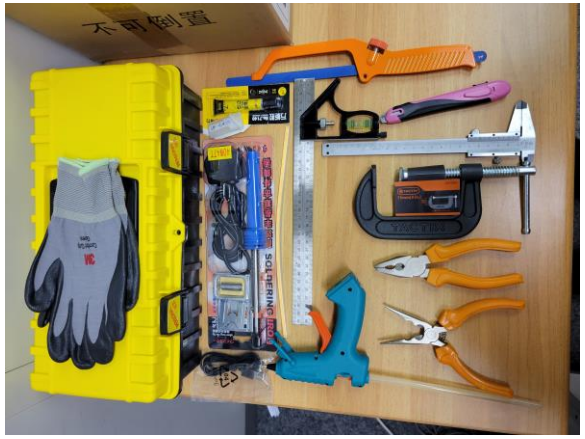


3D Car Racing



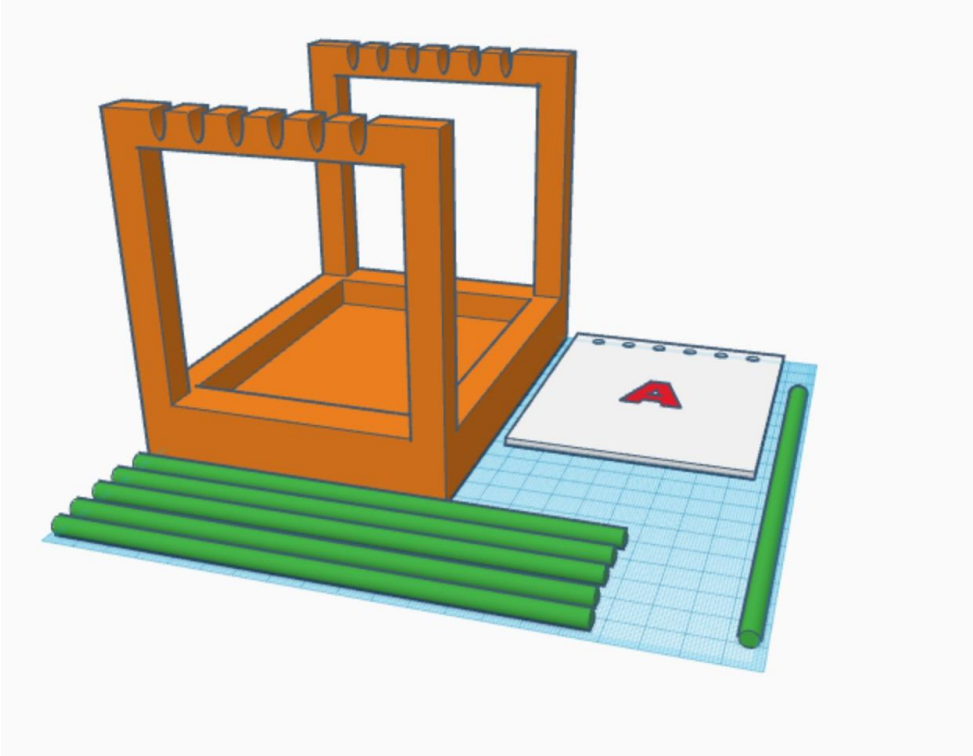
Showcase hands-on models by raw materials



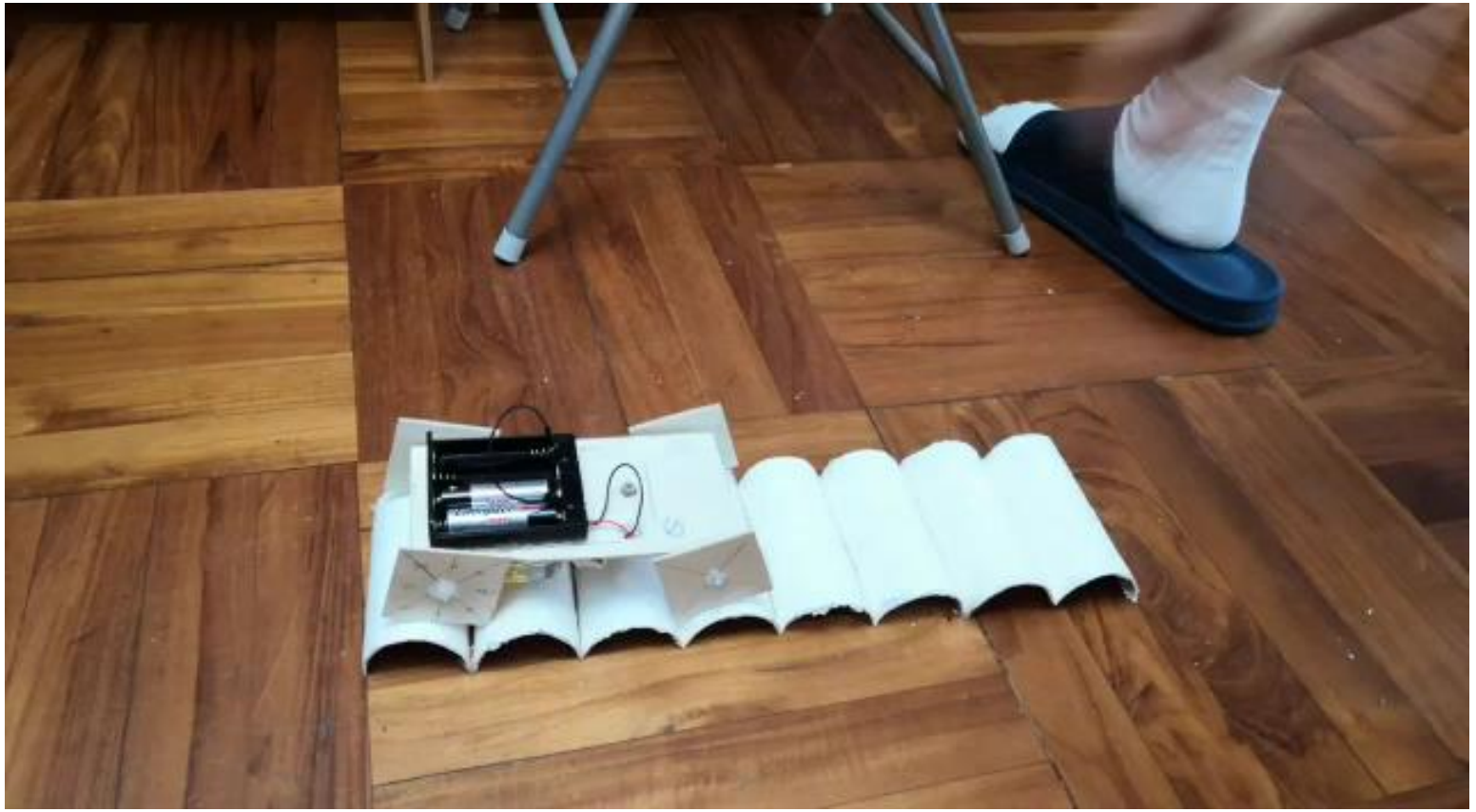


Sorting Machine

The first phase 2 meeting was arranged face-to-face for teaching sorting algorithm: bubble, binary, and merge sorts. Demonstration of binary sort was done through using the Poker. A 3D model on binary sorting machine was built by the 3D software Tinkercad.



Hands-on square-wheel car by a gifted student



Cannot be compared to most STEM exhibition which normally showcase fancy manufacture-designed robots with all sorts of AI and electronic devices.

BUT this is the rationale of this teaching and learning programme for math@STEM education in the hope that the beauty of mathematics behind the hands-on models can be appreciated and mastered.

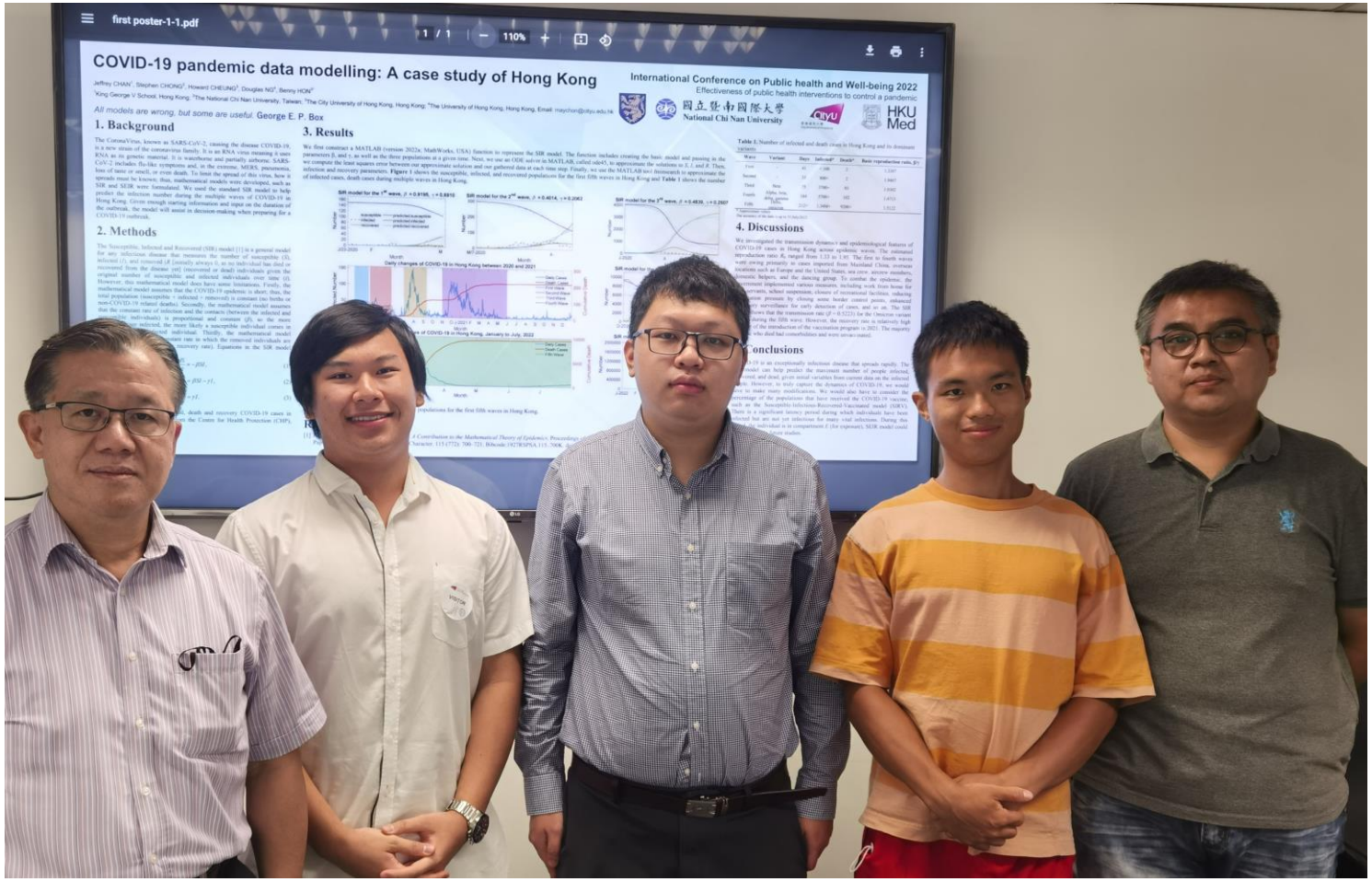
Project Plan: Phase 3 (Individual Research)

Phase 3

Lesson 7-10 Individual Research (14 & 28 November 2020, 12 & 26 December 2020) Zoom at CityU and face-to-face consultation by appointment during 1-31 January 2021	
Topics:	• How to do research in mathematics? • Literature survey • Methodology in Mathematical Modelling • Numerical software Matlab for solving math models
List of Students' Proposals (a total of 8 students were admitted into Phase 3 on Individual Research	• Three-body movement problem in Astronomy • Cryptology for one-time password used in Internet • Mathematical and 3D Model for Covid-19 • Heat Conduction Model for Design of Clothes • Mathematical Model for Cooling of Liquids • Predicting the Maximum Growth Potential of Nations through Analysis of Current Energy and Resource Statistics • Queueing System for Minimizing Customers' Waiting Time • Mathematical Logic in Human's Behavior

Throughout the research lessons, these students were required to give oral presentations of their mathematical models and proposed solution methodologies. Some of these research works are very impressive, showing the potential research ability of mathematically gifted secondary students.

Research Group on Covid-19 pandemic



A Research Group on Covid-19 pandemic data modelling in Hong Kong was established in the last summer 2022, which composed of one of the eight finally selected students from the GEF project; one CityU MA Year 3 student; and one Chemistry major Year 3 student from Taiwan Chi Nan University.

Research Methodology: Data collection, analysis, and visualization

- Data Sources

  Centre for Health Protection

- Tools for developing visualizations

  MATLAB, Tableau and Excel.

The graphical displays can help us identify trends patterns, outliers in the data and formulate hypotheses for further testing

The research group met regularly in every Saturday afternoon. Topics related to Covid-19 pandemic were proposed, discussed, and investigated.

Big data visualization of multiple waves of COVID-19 infection in Hong Kong

International Conference on Public health and Well-being 2022
Effectiveness of public health interventions to control a pandemic, 18-19 November, 2022

Stephen CHONG[1], Jeffrey CHAN[2], Howard CHEUNG[3], Douglas NG[4], Benny HON[3*]

[1]The National Chi Nan University, Taiwan; [2]King George V School, Hong Kong;[3]The City University of Hong Kong, Hong Kong; [4]The University of Hong Kong, Hong Kong.

Corresponding author: Benny HON Benny.Hon@cityu.edu.hk

1. Background

The COVID-19 pandemic has caused significant disruptions to healthcare worldwide. Figure 1(A) shows the cumulative confirmed COVID-19 cases per million people and Figure 1(B) shows shows people's concern during the fifth wave of COVID-19 in Hong Kong. Data visualization can aid in persuading people to change their behavior. Once a virus has spread, public health officials must make critical judgments about how much information to communicate and when to dispense it. One of the most critical components of limiting an outbreak is encouraging people to adjust their behavior when it is not immediately evident that they should. Data visualization has become highly significant in communicating and convincing people. The study's aimed to visualize the COVID-19 pandemic's transmission in Hong Kong during the first five wave, as well as to improve overall preparedness and response for communicable diseases of importance to the public. The Hong Kong government has developed contingency plans and drills to test the ability of relevant government departments and organizations to deal with potential major outbreaks of infectious diseases and public health emergencies, as well as to raise community and healthcare personnel awareness and capability.

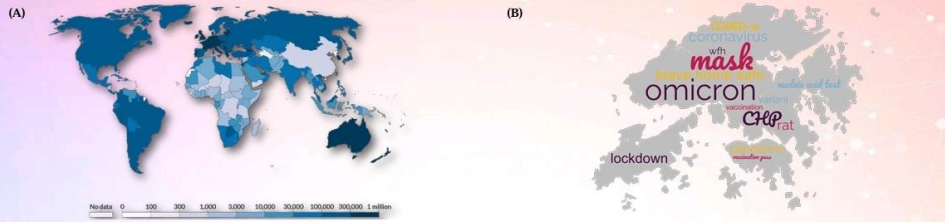


Figure 1. (A) Cumulative confirmed COVID-19 cases per million people between 22 January 2020 and 31 August 2022. (B) Word cloud shows people's concern during the fifth wave of COVID-19 in Hong Kong (source: Google analytics)

2. Methods

The daily number of confirmed COVID-19 cases in Hong Kong by the date of symptom onset was provided by the Centre for Health Protection (CHP). Data cleaning is the first step of fixing or removing incorrect, corrupted, incorrectly formatted, duplicate, or incomplete data within a dataset. Different data visualization techniques such as line graph, bubble chart, heat map, and word clouds are used to unlock the benefits and make accurate decisions from the vast data.

Several software tools will be used for developing visualizations, such as MATLAB, Tableau and Excel. The graphical displays can help us identify trends, patterns and outliers in the data, and formulate hypotheses for further testing.

3. Results

The following figures show different visualization results and insights derived during the first five waves in Hong Kong.

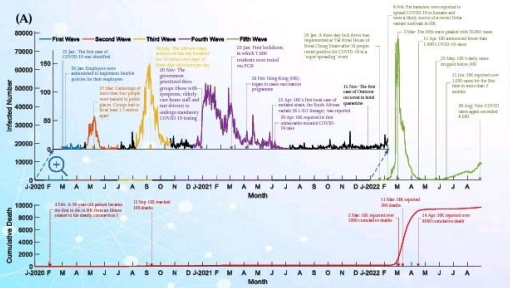


Figure 2. (A) Number of daily infected cases, cumulative death cases and highlights for the first five waves in Hong Kong. (B) Infographic: Current State of Hong Kong Economy – Five Key Points (source: https://www.amro-asia.org/infographic-current-state-of-hong-kong-economy-five-key-points/)

Figure 3. LeaveHomeSafe is a digital contact tracing app launched by the Hong Kong Government on 16 November 2020.

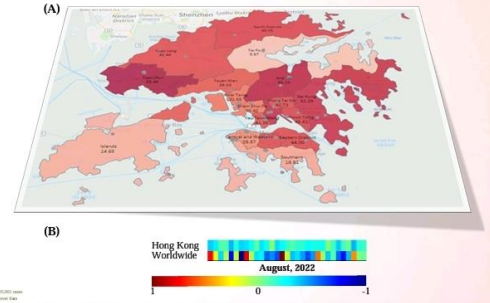


Figure 4. (A) Percentage changes of incidence of cases per 100,000 tested positive for COVID-19 by nucleic acid tests and rapid antigen tests by residential districts in July and August 2022, as well as the distribution of 43 public hospitals in Hong Kong. (B) Heat map shows the percentage of daily changes in COVID-19 Worldwide and in Hong Kong in August 2022.

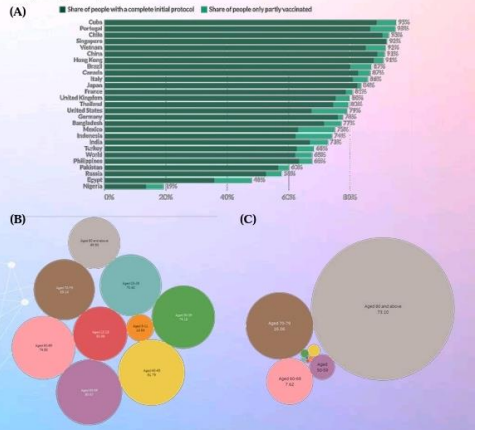


Figure 5. (A) Vaccination rate for different countries. (B) Vaccination rate for different age groups. (C) Death rate for COVID-19 patients who received one dose or less for different age groups.

COVID-19 pandemic data modelling: A case study of Hong Kong

International Conference on Public health and Well-being 2022
Effectiveness of public health interventions to control a pandemic, 18-19 November, 2022

Jeffrey CHAN[1], Stephen CHONG[2], Howard CHEUNG[3], Douglas NG[4], Benny HON[3*]

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All models are wrong, but some are useful. **George E. P. Box**

1. Background

Coronavirus, known as SARS-CoV-2 which causes the disease COVID-19, is a new strain of the coronavirus family. It is an RNA virus, which means it uses RNA as its genetic material. It is waterborne and partially airborne. SARS-CoV-2 includes flu-like symptoms and, in the extreme, MERS, pneumonia, loss of taste or smell, and even death. To limit the spread of this virus, how it spreads must be known; thus, mathematical models were developed, such as Susceptible-Infectious-Removed (SIR) and Susceptible-Exposed-Infectious-Removed (SEIR). We used the standard SIR model to help predict the infection number during the multiple waves of COVID-19 in Hong Kong. Given sufficient starting information and input on the duration of the outbreak, the model will assist in decision-making when preparing for a COVID-19 outbreak.

2. Methods

The SIR model [1, 2] is a general model for any infectious disease that measures the number of susceptible (S), infectious (I) and removed (R [initially always 0, as no individual has died or recovered from the disease yet] recovered or dead) individuals given the original number of susceptible and infected individuals over time (t). However, this mathematical model has some limitations.

Firstly, the mathematical model assumes that the COVID-19 epidemic is short; thus, the total population (susceptible + infectious + removed) is constant (no births or non-COVID-19 related deaths).

Secondly, the mathematical model assumes that the constant rate of infection and the contacts (between the infected and susceptible individuals) is proportional and constant (β), so the more individuals are infected, the more likely a susceptible individual comes in contact with an infected individual. Thirdly, the mathematical model assumes a constant rate in which the removed individuals are increasing (γ) (death rate or recovery rate). Equations in the SIR model include:

$$\frac{dS}{dt} = -\beta SI, \quad (1)$$

$$\frac{dI}{dt} = \beta SI - \gamma I, \quad (2)$$

$$\frac{dR}{dt} = \gamma I. \quad (3)$$

The daily number of confirmed, death and recovery COVID-19 cases in Hong Kong were collected from the Centre for Health Protection (CHP), Hong Kong.

We first constructed a MATLAB (version 2022a; MathWorks, USA) function to represent the SIR model. The function included creating the basic model and passing in the parameters β, and γ, as well as the three populations at a given time. We then used an ODE solver in MATLAB, called `ode45`, to approximate the solutions to S, I and R. We computed the least squares error between our approximate solution and our gathered data at each time step. Finally, we used the MATLAB tool `fminsearch` to approximate the infection and recovery parameters.

3. Results

Figure 1 shows the susceptible, infectious and recovered populations for the first five waves in Hong Kong. **Table 1** shows the number of infected and death cases during multiple waves in Hong Kong.

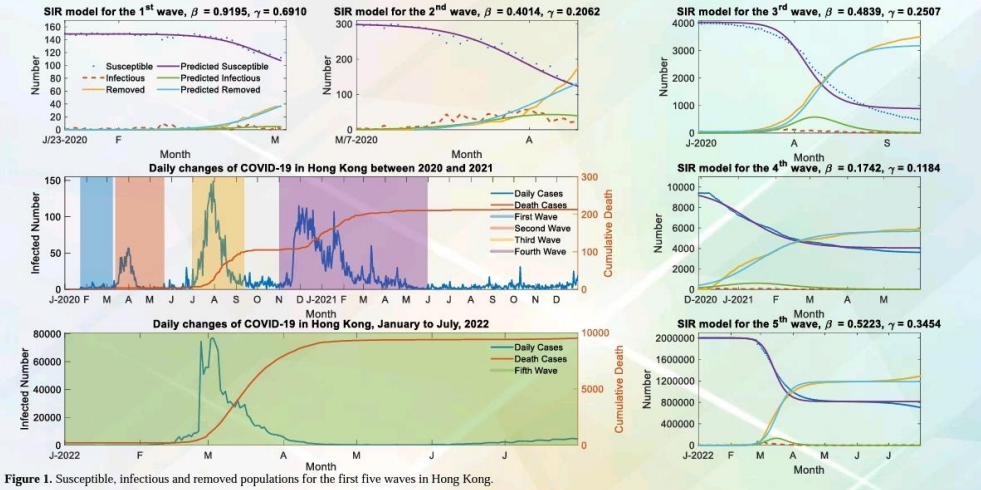

Figure 1. Susceptible, infectious and removed populations for the first five waves in Hong Kong.

Table 1. Number of infected and death cases in Hong Kong and its dominant variants

Wave	Variants	Days	Infected*	Death*	Basic reproduction ratio, β/γ
First	-	41	< 100	2	1.3307
Second	-	33	800+	2	1.9467
Third	Beta	75	3700+	93	1.9302
Fourth	Alpha, Beta, Delta, Gamma	184	5700+	102	1.4713
Fifth	Delta, Omicron	212+	1.34M+	9200+	1.5122

* Provisional figures
The data is up to 31/July/2022.

4. Discussions

We investigated the transmission dynamics and epidemiological features of COVID-19 cases in Hong Kong across epidemic waves. The estimated reproduction ratio R_0 ranged from 1.33 to 1.95. The first to fourth waves were primarily due to cases imported from Mainland China, overseas locations such as Europe and the United States, sea crew, aircrew members, domestic helpers and dancing groups. To combat the epidemic, the government implemented various measures, including work from home for civil servants, school suspension, closure of recreational facilities, reduction of importation pressure by closing some border control points and enhanced laboratory surveillance for early detection of cases. The SIR model showed that the transmission rate (β = 0.5223) for the Omicron variant was high during the fifth wave. However, the recovery rate is relatively high because of the introduction of the vaccination program in 2021. The majority of those who died had comorbidities and were unvaccinated.

5. Conclusions

COVID-19 is an exceptionally infectious disease that spreads rapidly. The SIR model can help predict the maximum number of people infected, recovered, and dead, given initial variables from current data on the infected people. However, to truly capture the dynamics of COVID-19, many modifications are needed. We would also have to consider the percentage of the populations that have received the COVID-19 vaccine, such as the Susceptible-Infectious-Removed-Vaccinated (SIRV) model. There is a significant latency period during which individuals have been infected but are not yet infectious for many vital infections. During this period, the individual is in compartment E (for exposure), and the SEIR model could be introduced in future studies.

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Suggestions to minimize the vaccination hesitancy of children in Hong Kong

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To the Editor

COVID-19 vaccine hesitancy is high initially (1) and still prevalent in Hong Kong.

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Implementation of the compulsory universal testing scheme in Hong Kong: Mathematical simulations of a household-based pooling approach

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This study aims to propose a pooling approach to simulate the compulsory universal RT-PCR test in Hong Kong and explore the feasibility of implementing the pooling method on a household basis. The mathematical model is initially verified, and then the simulation is performed under different prevalence rates and pooled sizes. The simulated population is based in Hong Kong. The simulation included 10,000,000 swab samples, with a representative distribution of populations in Hong Kong. The samples were grouped into a batch size of 20. If the entire batch is positive, then the group is further divided into an identical group size of 10 for re-testing. Different combinations of mini-group sizes were also investigated. The proposed pooling method was extended to a household basis. A representative from each household is required to perform the RT-PCR test. Results of the simulation replications, indicate a significant reduction ($p < 0.001$) of 83.62, 64.18, and 48.46% in the testing volume for prevalence rate 1, 3, and 5%, respectively. Combined with the household-based pooling approach, the total number of RT-PCR is 437,304,956,133, and 1,375,795 for prevalence rates 1, 3, and 5%, respectively. The household-based pooling strategy showed efficiency when the prevalence rates in the population were low. This pooling strategy can rapidly screen people in high-risk groups for COVID-19 infections and quarantine those who test positive, even when time and resources for testing are limited.

KEYWORDS

COVID-19, compulsory universal test, prevalence rate, sample pooling, mass screening, simulation

A brief research report has just been accepted to publish at the journal ‘Frontiers in Public Health’, which has a high impact factor of 6.641. Frontiers is ranked the third most-cited publisher in USA. This paper will appear by the end of this December 2022.

Conclusion

- This pilot research experience group between secondary school and university students demonstrates the benefit of collaborative teaching and learning education project (for example, the EDB Gifted Education Fund). Encouraging results can be achieved by arousing the interest of gifted students through teaching STEM and motivating their self-learning desire from solving real-life problems.

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Q & A

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