In Search of Quality Teaching for Gifted Students

Exemplified by the OALPG Course "Quantum Computing for Gifted Students"

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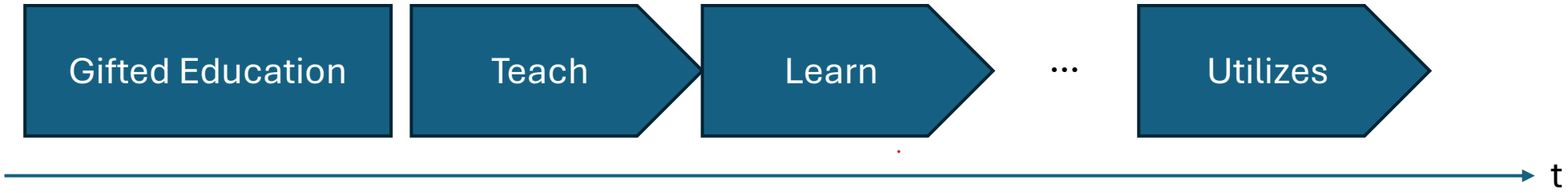
Outline

1) Overview of Gifted Education from our perspective
2) What are we teaching
3) Course design
4) Lesson's plan
5) Characteristic of off-school support
6) How can school-based whole-class teaching and school-based pull-out programmes complement and join hand with the off-school support that targeting at exceptionally gifted students
7) Discussion and Case studies: Teaching and Learning examples

Overview of Gifted Education from our perspective

Spacetime : We are now in Year 2024, In the age of Quantum 2.0. and post Generative AI.
"We are in an era where the speed of disruptive technological innovation and the accumulation of knowledge are both exponentially accelerating."

Specialized education for special student (Gifted students)

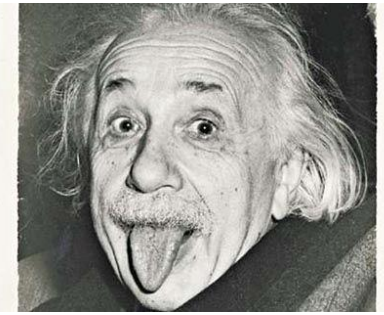


Prompt: You are a helpful assistant that answers question as simple as possible.

YOU: please help translate : "我們身處一個顛覆性科技的創新發展及知識累積的速度都呈指數加速上升的年代"

AI: We are in an era where the speed of disruptive technological innovation and the accumulation of knowledge are both exponentially accelerating.

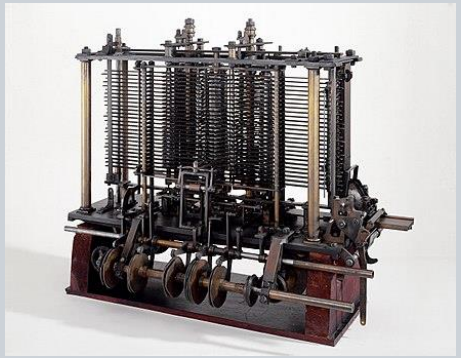
"Education is what remains after one
has forgotten what one has learned in school."
- Albert Einstein



What we are teaching : quantum computing as a challenging subject

Different Aspect	Classical Computer	Quantum Computer
Information representation	Data stored in the form of bits : 	Data in the form of qubit : {0001,0010 , 0100,...}  $\|\psi\rangle = a\|0\rangle + b\|1\rangle$

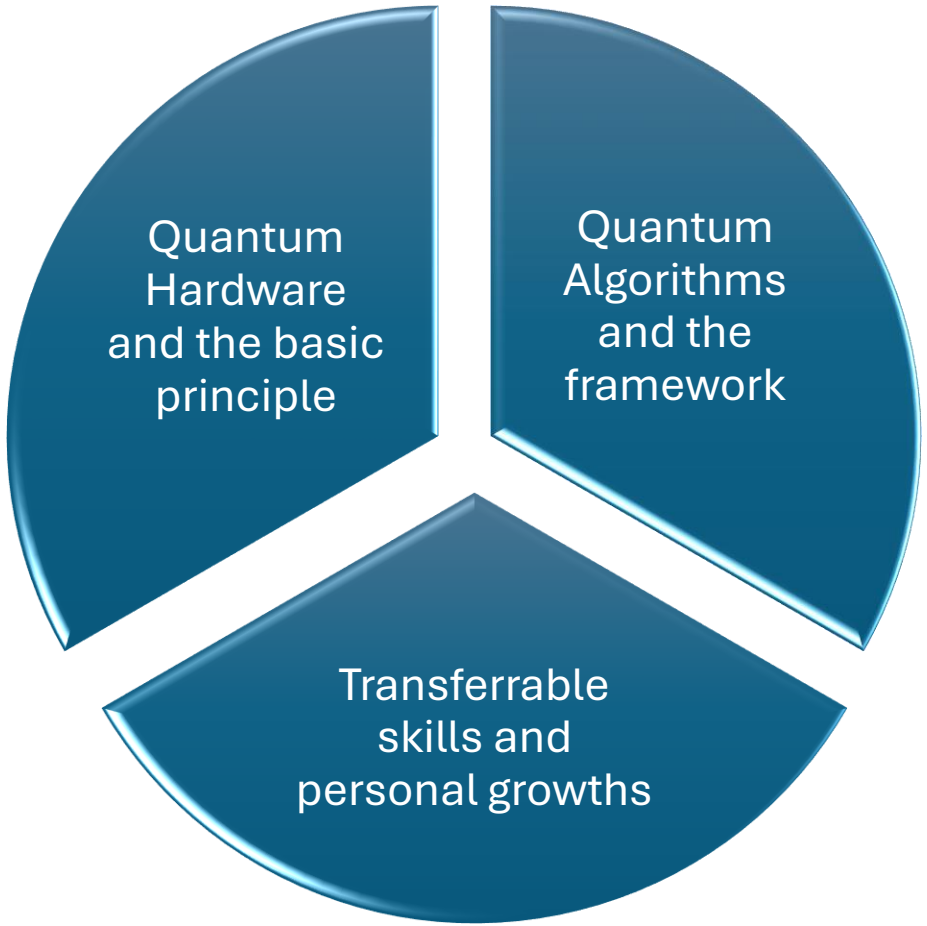
What we are teaching : quantum computing as a challenging subject

Different Aspect	Classical Computer	Quantum Computer
Working mechanism and logic	Classical mechanics  Analytical Engine by Charles Babbage or Electronic (Electrodynamics)	Quantum Mechanism  

What we are teaching : quantum computing as a challenging subject

Different Aspect	Classical Computer	Quantum Computer
Algorithm, function, Application	Daily life application, such as processing words, image, browsing internet, Classical sorting, Fast Fourier transform, Running machine learning code…	Grover's algorithm – unstructured search, Shor's algorithm – breaking encrypted message or bank account,etc. Demonstration of quantum phenomenon, …

Breakdown of knowledge to be delivered



- Classical computer vs quantum computer
- Example of quantum computer implmentation
- Hardware issue and how to deal with

- Deutch algorithm
- Search algorithm Grover
- Quantum Fourier Transform

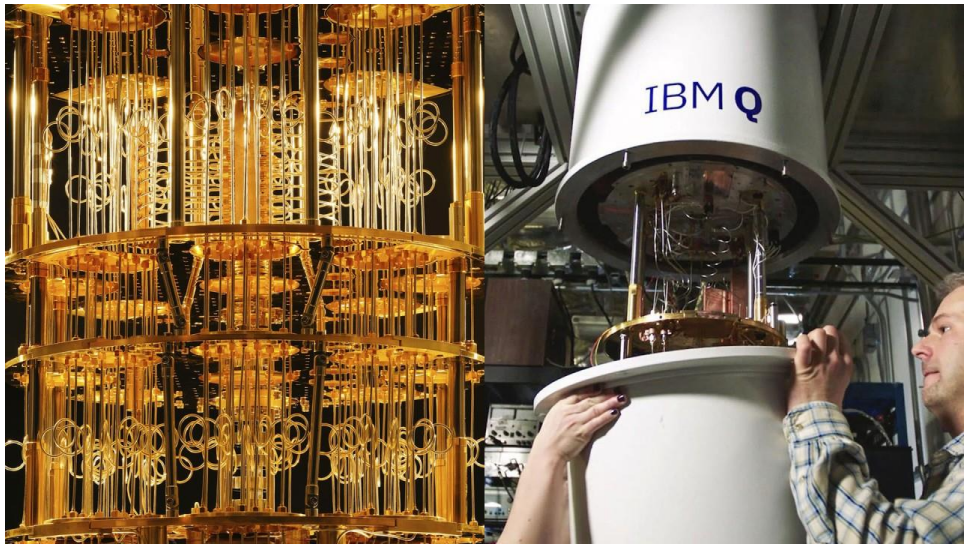
- Know how oneself and the world
- Overcome challenge
- Interpersonal skill

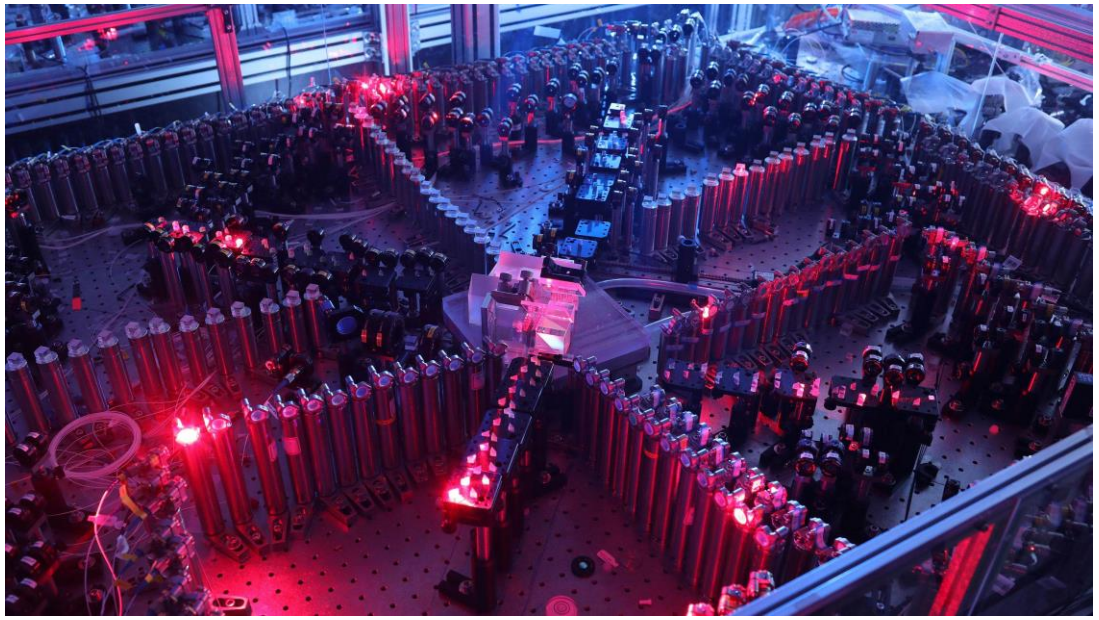
Course design

1. Emphasize the importance of **understand on basic fundamental principle** with necessary depth over superficial knowledge with breadth.
2. Emphasize the **use of real quantum computers**, allowing students to have an **intuitive sensory experience and real-life experience**, counteracting purely oral or abstract quantum concepts
3. Emphasize the **necessary breath** that cover a few key application area
4. Emphasize on **practicing the knowledge** through exercise and class activities
5. Integrate **advanced concepts early** to maintain engagement.
6. Use a **modular approach** to allow flexibility and pacing
7. **Emphasizing timely and appropriate challenges** aligned with educational psychology and students' psychological states
8. **Moral and conduct**

Example of quantum computer implementation

IBM

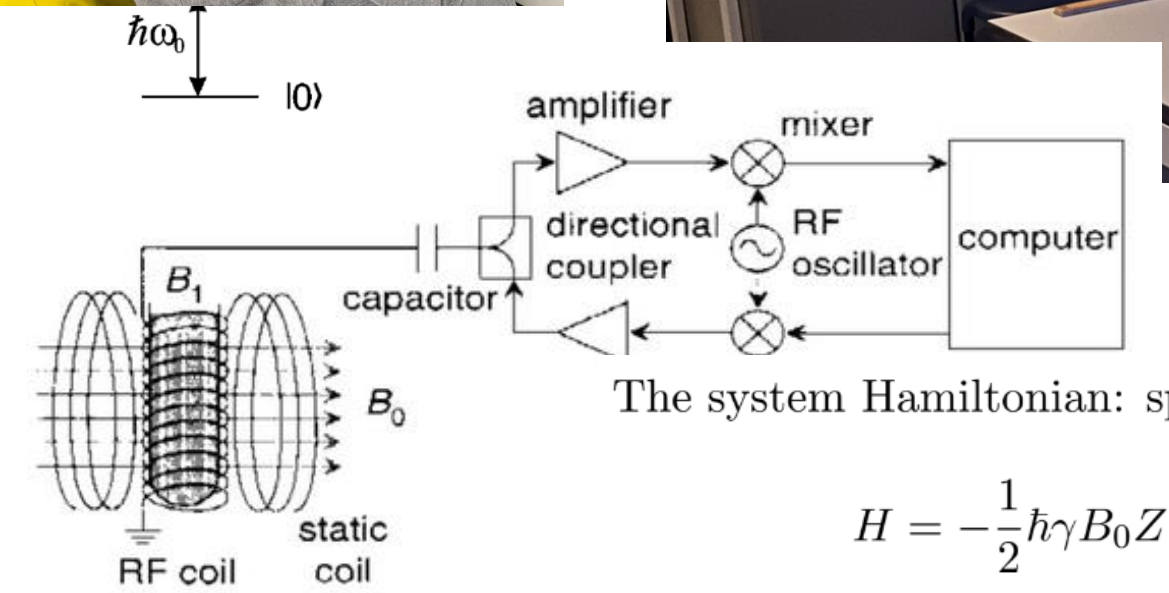




China: Jiuzhang

The teaching device student are using: SpinQ’s Germini

Example of quantum computer implementation



The system Hamiltonian: spin in magnetic field B_0:

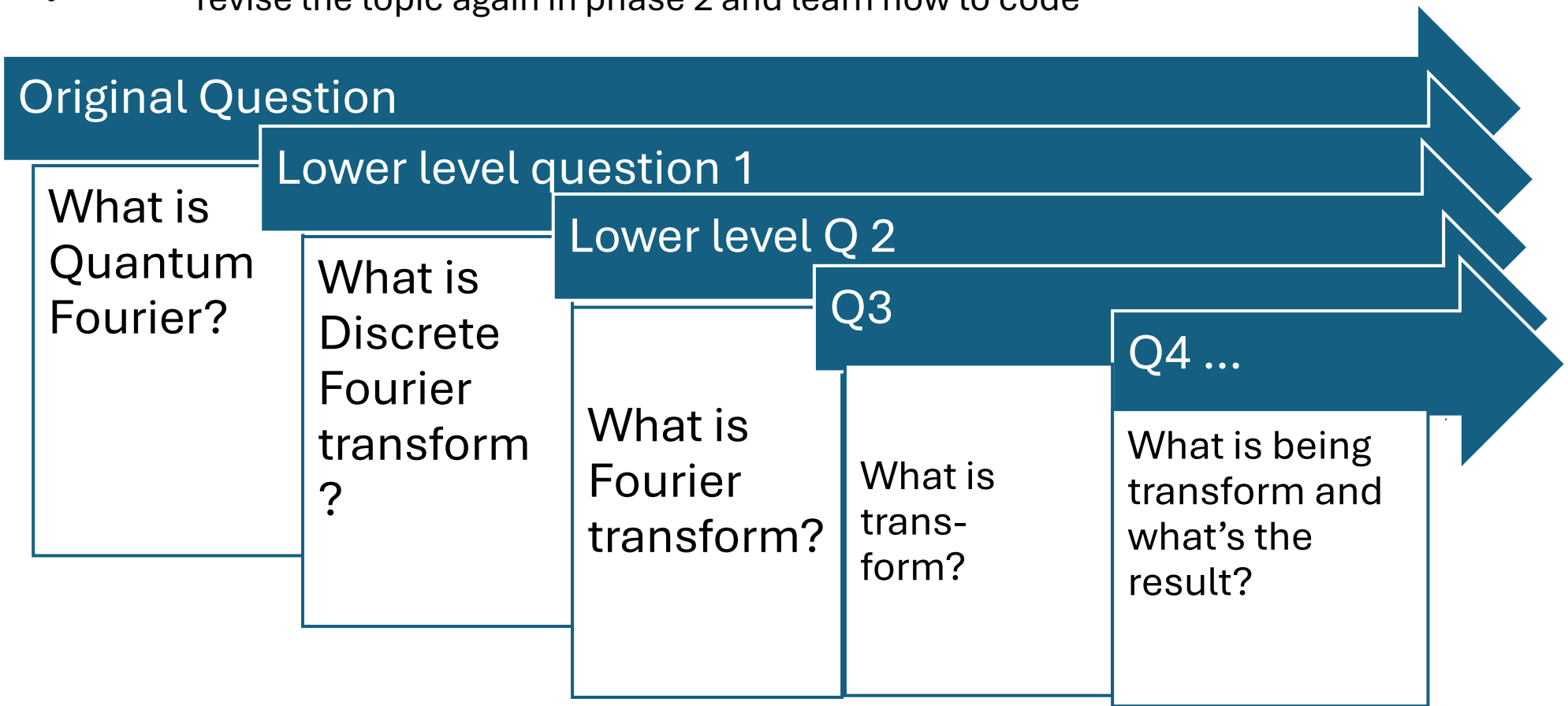
$$H = -\frac{1}{2}\hbar\gamma B_0 Z = -\frac{1}{2}\hbar\omega_0 Z = \begin{bmatrix} -\frac{1}{2}\hbar\omega_0 & 0 \\ 0 & \frac{1}{2}\hbar\omega_0 \end{bmatrix}$$

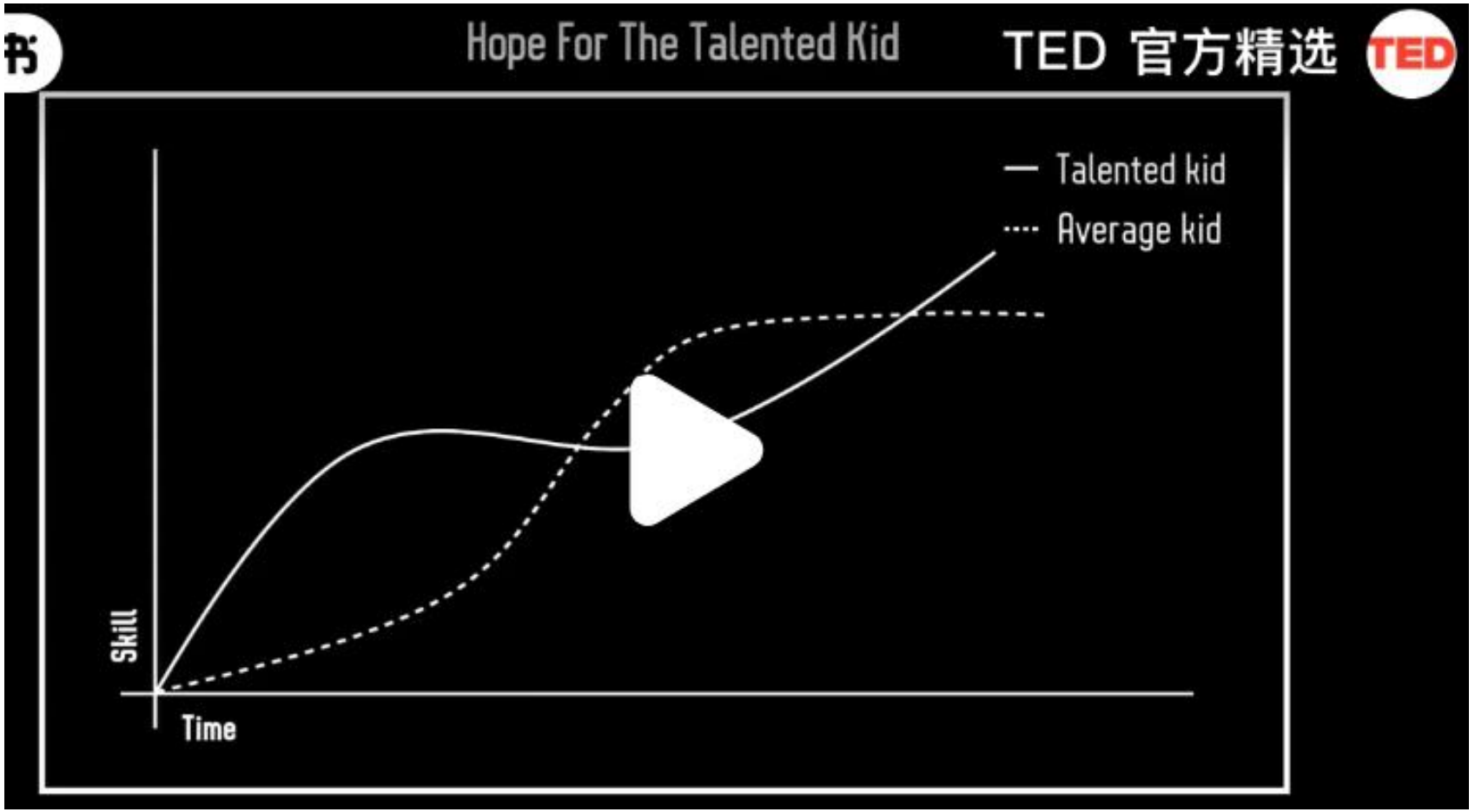
The path toward understanding

Case study: Quantum Fourier Transform

Challenge

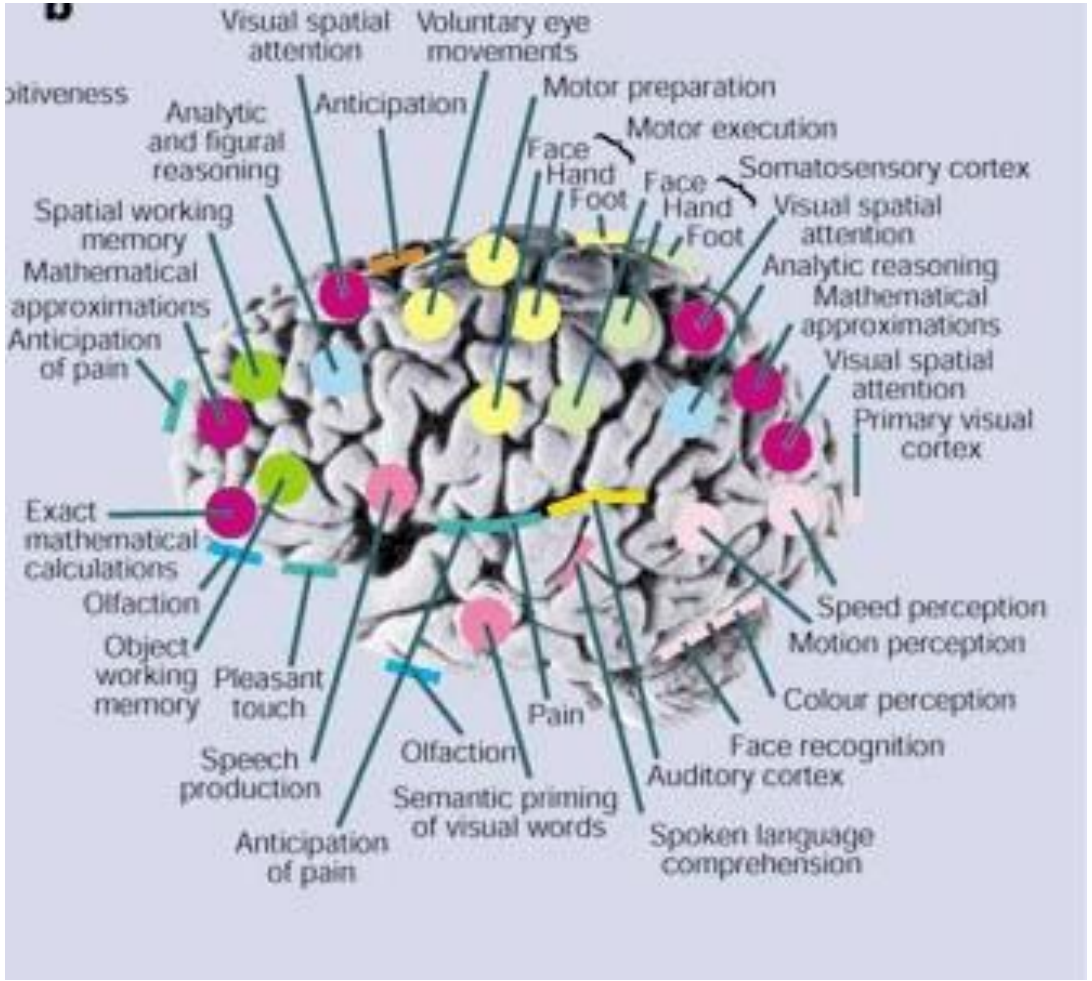
- How to overcome the challenges
- animation from the internet
- more hand-on exercise (and group work)
- start from the basic (Discrete Fourier series)
- revise the topic again in phase 2 and learn how to code





[天才的陷阱：为什么聪明孩子也会失败？ - 小红书 (xiaohongshu.com)]

Multiple exceptional student



Source :https://www.nature.com/articles/35011531/figures/2.com/articles/35011531/figure

資優學生的特質			
		強項	困難
認知能力		• 認知能力在正常或以上的水平 • 有高層次的思維技巧 • 邏輯思維、分析、推理、解難能力等較強 • 獨立思考的能力較強 • 能提出具創意的主意 • 很快掌握新知識及抽象複雜的概念 • 能掌握不同事件、意念和情境之間的連繫	• 書寫文字和推理能力稍遜
執行功能能力	執行功能能力	• 對圖象的觀察力較強 • 對已消化的知識和概念有很強的記憶力	• 組織資料的能力稍遜，當需要把意念轉換成文字時，尤其是非母語，困難更明顯 • 較難預計和分配時間，很多時不能在限期前完成任務 • 對不感興趣、重複的事情和處理文字的工作欠缺耐性 • 不能有效率地展開工作，通常會拖延
學習動機及自我效能感	學習動機	• 投放很多時間和精神在有興趣的課題上 • 勇於接受學業以外的挑戰 • 具好奇心，喜歡問問題和尋根究底	• 對於重複或涉及大量文字的工作會輕易放棄，因而不能完成任務 • 對不感興趣的事情欠缺耐性
	學習自我效能感	對自己感興趣的課題和科目會很有自信，敢於用文字以外的方式表達	• 對別人的評價十分敏感 • 容易質疑自己的學習能力，因而產生負面的自我評價

Lesson Plan

- 3 phases
- Phase 1: lecture and classroom
- Phase 2: programming tutorial
- Phase 3: Group project
- 3 hours per lecture

Phase 1 Schedule

Session	Date	Time	Topic	Venue
0	8-Jul	14:00-14:30	Orientation	Room 4504
1	8-Jul	14:45-17:00	*A brief history of computers*	Room 4504
2	15-Jul	14:00-17:00	*A brief introduction to quantum computers*	Room 4504
3	22-Jul	14:00-17:00	*Matrix representation of quantum gates*	Room 4504
4	29-Jul	14:00-17:00	*Quantum circuits, search algorithm*	Room 4504
5	5-Aug	14:00-17:00	*Complex numbers, single qubit gates*	Room 4504
6	12-Aug	14:00-17:00	*Universal circuits, quantum Fourier transform*	Room 4504
7	19-Aug	14:00-17:00	*Quantum mechanics, quantum entanglement*	Room 4504
8	26-Aug	14:00-17:00	*A brief introduction to building quantum computers*	Room 4504
9	2-Sep	14:00-17:00	*Breaking RSA encryption*	Room 4504
10	9-Sep	14:00-17:00	*An introduction to quantum cryptography*	Room 4504
11	16-Sep	14:00-17:00	*An introduction to quantum communication*	Room 4504
12	23-Sep	14:00-17:00	*An introduction to quantum error correction*	Room 4504

Phase 2 schedule

Session	Date	Time	Topic	Venue
1	7-Oct	14:00-17:00	*Learning by doing, Introduction to quantum programming platform*	Barn C
2	14-Oct	14:00-17:00	*Deutsch-Jozasa Algorithm*	Barn C
3	21-Oct	14:00-17:00	*Simon's Algorithm in Action*	Barn C
4	28-Oct	14:00-17:00	*Quantum Fourier transform in action*	Barn C
5	4-Nov	14:00-17:00	*Shor algorithm in action*	Barn A
6	11-Nov	14:00-17:00	*Grover algorithm in action*	Room 4503
7	18-Nov	14:00-17:00	*Quantum teleportation in action*	Barn A

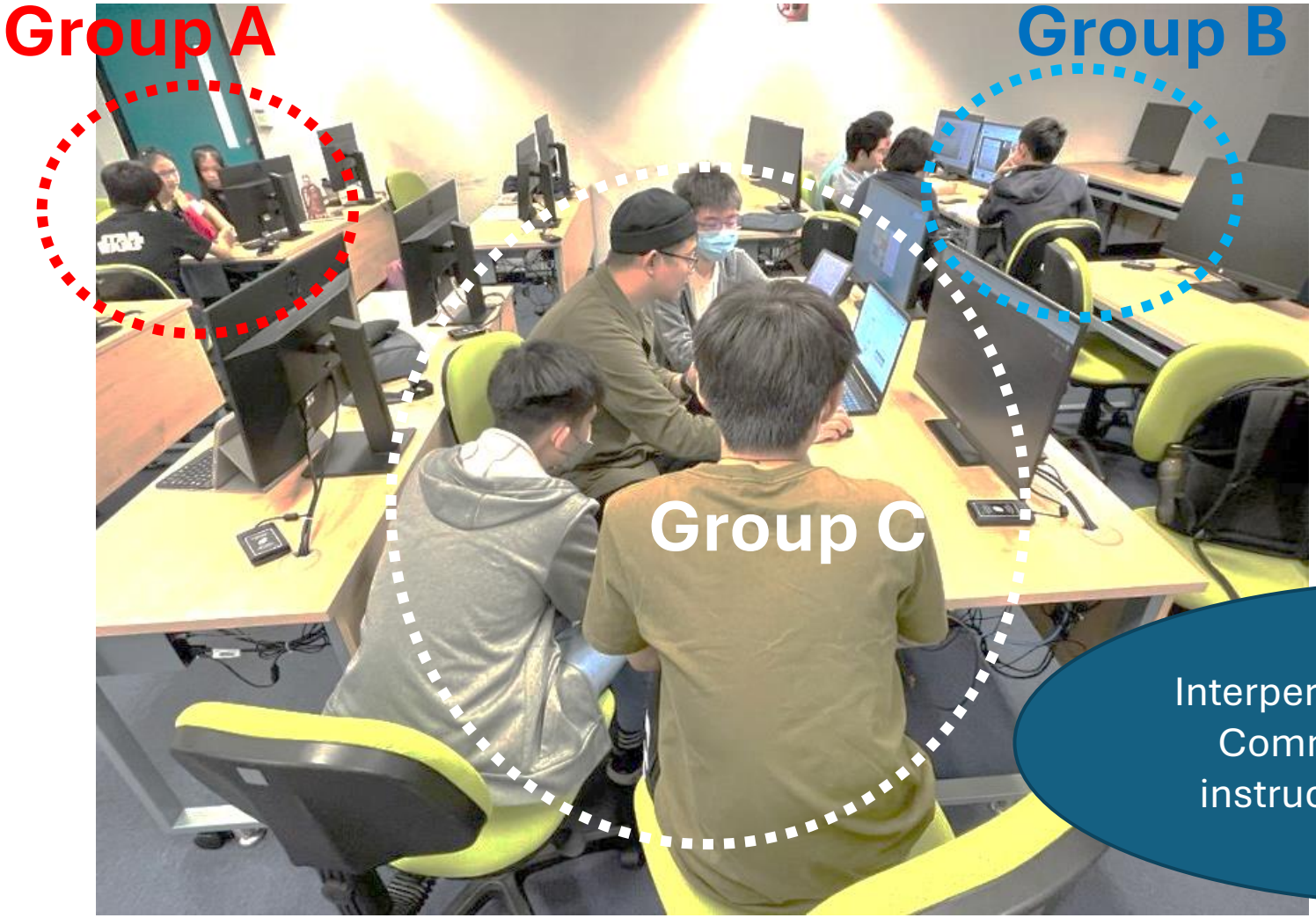
Lesson Plan – Phase 3

- Student are form group of ~ 5 people
- Each group have selected/assigned a topic they are particularly interested in
- There is a mentor for each group, giving constructive guideline and assistance to tailor specific individual need.
- Above all, Lecturer (Dr Choy, Dr Cheung and other professors who research area is quantum-related will give advanced constructive advice, assistance and supervision)

Phase 3 project list

1. Solving combinatorial optimization using QAOA
2. Solving satisfiability problems using Grover's
3. Solving the traveling salesman problem using phase estimation
4. Bell's inequality -> include density matrix and entanglement in 3 qubits
7. Quantum mini golf
9. Quantum facial recognition/ edge detection
10. Entanglement vs measurement

Interpersonal skill



Interpersonal and social skill:
Communicating with the instructors and groupmate

資優教育學苑與科大合辦量子計算課程 助高中生了解量子電腦應用等

發佈日期: 2024-02-15 10:00 | 港澳

大學推進階課程助資優生發展興趣　中五生簡報量子計算：沒想到能接觸厲害東西

有線新聞 · 2024年02月15日

分享

【有線新聞】施政報告提出要進一步培育本地科技、工程、藝術及數學人才，有大學推出進階學習課程，協助資優學生在常規課堂外發展他們的興趣。

這一批在台上簡報的中學生，題目都是關於量子計算在不同領域的應用，台下「聽課」都是大學教授。這群都是資優生，正在常規中學課程外參與大學舉辦的進階學習班，鑽研量子計算和量子信息處理科學。

中五學生何睿寧：「量子計算這樣東西聽起來像很高科技或者很前沿的科技，但沒想到我報讀完這個課程後可以那麼近距離接觸這麼厲害的東西。」中六學生!

Characteristic of off-school support and complement from Level 1 and 2