Integrating Quantum Science into K-12 Classrooms via Engaging Activities

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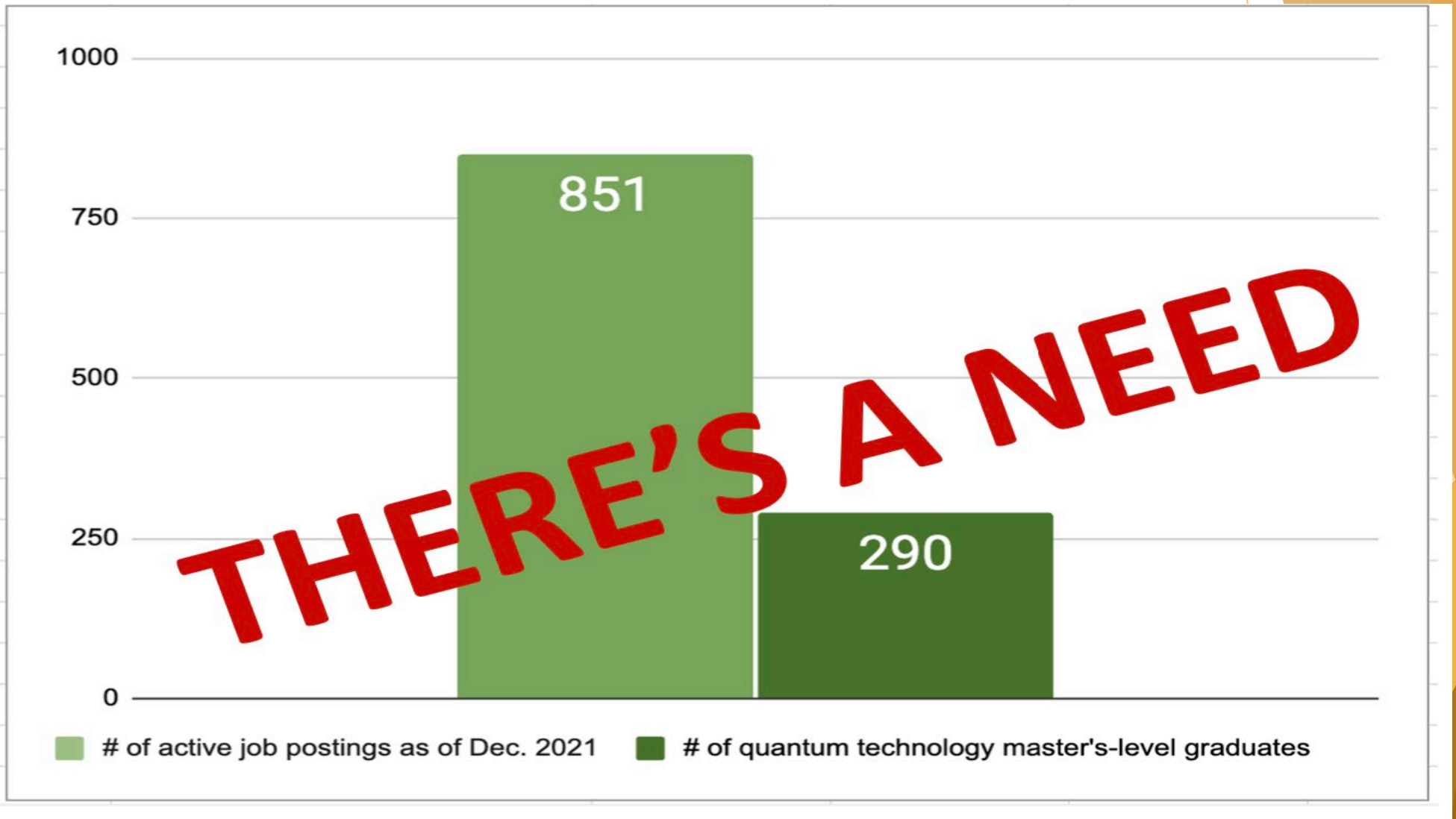
WHY talk about quantum in high, middle, elementary?

- https://www.mckinsey.com/



WHY talk about quantum in high school?

- **62%** (students) would consider a career in at least 1 of the following

  biotechnology

  artificial intelligence

  financial technology

  quantum computing

  5G/6G internet networks

  semiconductors

- **91%** of the respondents: agree preparing students is important
  67% indicated it was VERY important.

- **33%** (students) specifically said schools were doing a "poor" job of preparing them for these careers

Students SEE A NEED

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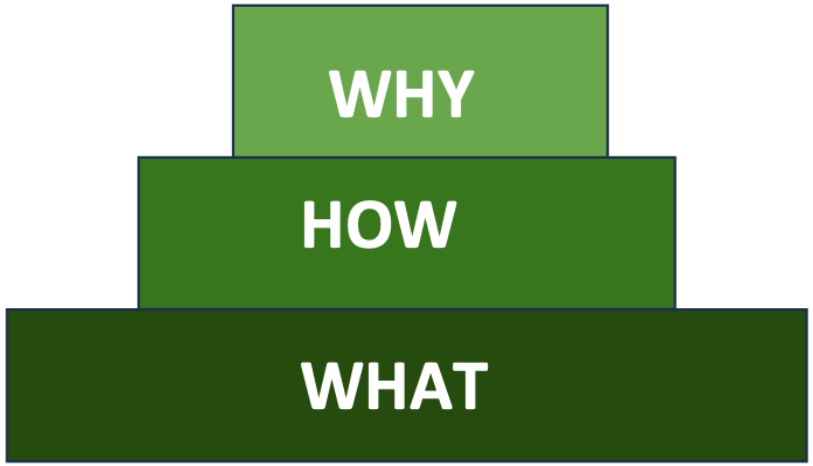
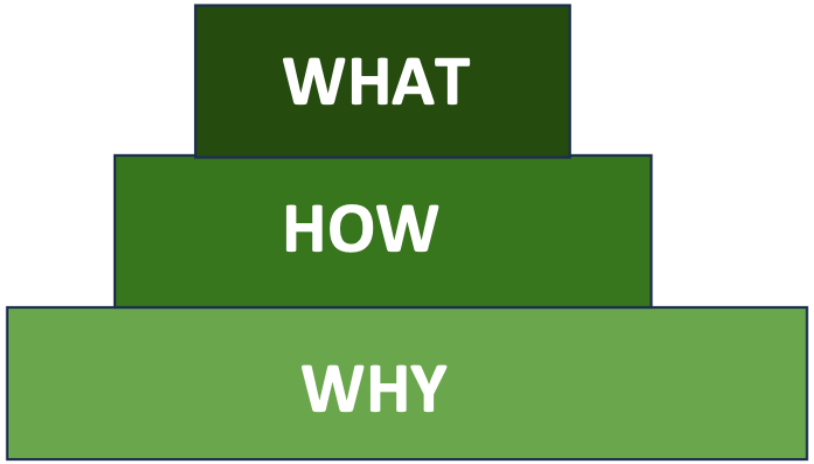
June 2023, 1000 K-12 teachers, 1002 students (12-18 yrs), 906 parents

Shifting our Thinking about Quantum

Which Model Evokes Change?





If you don't know **why** you do what you do, then no one else will either

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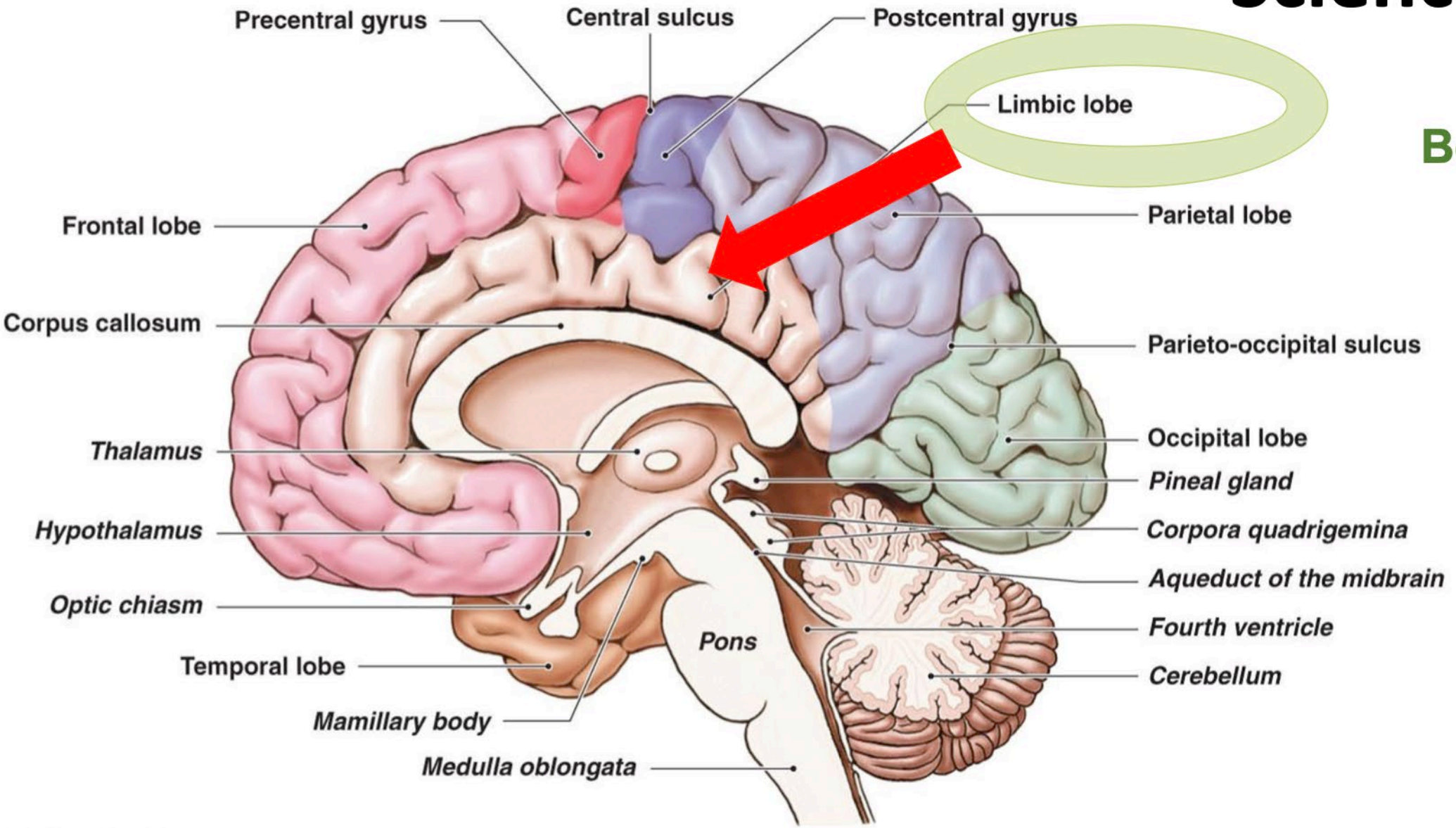
- Believed they could **change** the course of the world.
- Believed they could figure it out
- It was “fun”
- “The greatest thing in our favor was growing up in a family where there was always much encouragement to intellectual curiosity” [1]

Science of WHY

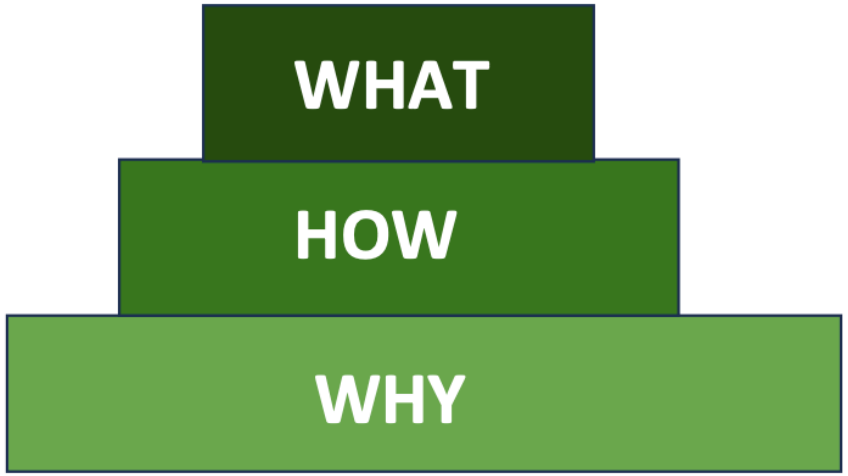


Behavior

https://mapp.mgh.harvard.edu/your-brain-an-introduction-to-its-anatomy/

The WHY is clear..

Our students are missing out on jobs in the quantum field because our teachers are not equipped to teach it to them



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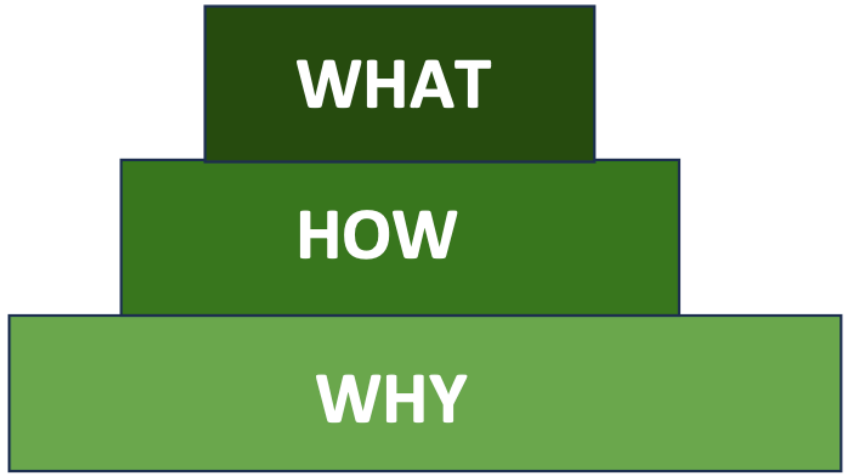
HOW?

Use a known model



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Law of Diffusion Innovation

- Process that occurs as people adopt a new idea, product, practice, or philosophy

- Describes how new ideas, behaviors, technologies, or goods spread through a population.

Barriers to Crossing the Chasm

Perceived complexity and/or socio-economic incompatibility

- • **Usage** When the system being proposed is incompatible to existing usage, it is difficult to accept
- • **Value** Perceived value is low; does new = better; benefit vs price
- • **Risk** Fearful so one continues to use existing alternatives; Fear to take risks: physical, social, financial, psychological, time; need encouragement
- • **Psychological factors** Two common threats: tradition (what is right) and image (self image, attitude)

Challenges of Quantum Change In K-12

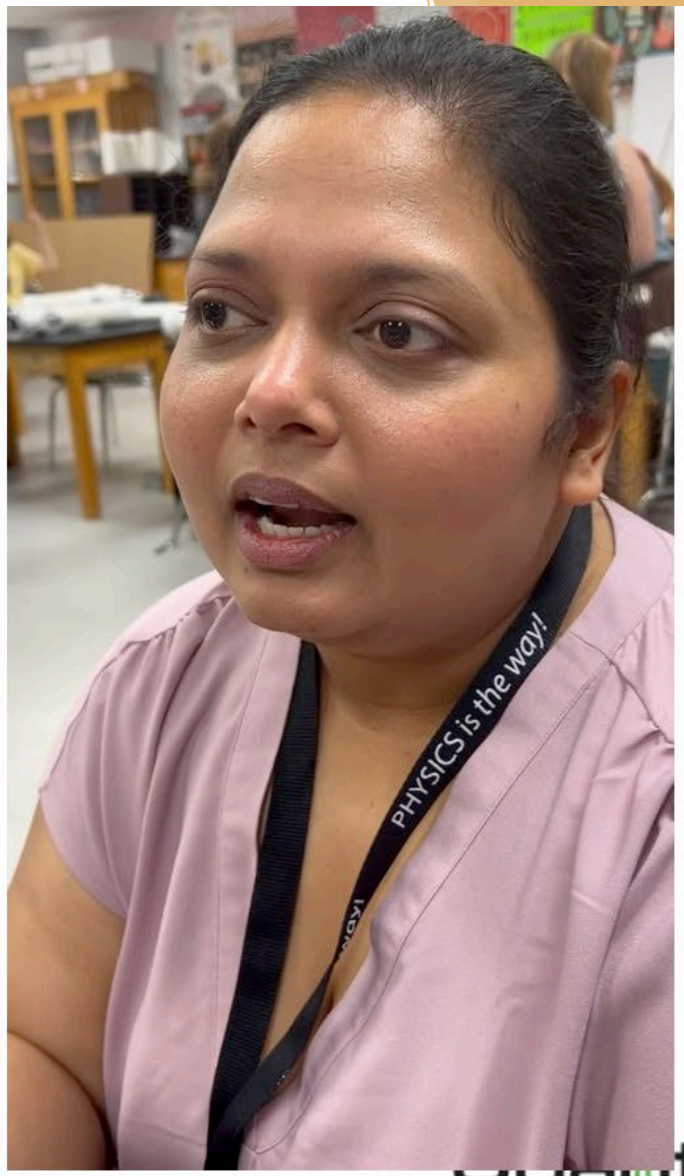
- Recognize the problem
- Inadequate background in content and context
- Limited appropriate resources
- Lack of context = limited curriculum connections
- Lack of connection to standards

5 Step Process for Educators

- Awareness/Knowledge: Recognition of the unknown.
- Interest/Persuasion: Interest leads to understanding and ultimately persuasion or purpose.
- Evaluation/Decision: Is the destination worth the trip?
- Trial/Implementation: Can this be done?
- Adoption/Implementation: Let's do this!

Awareness/Knowledge:
Recognition of the unknown

- “I had no idea….”
- Pre/Post Assessments
- Self Efficacy (confidence on assessments and survey)
- Recognition that it will take time and effort

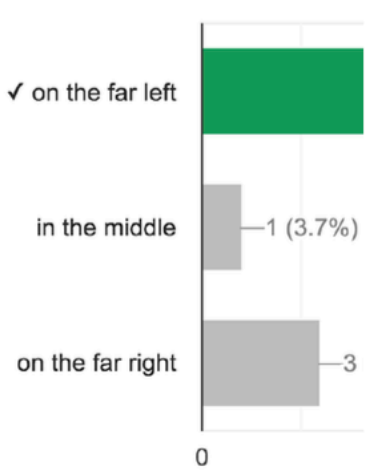


Recognition/Knowledge:
2021 Sample Pre/Post Teachers (Year 1 online)

Heisenberg Post (27 Responses)

1. Based on the picture below, the widest slit would be

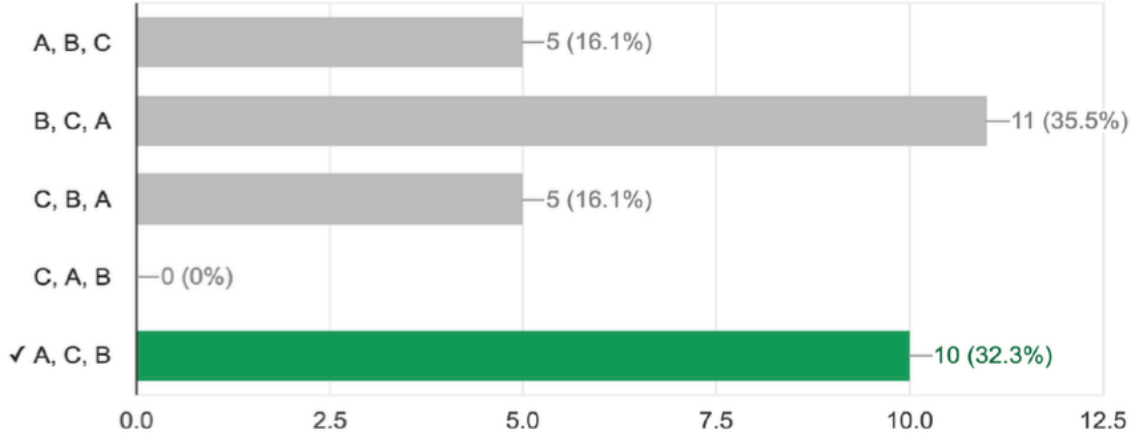
23 / 27 correct responses



Heisenberg Session
Pre (38 responses)

1.1. Rank the pictures below according to those that passed through the widest slit to the narrowest. Widest will be the first answer, narrowest will be the last answer.

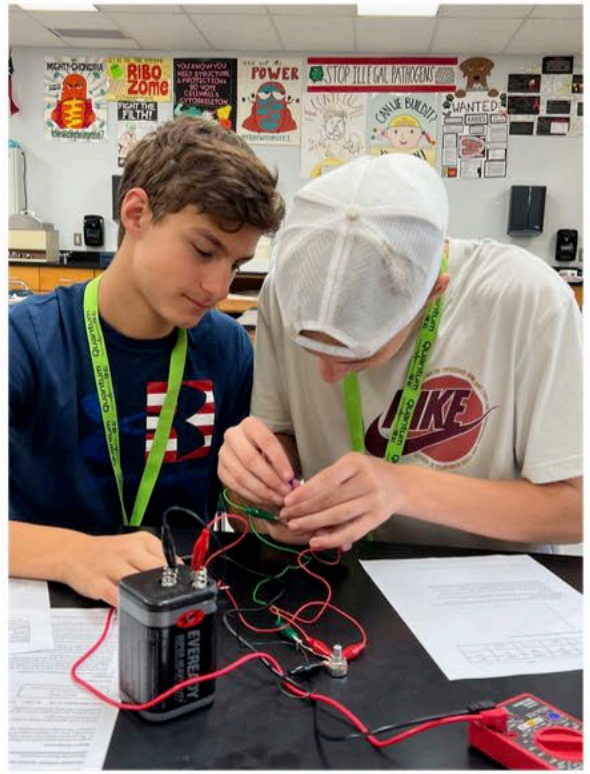
10 / 31 correct responses



Self Efficacy:
Photoelectric Effect (2023)

Teacher

- Pre 53%, 2.9 confidence
- Mid. 66%, 3.32 confidence
- Post 60.7%, 3.37 confidence



1. Photoelectrons are emitted by a metal surface when the frequency reaches 8.0×10^{14} hertz. As the frequency of the incident light increases, the photons striking the metal surface increase in
a) number
b) energy
c) speed
d) wavelength

4. The phenomenon that can be explained only in terms of the particle model of light is
A) reflection.
B) refraction.
C) the photoelectric effect.
D) diffraction.
E) None of the above choices are correct.

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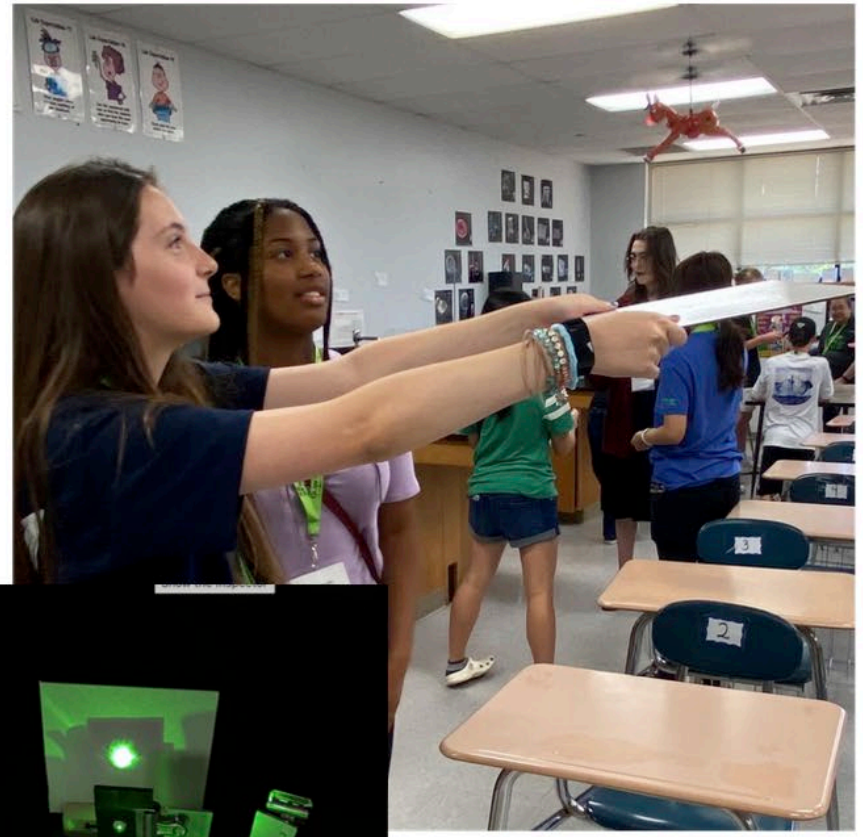
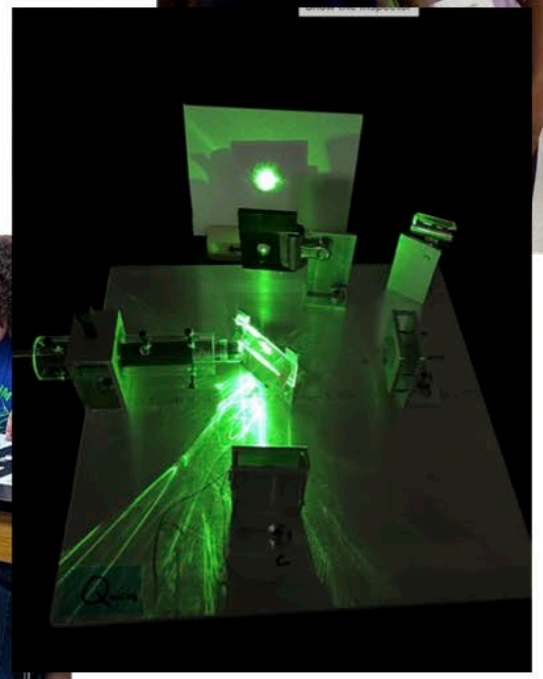
Interest/Persuasion:

Interest leads to understanding, persuasion, and purpose

- Conferences (over 500 teachers)
  - National, state, local
- Engaging activities
- Embed into STEM content
- Identifying peers with similar interests





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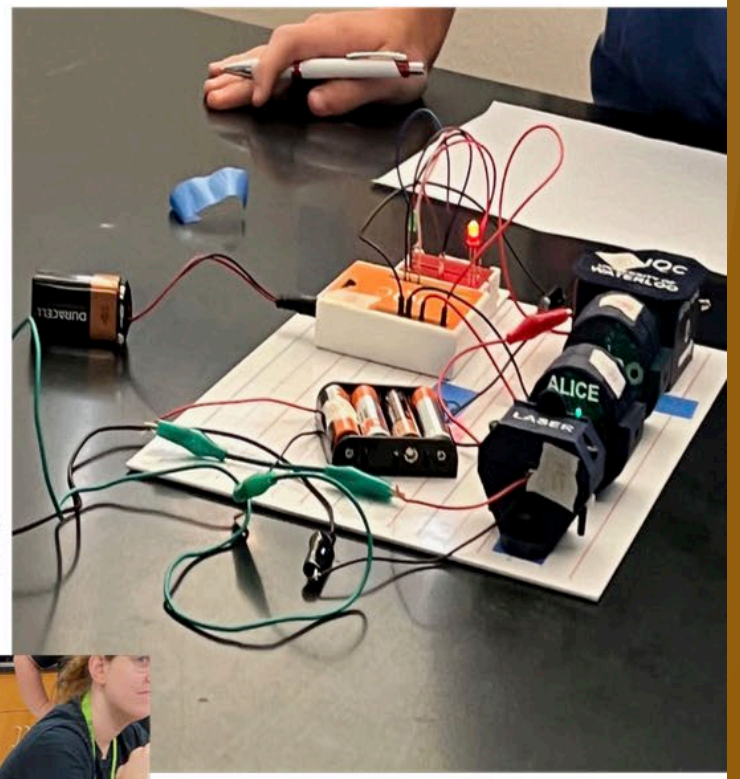
Evaluation/Decision:

Is the destination worth the trip?



Project Impact

- Time for cognitive confidence
- Classroom implementation (#successes vs #failures)
- Equipment needs
- Sustained peer support

Limited Impact

- Administrative expectations
- Standards

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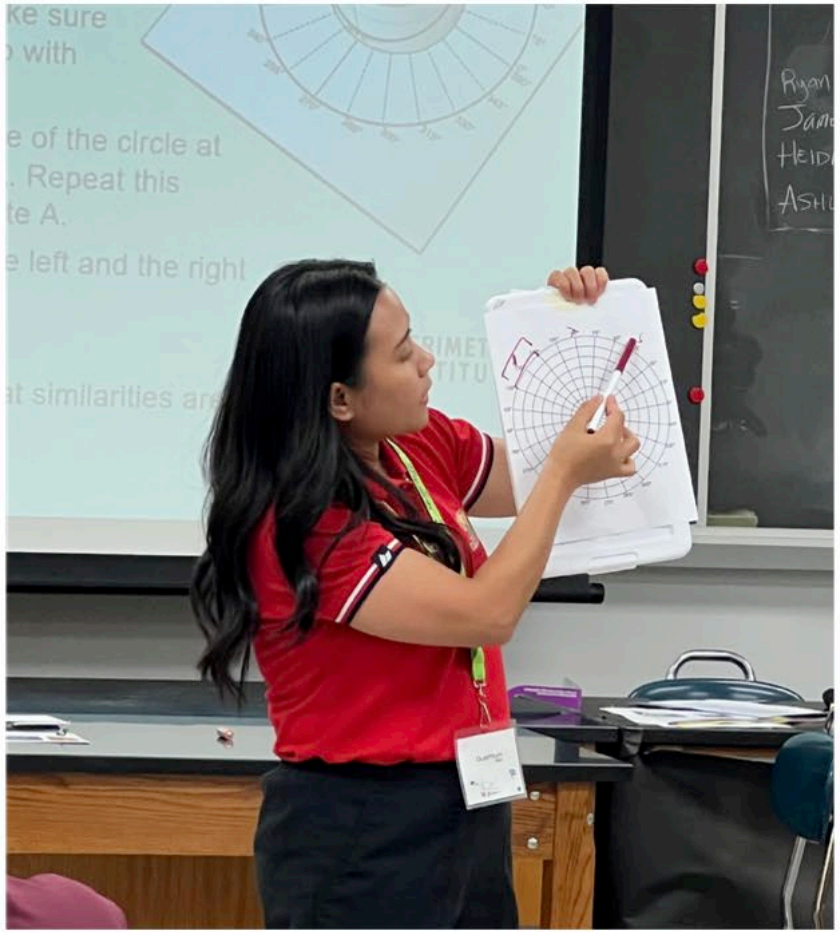
Trial/Implementation:
Can this be done?



Data being collected and analyzed

- Student Camps
  - At 4 sites in 2022
  - 1 site in 2023
- District Camps
  - In 5 districts in 2023
- Classroom Implementation
- Practice Teaching (camps)
- Student Understanding (Assessments and Feedback)

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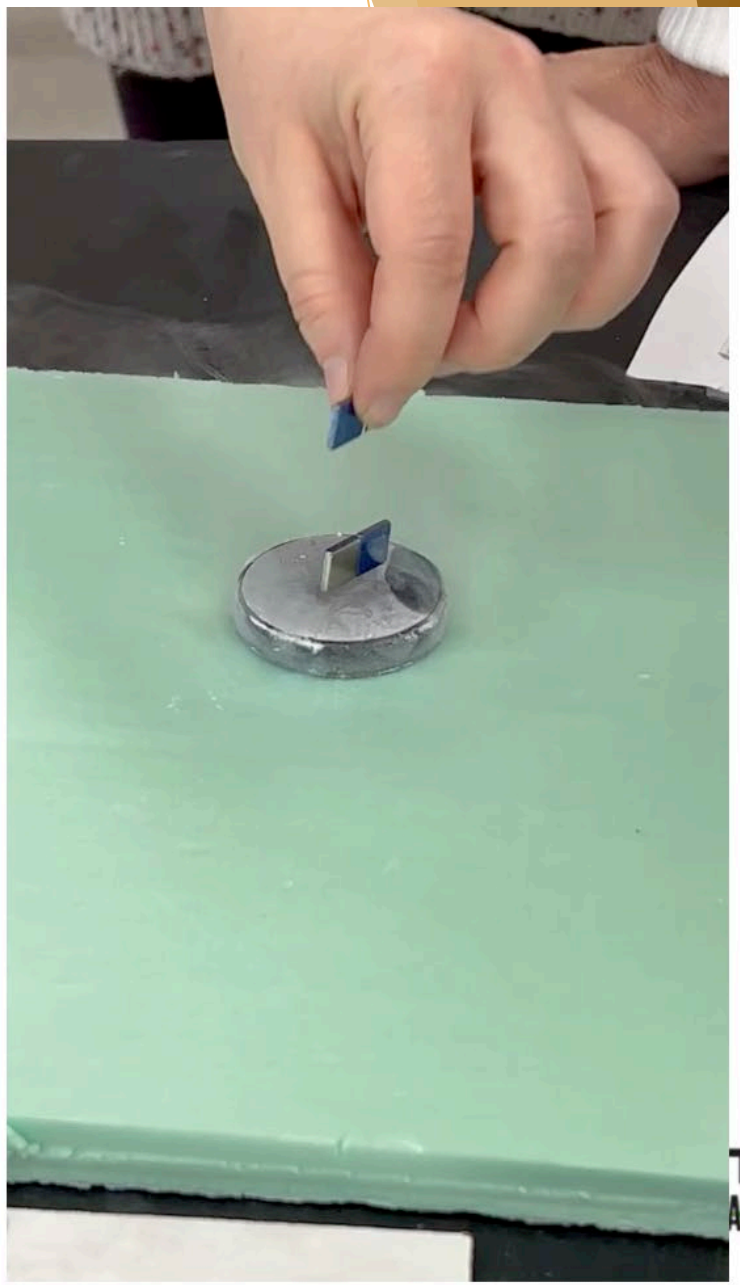
Quantum Locking

5. Quantum locking refers to
A. A special security lock used to protect internet transactions
B. A superconductor that is physically trapped in a magnetic field
C. how a quantum computer secures information being stored
D. An object that does not fall because there is electric field holding it up



Student

- Pre 33%
- Post 91%

Teacher

- Pre 70%, 1.7 confidence
- Mid 100%, 4.2 confidence
- Post 91.4%, 4.25 confidence

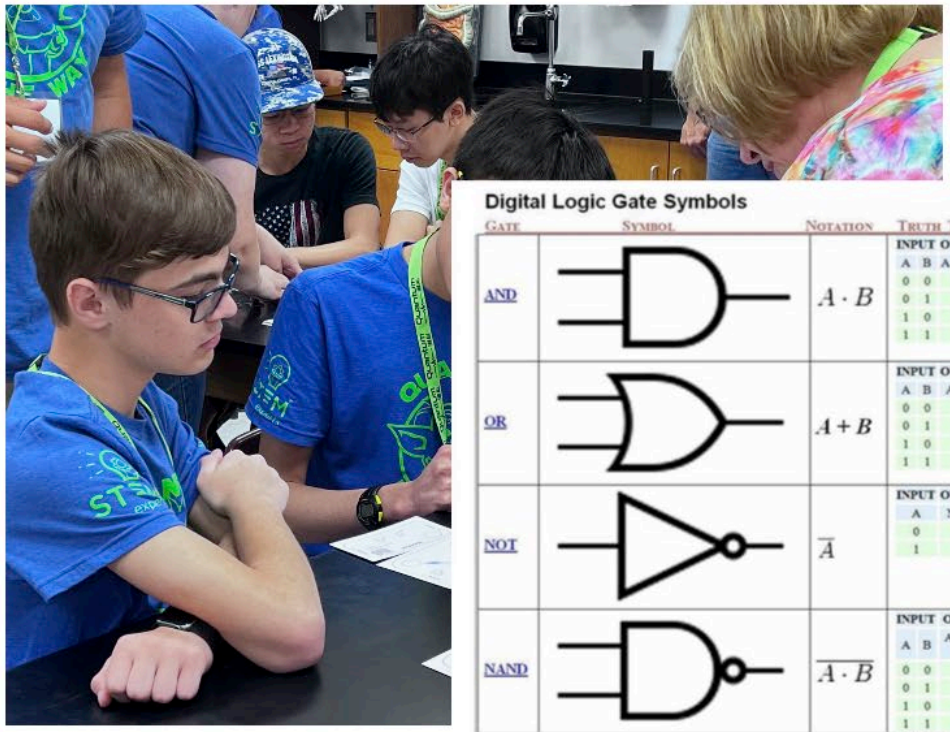
Logic Gates

Teacher

- Pre 66.6% correct, 2.3 confidence
- Mid 93% correct, 4.54 confidence
- Post 96% correct, 4.52 confidence

Student

- Pre 35% correct
- Post 62% correct



Digital Logic Gate Symbols

Gate	Symbol	Notation	Truth Table
AND		$A \cdot B$	INPUT A B / OUTPUT A AND B: 0 0 0; 0 1 0; 1 0 0; 1 1 1
OR		$A + B$	INPUT A B / OUTPUT A OR B: 0 0 0; 0 1 1; 1 0 1; 1 1 1
NOT		$\overline{A}$	INPUT A / OUTPUT NOT A: 0 1; 1 0
NAND		$\overline{A \cdot B}$	INPUT A B / OUTPUT A NAND B: 0 0 1; 0 1 1; 1 0 1; 1 1 0
NOR		$\overline{A + B}$	INPUT A B / OUTPUT A NOR B: 0 0 1; 0 1 0; 1 0 0; 1 1 0
XOR		$A \oplus B$	INPUT A B / OUTPUT A XOR B: 0 0 0; 0 1 1; 1 0 1; 1 1 0

5. Use the truth tables for classical gates to determine the final result if 2 bits both equal to "1" are sent through an AND gate and then a NOT gate
   A) The bit equals "0".
   B) The bit equals "1".
   C) One bit becomes "1" and the other become "2".
   D) It goes into a state of superposition

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Superconductor

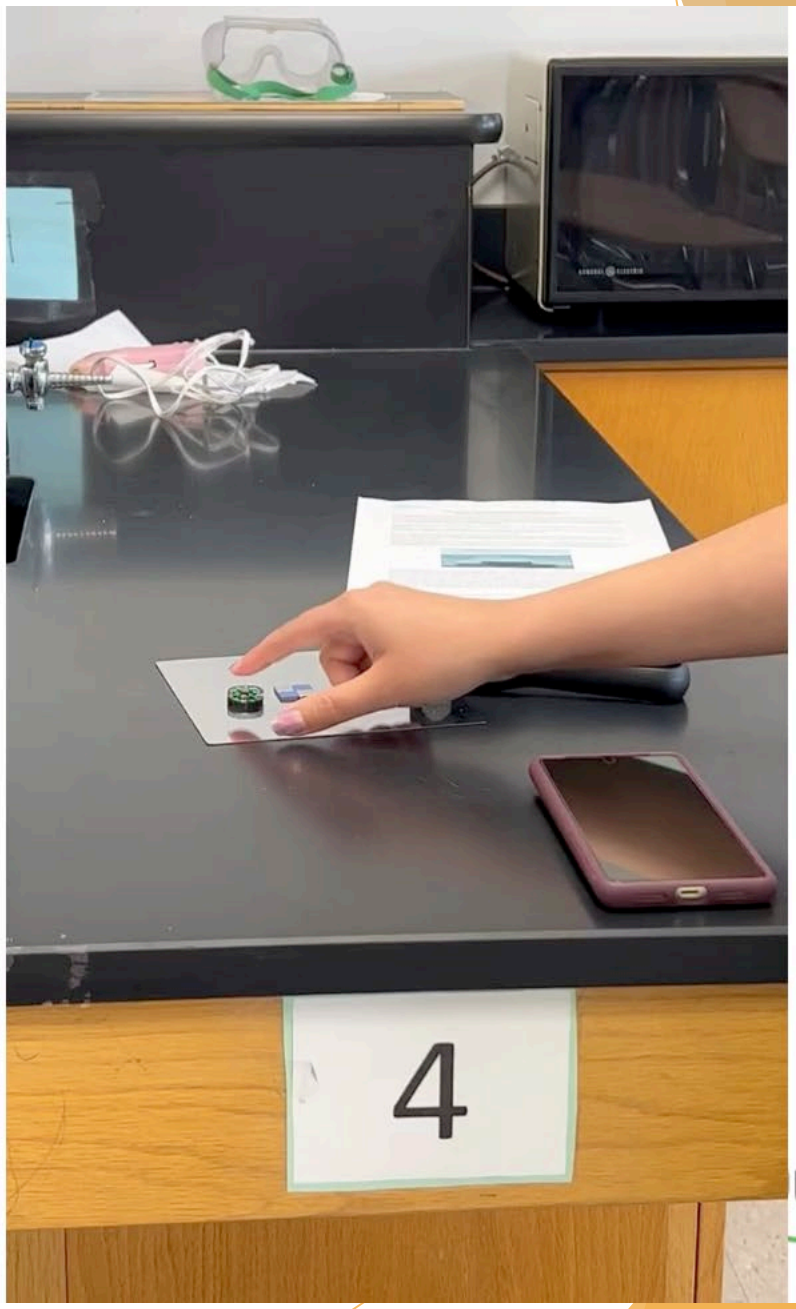
Student

Pre 44% correct

Post 85.7% correct

3. A magnet becomes a superconductor when

A. it is cooled below the critical transition temperature
B. there is no magnetic field present
C. it is at the critical transition temperature
D. it conducts only when moving at supersonic speeds



Adoption/Implementation:
Let's do this!

- "The opportunity to immediately practice the concepts and experiments with students within the second week was wonderful experience."
- "I strongly feel the workshop and camp have enabled me to implement these activities in my classroom."
- "I feel the way the lessons were sequenced and implemented are much more injectable into standard high school physics curricula."
- "The vast majority of the content and instructional strategies we covered in this camp over the last two weeks will make its way into my classroom and that is generally not the case with other PD I have done in the past."

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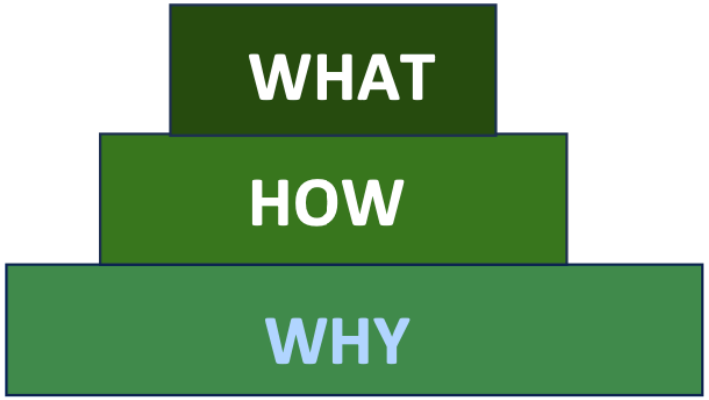

It is not about what you do, but WHY you do it

Not preparing students for jobs available or for what THEY want to do

Teachers are not equipped

No advances may leave **US** farther behind.

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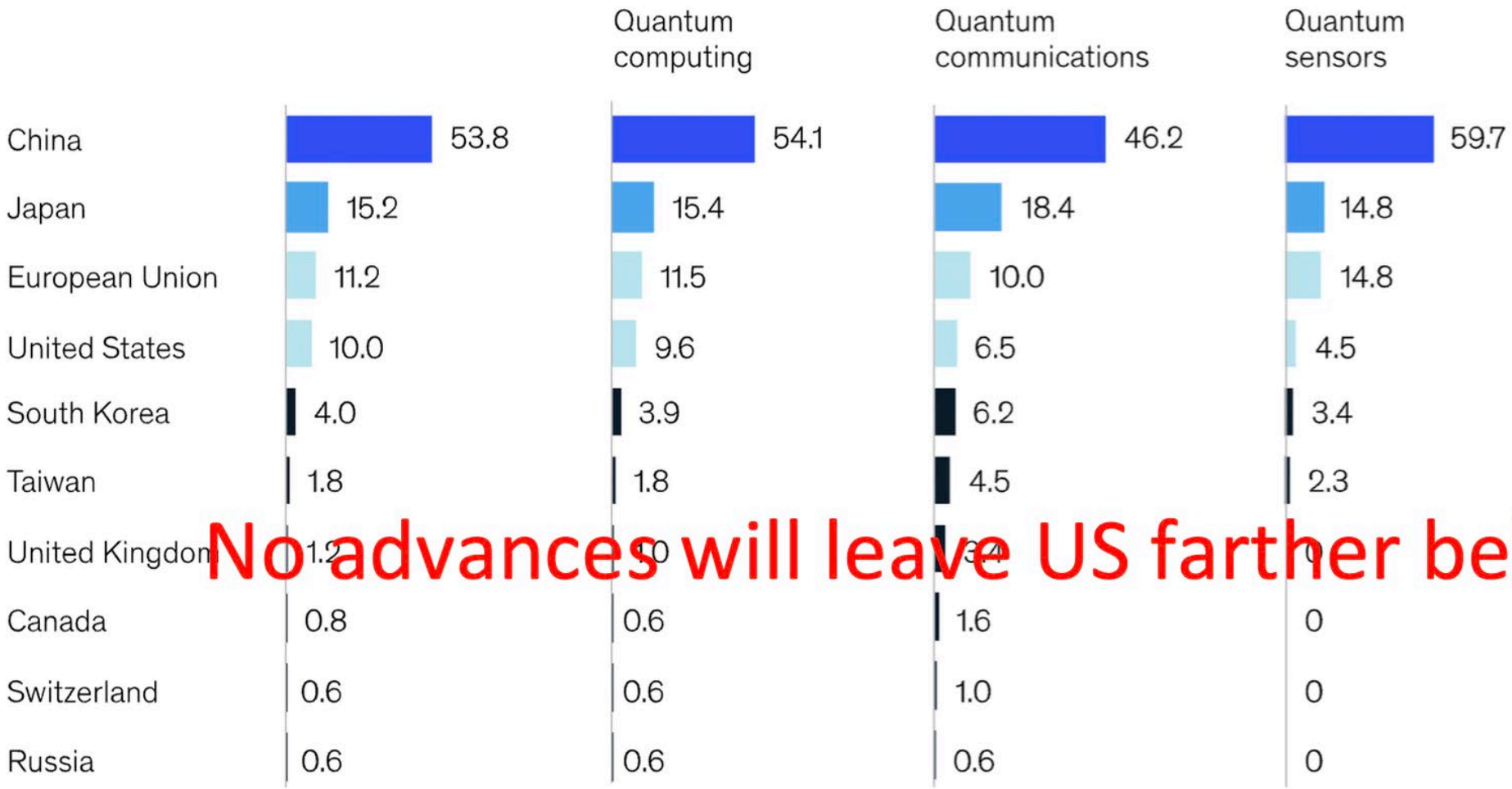
China holds the largest share of patents in all major types of quantum technologies.

Share of quantum patents by company headquarters, 2000–21,[1] %



No advances will leave US farther behind.

[1]Only 50% of headquarters for patent applications are disclosed.
Source: Expert interviews; Innography; McKinsey analysis

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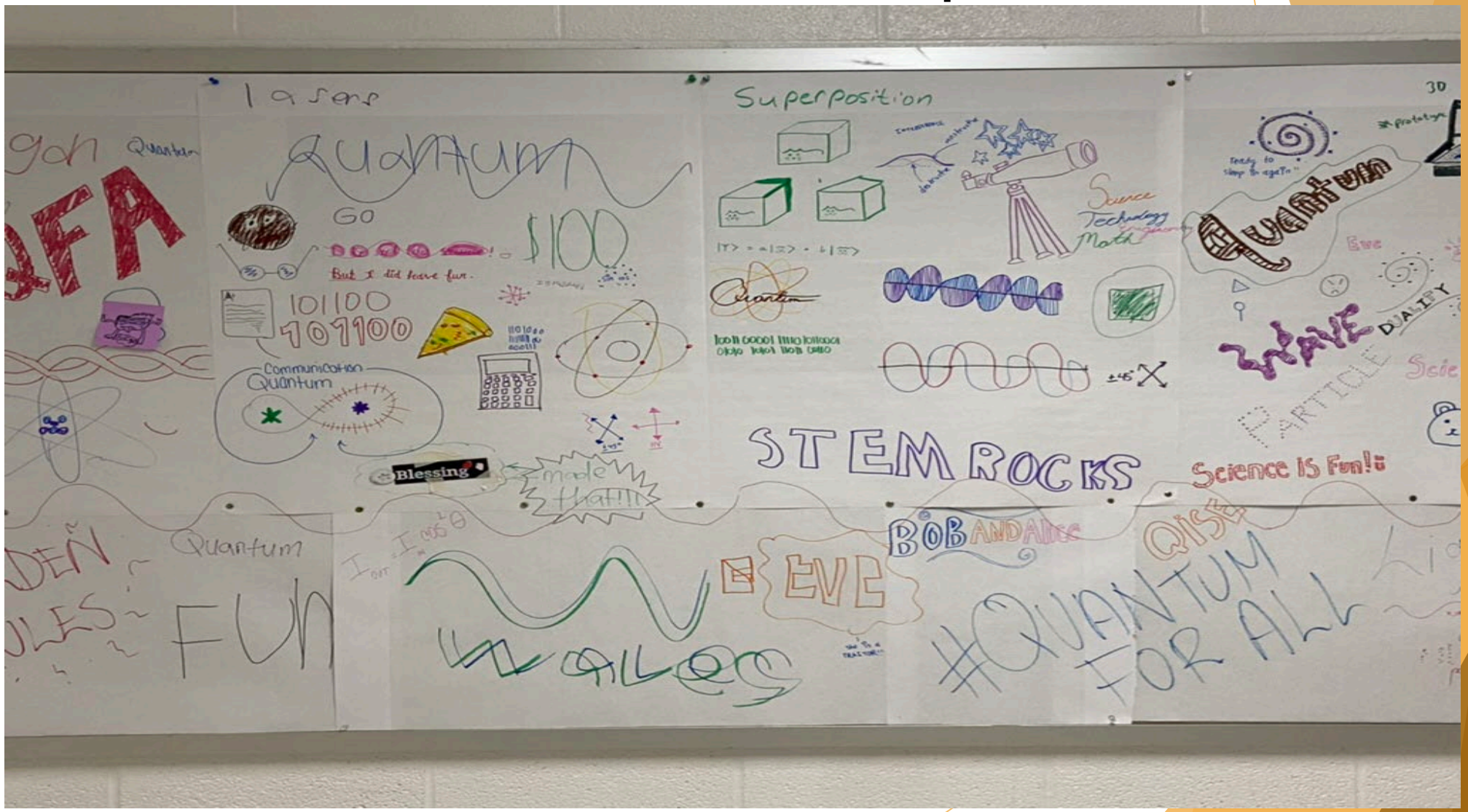
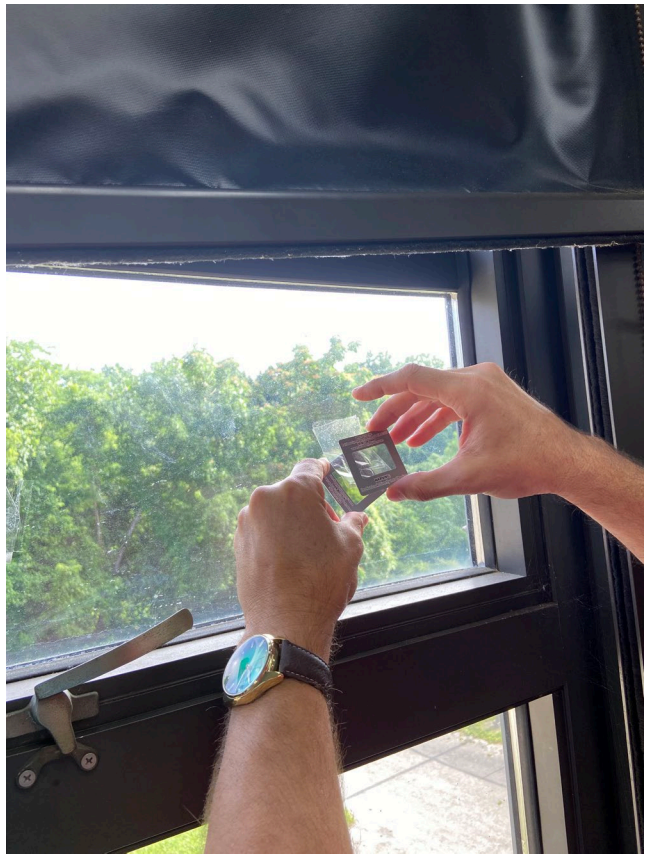
Quantum for All at Morgan State University 2022 Teacher/Student Camp



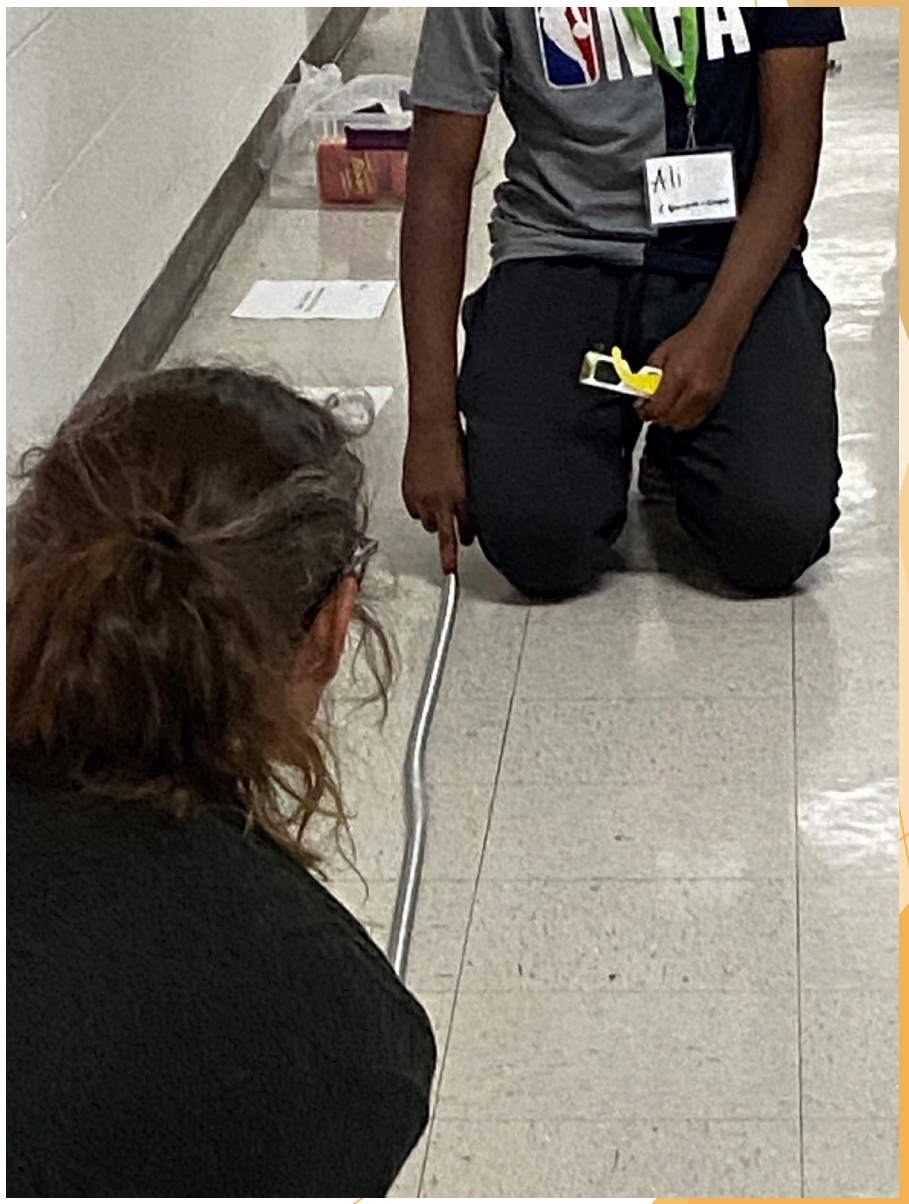
Quantum for All at Morgan State University 2022 Teacher/Student Camp

Quantum Science Focus Activities For Teachers And Students In K-12

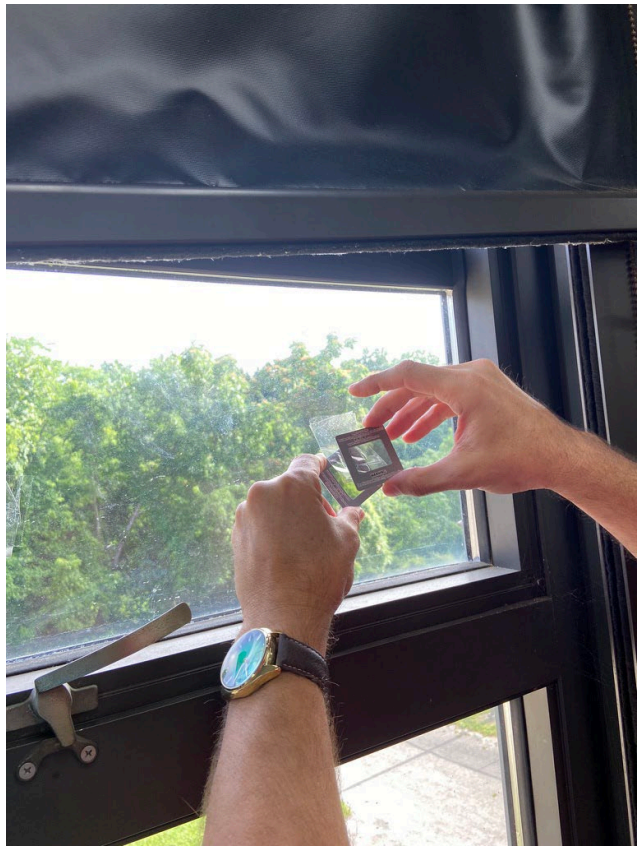
- **Simple Materials**

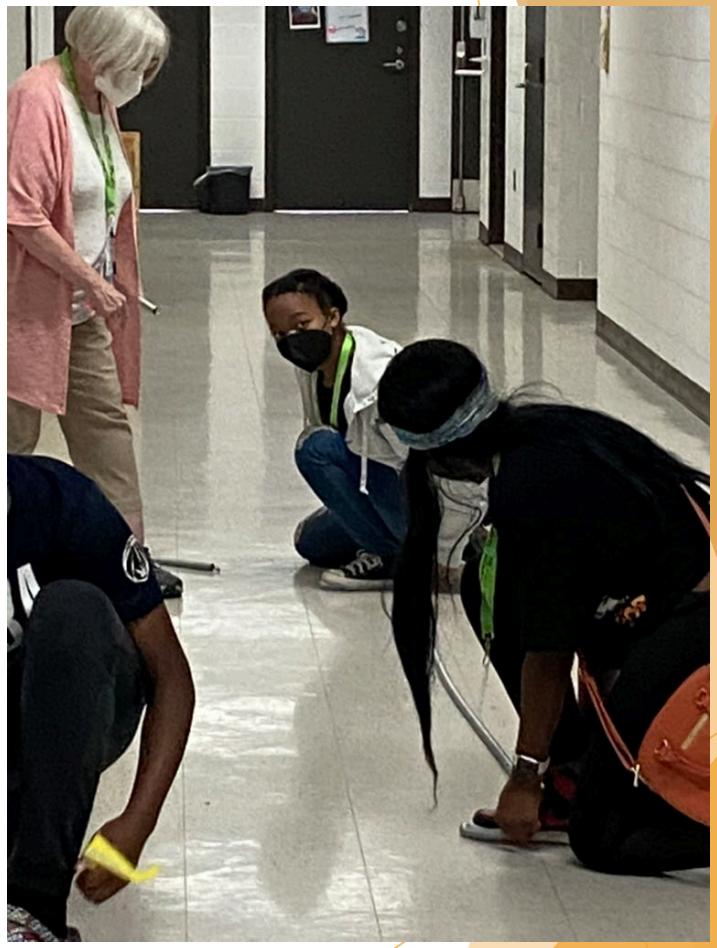


Quantum Science Focus Activities For Teachers And Students In K-12



Quantum for All at Morgan State University 2022 Teacher/Student Camp





WHY?

Quantum opportunities should be for **ALL**

OUR

It is their future

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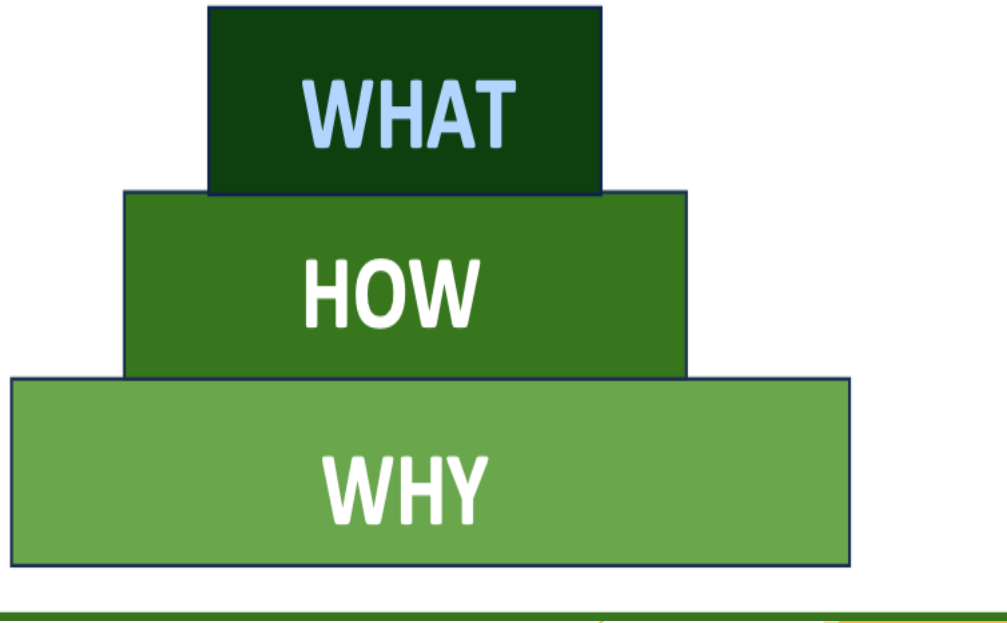
Let’s Create a TEAM

- **WHY** is obvious
- **HOW** is challenging, but we can do this (TEAM)

1. Support Teachers
2. Create Partnerships
3. Encourage each others (TEAM)

- **WHAT** WE do proves what WE believe



Acknowledgement:

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Quantum for All
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MicroNano Educational Outreach
National Q-12 Education Partnership

Thank you
For Your Attention

Any Questions

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