

World Quantum Day
April 14, 2022

What is quantum
science and why
should I care?



- State Chief Information Officer
- Secretary, Illinois Department of Innovation & Technology
 - Panel Moderator
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Jennifer Ricker

Agenda

How will quantum impact our future?

How is the quantum internet different than what I use on my phone?

How do I learn more about quantum science?

What is quantum science?

What pathways are available in Illinois with a focus on engaging underrepresented students in STEAM?

How can students get involved?

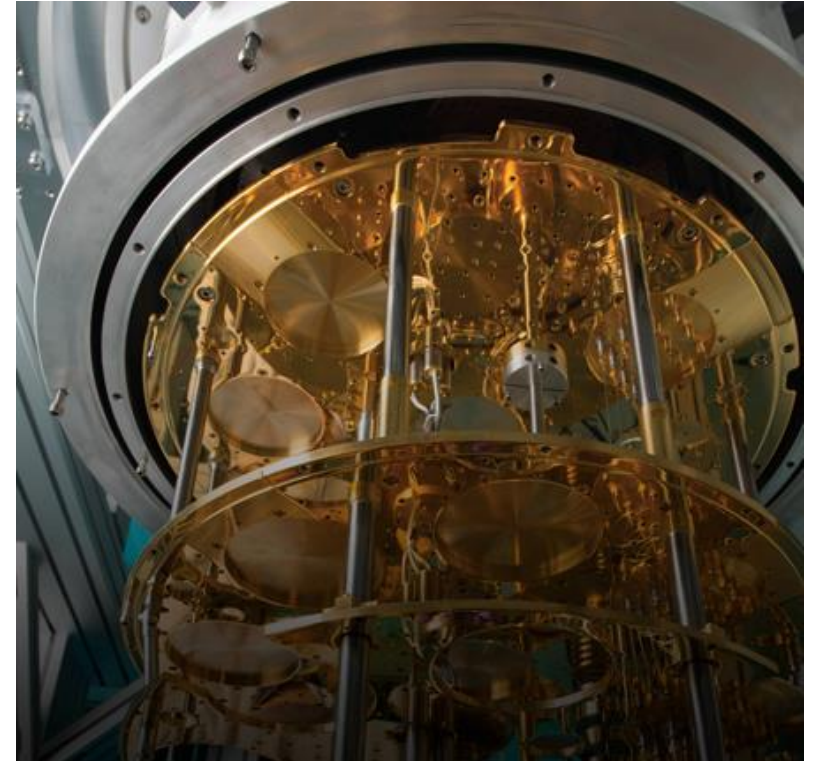


What is Quantum Science?

- According to [Q-NEXT](#), a collaboration involving the world's leading minds from the national laboratories, universities and the private sector, advances in quantum information science have the potential to revolutionize information technologies, including quantum computing, quantum communications and quantum sensing.
- Quantum Information Science, or QIS, exploits quantum properties (such as coherence, superposition, entanglement and squeezing) and combines them with elements of information science to acquire, communicate and process information beyond what classical approaches can achieve.

Investments in Quantum Science in Illinois

- Illinois is home to two of only five National Quantum Information Science Research Centers – [Argonne National Laboratory](#) and [Fermi National Accelerator Laboratory](#)
- Illinois universities include some of the global leaders in the development of next-generation quantum technologies, applications and industries, including the [University of Chicago](#), [University of Illinois](#), and [Northwestern University](#)
- The [Chicago Quantum Exchange](#) is the hub for researchers to advance efforts in the science and engineering of quantum information



Dr. Mark Vondracek

- PhD in particle physics (UIUC), 1995
- Global Teacher Prize Top 50 Finalist, 2015
- ISBE Award of Excellence, 2005
- Contemporary Physics Education Project (CPEP) National Teacher of the Year, 2019
- Physics Teacher & Research Adviser, Evanston Township High School
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Why is there Quantum Science?

- ~**130 years ago**, some thought physics was complete. **THIS is what we teach.**
- But **new phenomena were discovered that classical science could not explain** – atomic spectra, radioactivity & X-rays, electron, speed of light, issues with energy – required new ideas...quantum theory (1900) & relativity (1905)
- In 120 years, these ideas have revolutionized our research base, global economy, how we navigate, medical treatments, numerous fields of technology (and the jobs that come with it), and geopolitics forever...but **we BARELY MENTION IT IN K-12, LET ALONE TEACH IT OR PREPARE STUDENTS SO THESE ARE REAL OPTIONS**

Examples of QS in our lives we aren't aware of

- Off the top of my head:

lasers, quantum computing/encryption, how anything solar works, electron microscopy, particle-wave duality, superconductivity/superfluids/low-temp science, Bose-Einstein condensation, laser cooling, atomic spectra, nuclear spectra, nuclear reactors, nuclear weapons, how MRIs work, particle beam cancer treatments, radioactivity/half lives/nuclear waste, cosmic rays & influence on evolution, standard model (at least up, down quarks we are made from), much of nanotechnology, entanglement, wave functions, quantum cryptography, band theory & material science, strong & weak nuclear forces, nucleosynthesis & notion we are made of star dust, mass spectrometry, particle & nuclear accelerators, ...

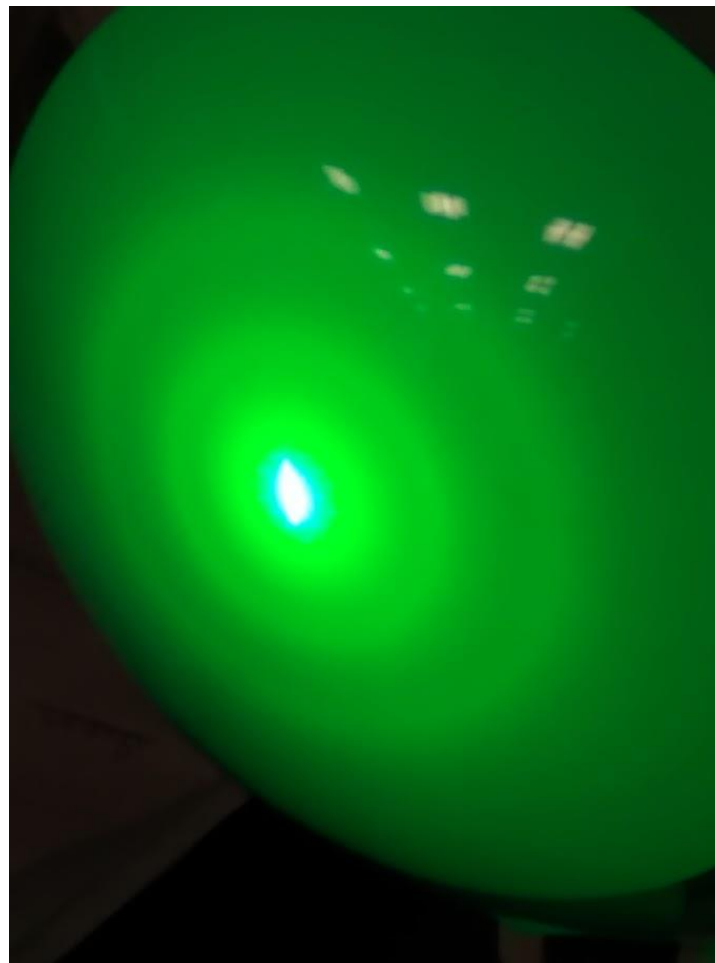
Planting QS Seeds in our Classes

- Most exposure to QS is in **Chemistry** classes for atomic structure & periodic table; *very little, if any* in most **Physics** classes (more likely to mention relativity than QM)

BUT:

- When talking about **matter**, mention quarks, nuclear forces, radioactivity & dating (half-life demo or simulation lab)
- **Newton's laws:** $F = ma$ doesn't work for atoms, particles; a need for new mechanics called QM
- **SHOW** particle-wave duality, heart & soul of QM, if school has CRT

Electrons: Particle or Wave?



Planting QS Seeds in our Classes

- **Energy**: spectroscopy lab to see lines, quantized energy levels (how we know what stars are made from); $E = mc^2$ & nuclear energy, weapons; conservation of mass & conservation need to be combined to be correct
- **Momentum**: photons have momentum without mass!
- Uncertainty principle mentioned in some **chemistry** classes leads to violations of conservation laws and virtual particles
- **Waves and optics**: wave superposition & interference is fundamental to QS; lasers are quantum devices
- **Biology/Evolution**: some genetic mutations from particles crashing into DNA molecule; electron microscopes; MRI technologies to see inside body; carbon and other dating techniques

Planting QS Seeds in our Classes

- NUMEROUS QS concepts can be included, mentioned **in the normal progression** of science curricula
- Don't need full units on any of this in K-12, but **AWARENESS** is important key for students
- My experience - **many HS students intrigued, excited** when they hear about these strange concepts no one ever told them; and **many** who went into STEM in college are involved in some way with QS

Planting QS Seeds in our Classes: The Village

- **Other Subject Areas can help:**

- **History**: how have geopolitics changed due to QS (e.g. nuclear age)
- **Computer Science/Engineering**: what is meant by Quantum Computing; what QS-based technologies are in our everyday lives we don't realize? Coding of any kind useful to prepare students for college QS
- **Mathematics**: QS is built around probability, statistics; if calculus, 1-D quantum examples can be solved (or SHM in Physics C classes)
- **English/Literature**: Sci-Fi novels...what turned out to be real in modern science, life?
- **College & Career/Counseling**: be aware of, provide students with lists of QS-related college programs & careers

Resources & Ideas

- Anywhere in the state, teachers can contact professors, scientists/engineers in QS-related fields to meet with classes via Zoom
- For serious STEM students, ask college/university/industry/museums about internships, research opportunities (sometimes surprised what's possible!)
- Countless online sites, videos, Ask a Scientist, organizations with QS info. One example Quantum Atlas, <https://quantumatlas.umd.edu/>
- FNAL Education page: <https://ed.fnal.gov/>
- ANL Education page: <https://www.anl.gov/education>

Dr. Diana Franklin

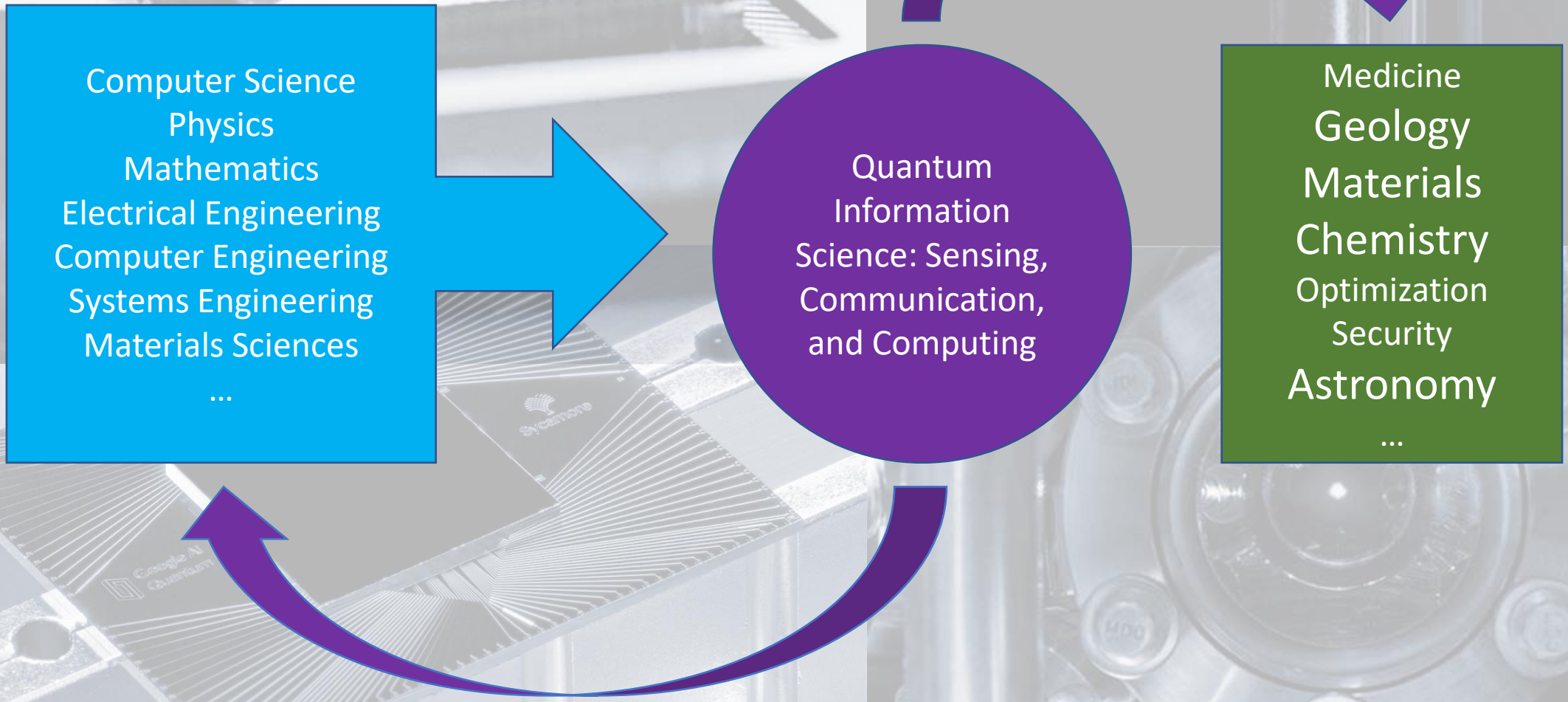
- [Associate Professor](#),
Department of Computer Science,
University of Chicago
 - [CANON Research Lab](#)
- Research areas:
- quantum architecture
 - computer science education
 - quantum computing education

Email: dmfranklin@uchicago.edu

Website: <http://canonlab.org>

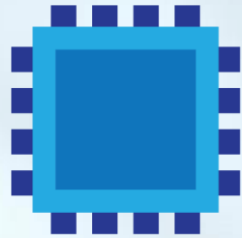
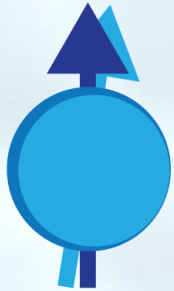


What is QISE?

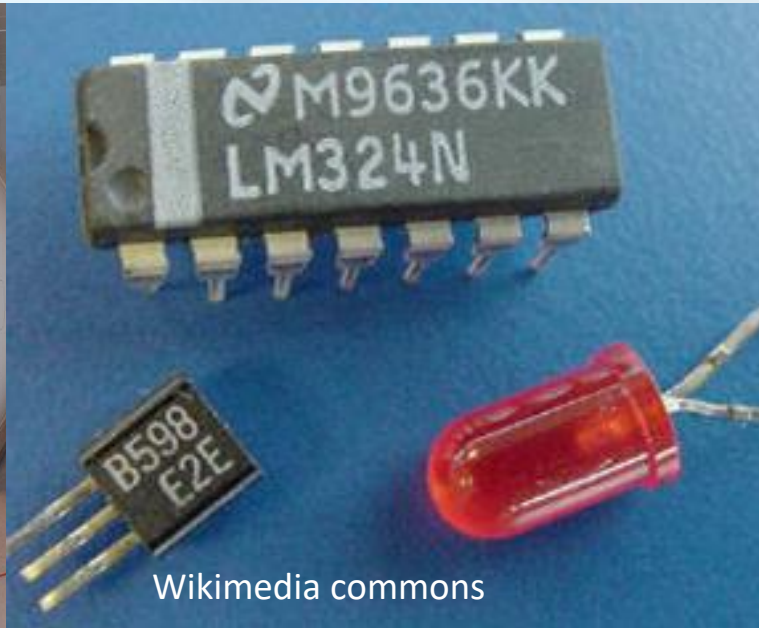


Where can you find “quantum” in technology?

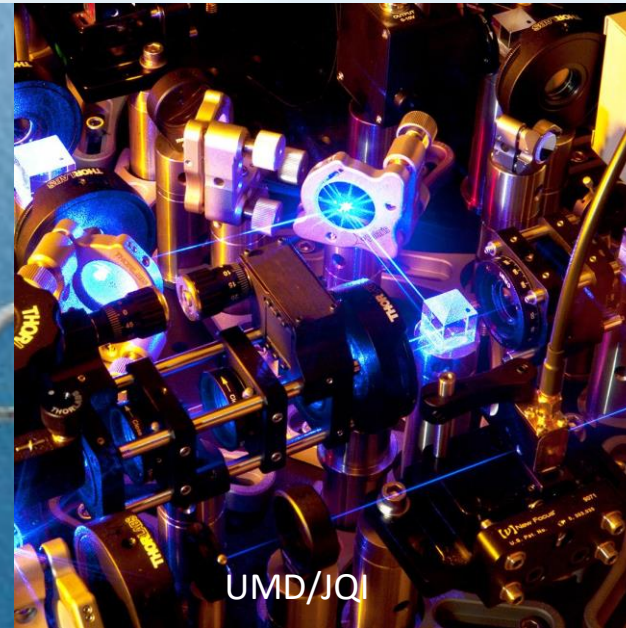
Some 20th century examples:



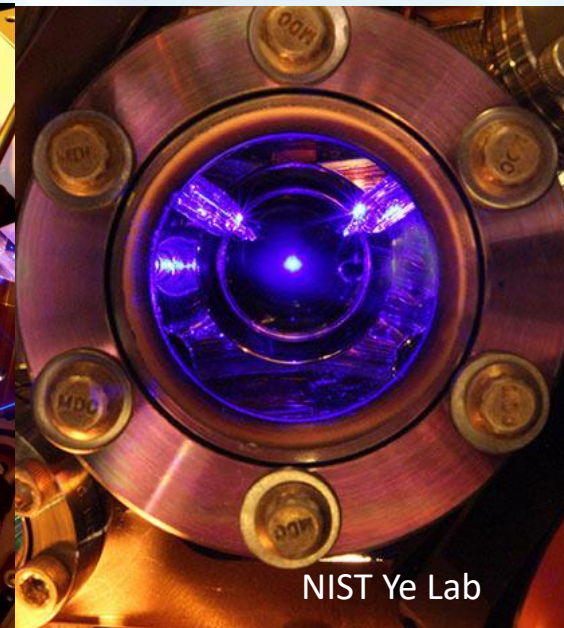
Wikimedia commons



Wikimedia commons



UMD/JOI

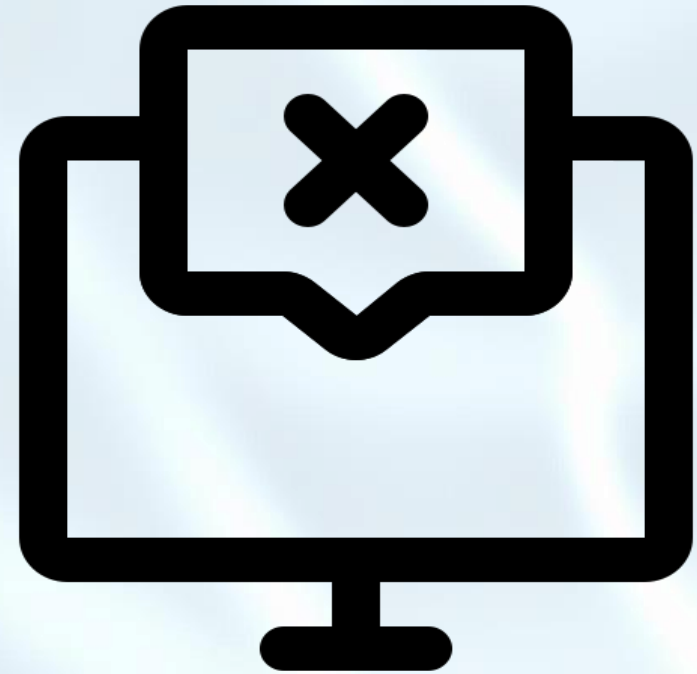


NIST Ye Lab

Quantum Computers are hammers looking for a nails



Quantum Computers are slower and less reliable than classical computers at arithmetic operations



Quantum Computers can hold more data than classical computers, *but you can't read out all of that data!*



Quantum Computers will not replace classical computers - they will be in the cloud as a resource.



Quantum Computers may be able to solve problems
classical computers will never be able to solve



Why *earlier* quantum education?

Spark
interest in
quantum or
other STEM
careers

Increase
diversity in
quantum
fields

Increase
public
awareness
and literacy
of quantum
technologies

Develop
intuition for
QISE at
earlier ages

Increase # of
students with
access to
emerging
technology

Learning from History

Computer Science, Data Science, Machine Learning

- Impacted society inequitably before being widespread K-12 adoption
- Playing catch-up trying to get diverse knowledge, workforce to promote equity

Quantum Computing education: Current Status

- Interest, but few polished materials available
- Ready for short, individual, one-time activities
- Still working on other models of adoption

K-12 Needs

Teacher PD

Awareness
efforts

Research on
what works

Educative
materials

Educational
Opportunities

National Q-12 Education Partnership

Spearheaded in 2020 by NSF and WHOSTP

- Q12 community extends beyond partner organizations
- Planting seeds, strengthening collaborations across industry, non-profits, academia, and government

Collaborating NSF projects on Key Concepts

Preparing Secondary Teachers and Students for Quantum Information Science (K. Matsler)

Cross-Discipline Approach to Quantum Computing in High Schools: Building towards a Quantum Computing Workforce (M. Hannum)

OPTICA | Formerly OSA

APS
physics

IBM

Google

Microsoft

MONTANA INSTRUMENTS
COLD SCIENCE MADE SIMPLE

SPIE.

IEEE★USA

ZAPATA

rigetti

LOCKHEED MARTIN

aws

BOEING

intel.

Honeywell

AAPT American Association of
Physics Teachers

QUBIT
X QUBIT

Quantum
FOR ALL

High-Level Ultra-Short-Term Goals

Teachers:

- Awareness - What is QIS, how is it useful, how could you do something?
- Confidence - Low-overhead introductory activities
- Resources - Help curriculum developers and teachers create material

Students:

- Interest - increase chances someone is interested and willing to look into QIS
- Confidence - instill belief that they can do it if they want
- Experience - provide small amount of knowledge to give them an edge

Getting QISE into classroom: Framework

Framework led by C. Singh, D. Franklin

- ~20 teachers and educators.
- Each working group met from May-August to develop learning outcomes and trajectories
- Aligned with existing curricula and frameworks for teaching physics and CS
- **Version 1 available for feedback**

Infusing QISE into HS subjects takes different forms



Image from QuantaMagazine, 2020 DVDP

QUANTIME



Start getting teachers comfortable with QIS

Introduce students to specific aspects of quantum information science

No experience necessary

No more than one hour activity

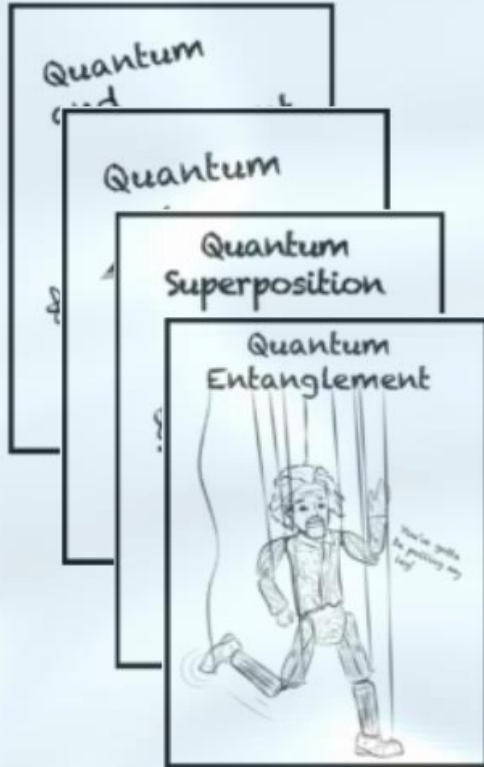
Video introduction and conclusion, facilitation guide or online tutorials for activities

Available TODAY!!! World Quantum Day (April 14th)


<https://q12education.org/quantime>

http://epiqc.cs.uchicago.edu/resources

11 Zines



5 Activities

EPIQC 

Measurement Perturbs State
Explore how measuring something can change it

Learning Goals

- Understand that measurement methods can change the thing being measured.

Importance in Quantum Computing
The state of a quantum bit, or qubit, changes when you measure it.

Materials

- Various flavored Jelly Belly jelly beans (or similar candy)
- Paper towels or napkins
- [Measuring Jelly Beans worksheet](#)
- [Measurement worksheet](#)







Preparation


- Print the *Measuring Jelly Beans* and *Measurement* worksheets.

Measuring Jelly Beans


Jelly bean color: _____

Non-destructive Measurement Methods


Method	What flavor do you think it is?	Why do you think that?	How sure are you?
Look			  
Smell			  




2 edX Classes

 **Introduction to Quantum Computing for Everyone**

This first course in quantum computing is for novices and requires learners to have only basic algebra. It covers the future impacts of quantum computing, provides intuitive introductions of quantum physics phenomenon, and progresses from single operations to a complete algorithm.

 **Estimated 5 weeks**
3–5 hours per week

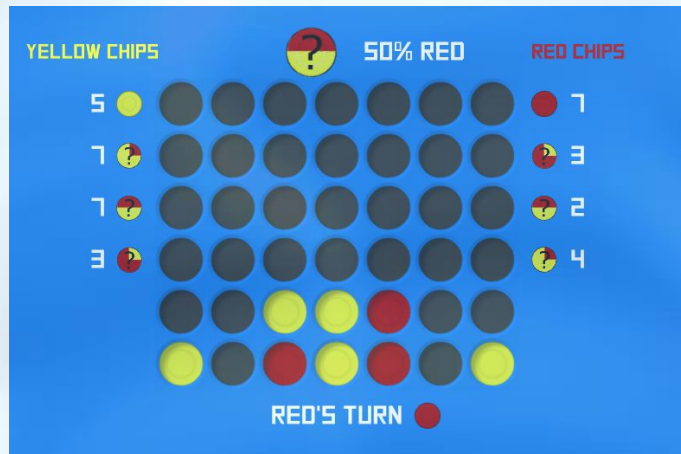
 **Self-paced**
Progress at your own speed

Coming Soon:



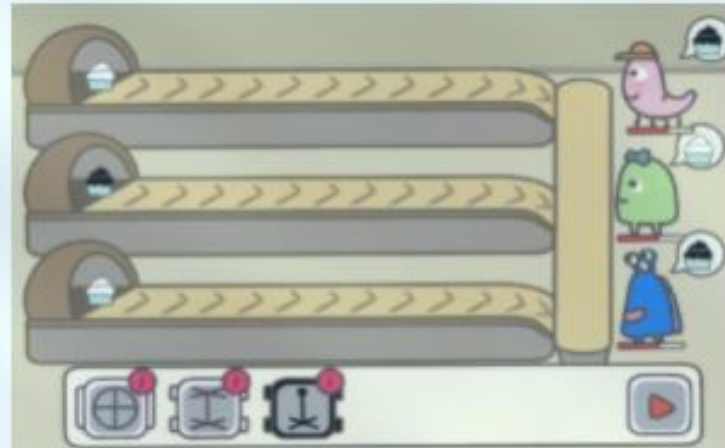
QueueBits:

Superposition + Connect 4



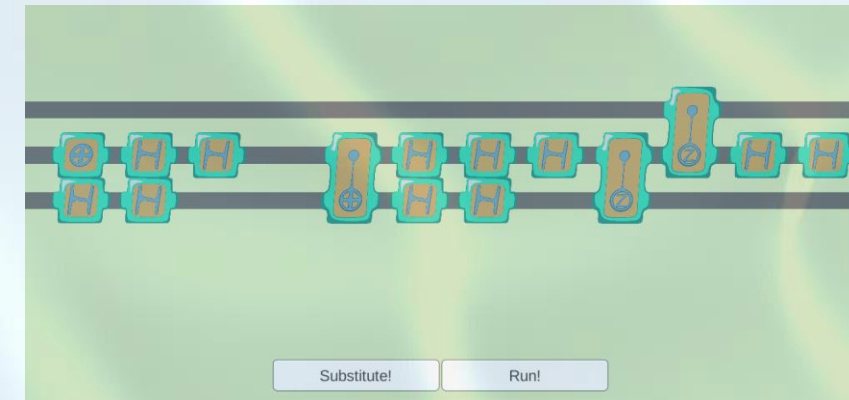
Qupcakery:

Quantum Operations



Crazy Circuits:

Quantum Circuit Simplification



Find more quantum computing resources at: <http://epiqc.cs.uchicago.edu/resources>



Keith Jacobs

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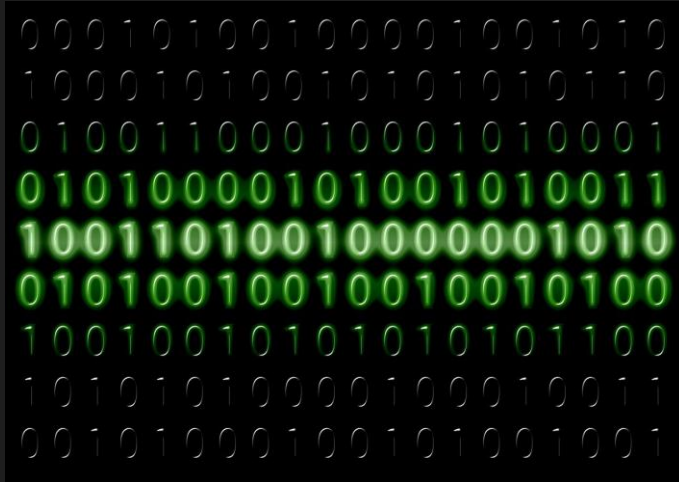
HOW DO WE GET
TO QUANTUM
CAREERS?

WHAT ARE THE
PATHWAYS?



HIGH LEVEL VIEW

Binary



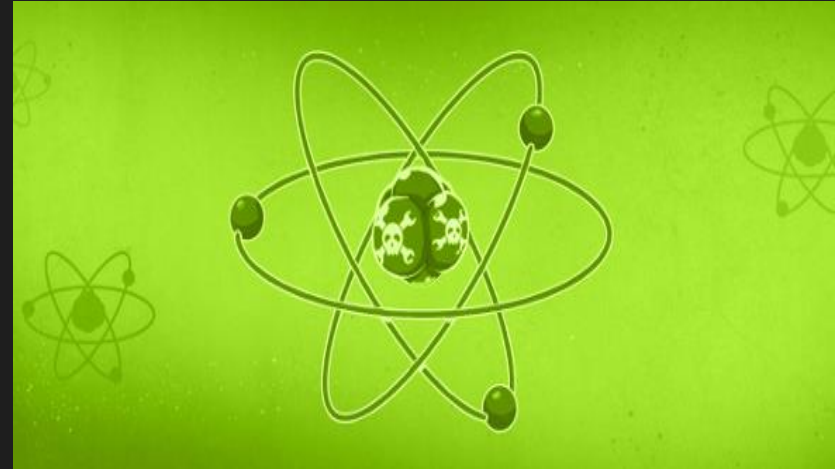
Binary Digits

CS

Math

ECE

Quantum



Physics

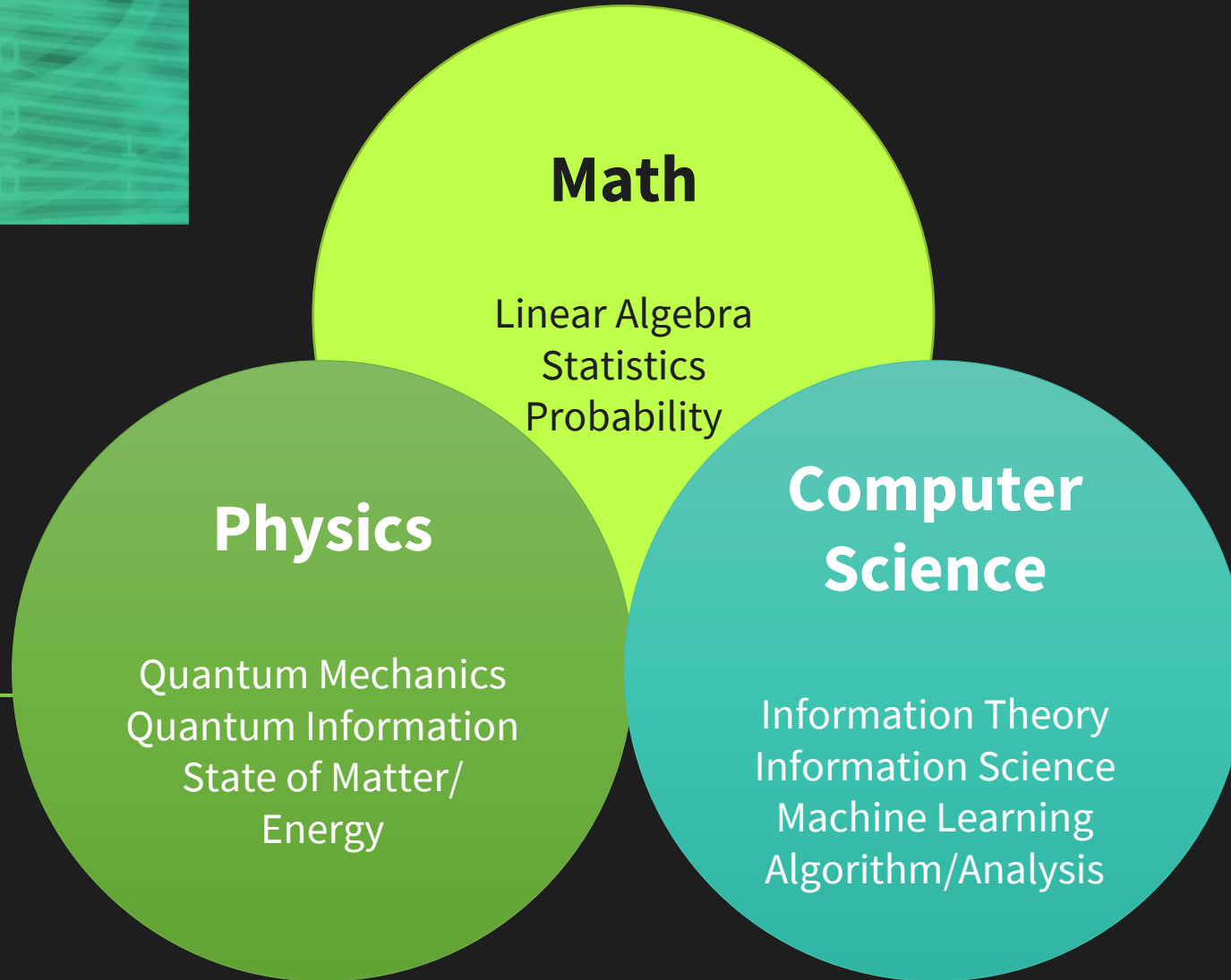
Algorithms

Informatics

Math

CS

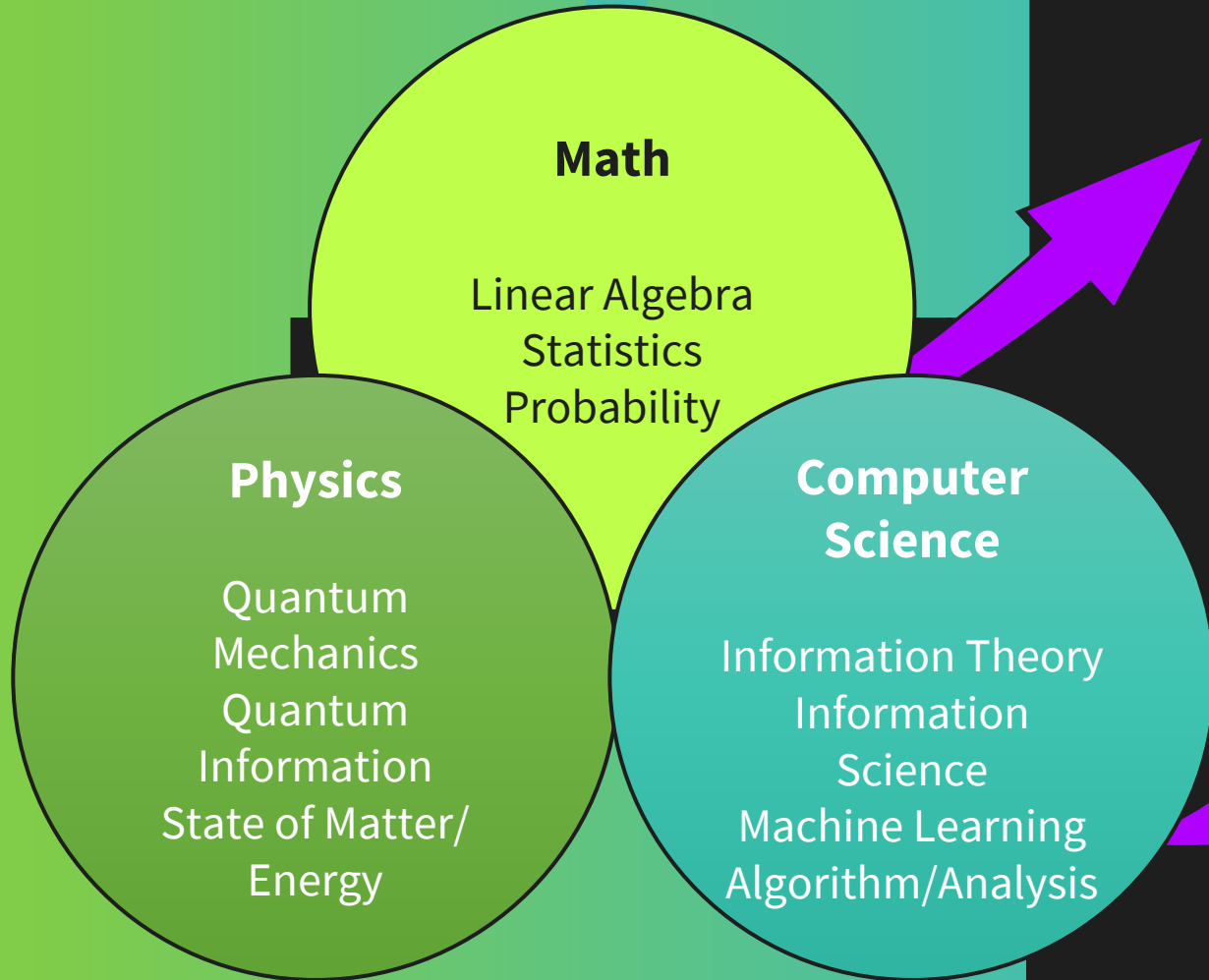
BUCKETS



Quantum Computing Scientists

**22% Expected Job Growth
Between 2020 and 2030**

(Bureau of Labor Statistics)



OR



3 PATHS TO QUANTUM



QUANTUM RESEARCH/DEV

- Graduate level education (MS /PhD)
- 6-9 years
- Very straightforward and specific
- Theoretically Based

Example Career:

- **Superconducting Qubit Researchers**
- **Quantum Physics Researchers**
- **Quantum Computer Architects**
- **Quantum Algorithms Researchers**



UTILIZE QUANTUM AS A TOOL/

- Bachelor level education/Knowledge
- 4 + years
- Field related to CS/QC
- Practically based

Example Career:

- **Data Scientist**
- **ML Engineers/Scientists**
- **Software Development**
- **UX Design/ HCI/ Behavioral Scientist**



ADOPT AND ADVANCE ACROSS FIELDS

- Varied Education/ Knowledge
- Skill Dependent
- Varied Years Experience
- Fields related to and interrelated to CS
- Practicically Based

Example Careers:

- **Unknown, Think NFTs to Blockchain**
- **Only be available to those ready for the journey**



REQUIRED SKILLS

QUANTUM PROGRAMMING (QCL, Q#, QML, ETC.)

- Scratch, Lego Mindstorms,
- Python, C / C#

ALGORITHMIC COMPUTATION

- Probability Based/ Statistics, Information Science
- Minecraft and other stand alone activities/ curriculum

MACHINE LEARNING & AI

- Weka, R, Big Data
- Text and Image based
- Tools/Curriculum Currently being developed



TAKE HOME MESSAGE:

Meet the youth
where they are
and keep them
engaged in
emerging
technologies.



Joseph Fatheree

- Doctoral Student, University of Illinois EPOL
- Top 10 Finalist for the 2016 Global Teacher Prize
- NEA National Award for Teaching Excellence 2009
- Illinois Teacher of the Year 2007
- Innovation Teacher, Effingham High School
- Email: josephfatheree@gmail.com
- Phone: 217-663-3530

Resources

[National Q-12 Education Partnership](#)

[QuanTime](#)

[DoIT's Quantum Illinois](#)

Questions?

To follow-up with resources or questions, please email:
DoIT.steam@illinois.gov

