Building the Quantum Workforce K-12 through Undergraduate Education

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Mason’s Quantum Science & Engineering Center (QSEC): engaging K-20+ students and educators in content-rich quantum experiences and increasing their understanding of and interest in quantum careers
Need for Equity and Access
+ Lack of knowledge and fear
= More education in formal K-12 Settings
Survey of Undergraduate STEM Students

Participants recruited via emails, posters, & social media

- 185 undergraduate STEM majors at George Mason University

**Major**
- 35% Physics, Eng, Chem, Math, Geo
- 40% Cyber, CS, IT Data Sci
- 25% Bio, Psych, Forensics, Kinesiology, Neurosci.

**Gender**
- 48% Male
- 38% Female
- 10% Non-binary
- 4% Gender not reported

**Race/Ethnicity**
- 39% White
- 12% Asian
- 7% Black/African American
- 10% Hispanic/Latino
- 26% Native American
- 5% Multi-racial
- 1% Race/ethnicity not reported
Interview Participants Inclusion Criteria

*Interest in quantum careers (“agree” or “strongly agree”) (Note: More students interested than spots)*

- 13 undergraduates in 4 interviews
- 10 males, 3 females
- Majors:
  - 7 computer science; 2 physics; 2 math; 1 electrical engineering; 1 forensic science
Student know little about quantum but are interested in quantum careers

“I only know a little bit, and physics definition of quantum but I want to learn more about it.”
Interest Differs by Gender and Major

Gender difference disappears when only computer and physical science, engineering, math majors

p=0.002
Barriers

• Students don’t know what quantum is
• Most interested students are in fields with less representation
• Quantum thought to be difficult to understand
• Seems to be “risky” in terms of jobs and practicality

“there’s not a wide range of jobs in the field ... you’re taking a risk studying it.”

“I don’t think it could be as practical as math or physics.”

“You probably need a PhD to realistically get a career in the field, and even then the positions will be competitive.”
Opportunities

• It is exciting and cool
• Mentors can make a big difference
• Introduction at a young age can have a big impact
• There will be applications to real world problems
• Most students learned about quantum online

“I think the exposure is the most important... an application for real world problems in the simplest sense, I think, will be beneficial, because quantum can be applied to a lot of things.”

“It's also kind of a realm where normal physics kind of just gets thrown out the window. And that was something that kind of stuck with me and I was like wow that's really interesting”
Six sessions over the year:
  ○ 5 in person 5-hour PD
  ○ 1 virtual 2-hour PD

73 teachers Oct 2022 - July 2023
5 worked on summer curriculum development
Overview of quantum concepts & resources

- Distinction between classical and quantum
- Quantum states, superposition, entanglement, and measurement
- Polarizers as a quantum effect
- Quantum applications
- Quantum Chutes and Ladders
- Quantum activities in small groups
Teacher Perspectives

- **Elementary** focus:
  - Equity & Access

- **Secondary** (middle and high school) focus:
  - Equity
  - Content

“Things are going to progress and develop rapidly in this field, and this could give our young students a leg up in this area of science”

“It is totally untraditional. Now we are talking about electrons not having a specific location but a statistical probability of a location”

“English Learners have the same opportunities as native speakers to join STEM lessons, and they all start at the same knowledge level with quantum.”
Barriers/Concerns

- Unclear connection to standards
- Lack of resources, especially for young children and English Learners
- Uncertainty of students having needed background knowledge

Length and format made huge difference in teacher comfort level
- 17% of face-to-face attendees expressed concerns about content knowledge
- 46% of online attendees said they were not comfortable to teach it

“I don't totally understand it myself and won't feel comfortable answering questions”
Quantum Immersion for High School Students

2 weeks online learning key concepts and about careers and applications
1 week immersive career-focused in-person

“If it wasn’t for this program I wouldn’t see myself getting interested in quantum until at least by the time I will be in college, so I’m really grateful I got the headstart.”

“I feel like I could incorporate quantum into medicine which is really exciting.”

“My perspective has shifted and I can see myself looking into Quantum Cryptography.”

“It has deepened my interest in STEM”
Optional internships and QWC Posters
Recommendations:

• Build an understanding of quantum and quantum careers early
• “Demystify” quantum, emphasize interest and remove sense that you have to be a genius to understand it
• State standards that include quantum and knowledge about how quantum connects to current standard is important
• Teachers will need support developing the knowledge and confidence to include quantum in the curriculum
• Students can do a lot in quantum with no background knowledge – engage a diverse group early and often
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Fields believed to require brilliance have fewer women
(Leslie et al. 2015, Science 347, 262)

"Just getting more women in tech, I feel like, it's the first biggest hill before even broaching quantum computing and stuff like that. I guess to me it's like where to even start introducing quantum computing when a lot of women don't even know or get into computer sciences."

"when I think of quantum computing and all that stuff, it's just a mystery to me. It's just something that super geniuses talk about in their free time, doing it as a career."

Fig. 1 Field-specific ability beliefs and the percentage of female 2011 U.S. Ph.D.'s in (A) STEM and (B) Social Science and Humanities.
Challenge: Most Institutions do not have QIS Courses or Programs

- 74 institutions offered QIS courses (2019-2021; Cervantes et al. 2021, AAPT)
  - 65 (88%) are PhD granting institutions
  - PhD institutions serve 40% of physics Bachelor’s degree graduates (AIP 2020).
  - Students at PUIs (including most HBCUs and MSIs), much less likely to have access to a QIS course.
- In 2021 there were 3 certificates and 7 MS programs in US (https://arxiv.org/pdf/2109.13850.pdf).
- In 2023 >6 new MS programs and 7 new certificates added
Who does Industry Expect to Hire?

"I think the exposure is the most important. We were talking about how quantum seems like a very scary subject to look into. It's, well, it's out of my hands because I don't understand physics at all, so I think exposure in terms of [at a] younger age, introducing concepts of quantum that can slowly get more detailed and maybe specific. But an application for real world problems in the simplest sense, I think, will be beneficial, because quantum can be applied to a lot of things."
Challenge: Feeder Disciplines Struggle with Diversity

Without direct effort we risk reproducing these results in quantum