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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

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Need for Equity and Access
+
Lack of knowledge and fear
=
More education in formal K-12 Settings

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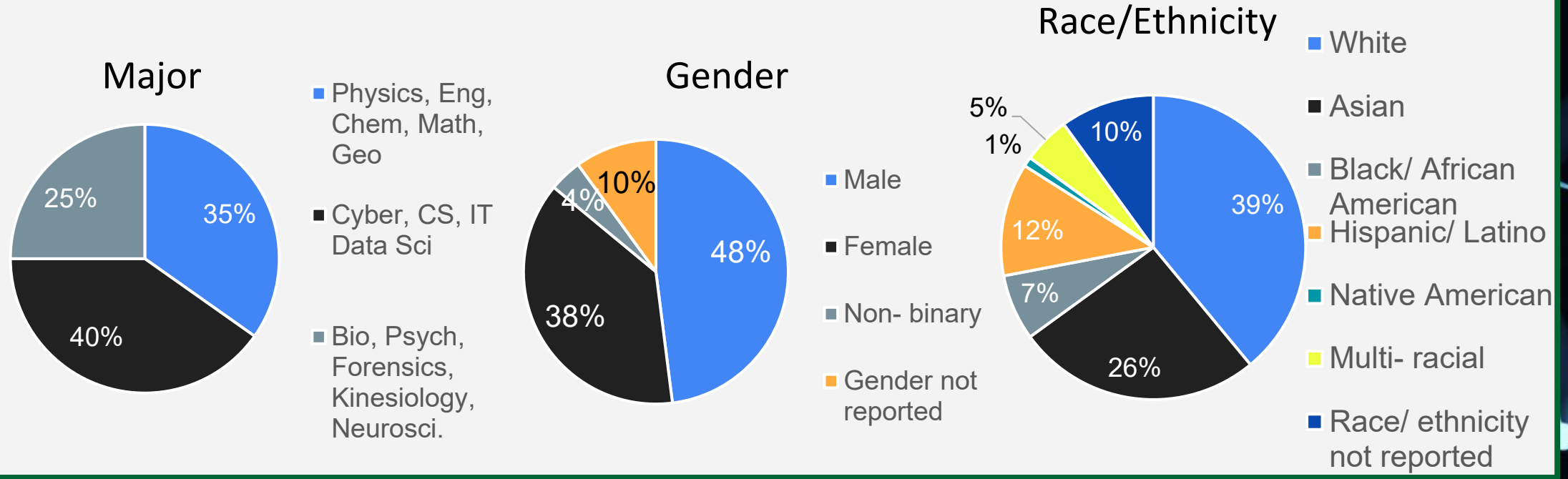
Survey of Undergraduate STEM Students

Participants recruited via emails, posters, & social media

- 185 undergraduate STEM majors at George Mason University



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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

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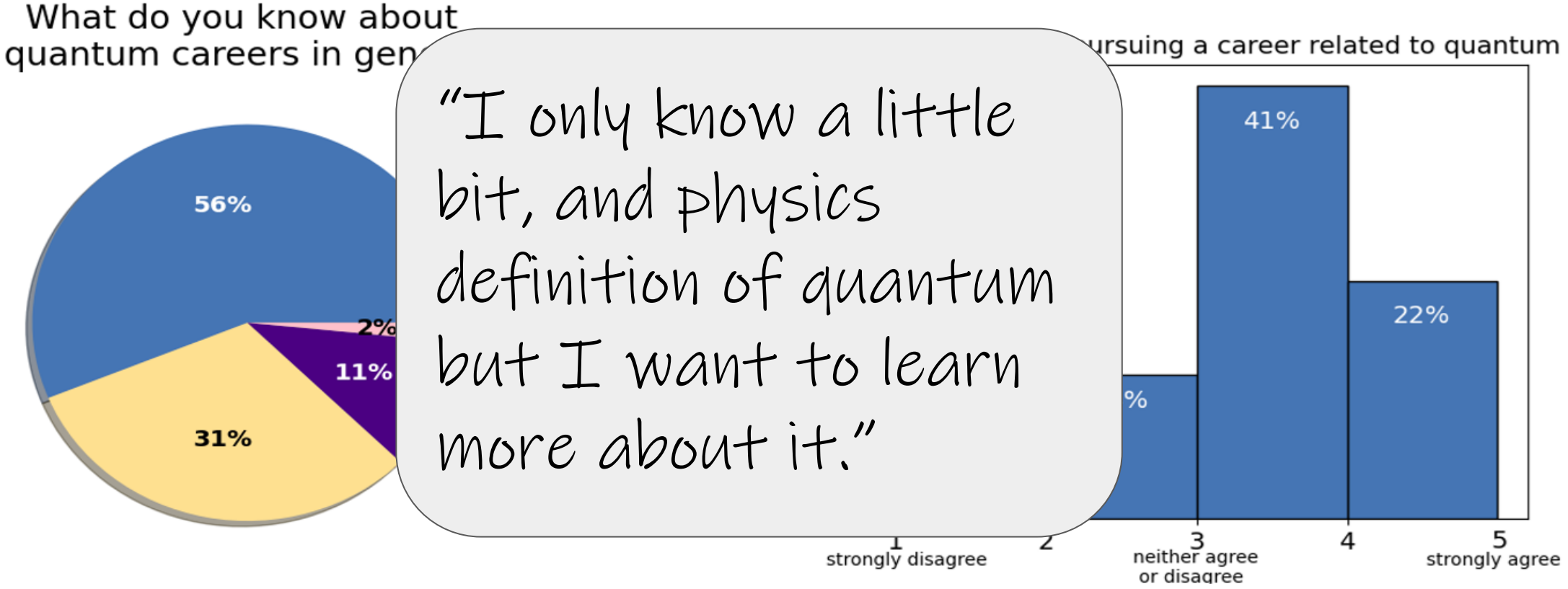
Student know little about quantum but are interested in quantum careers



"I only know a little bit, and physics definition of quantum but I want to learn more about it."

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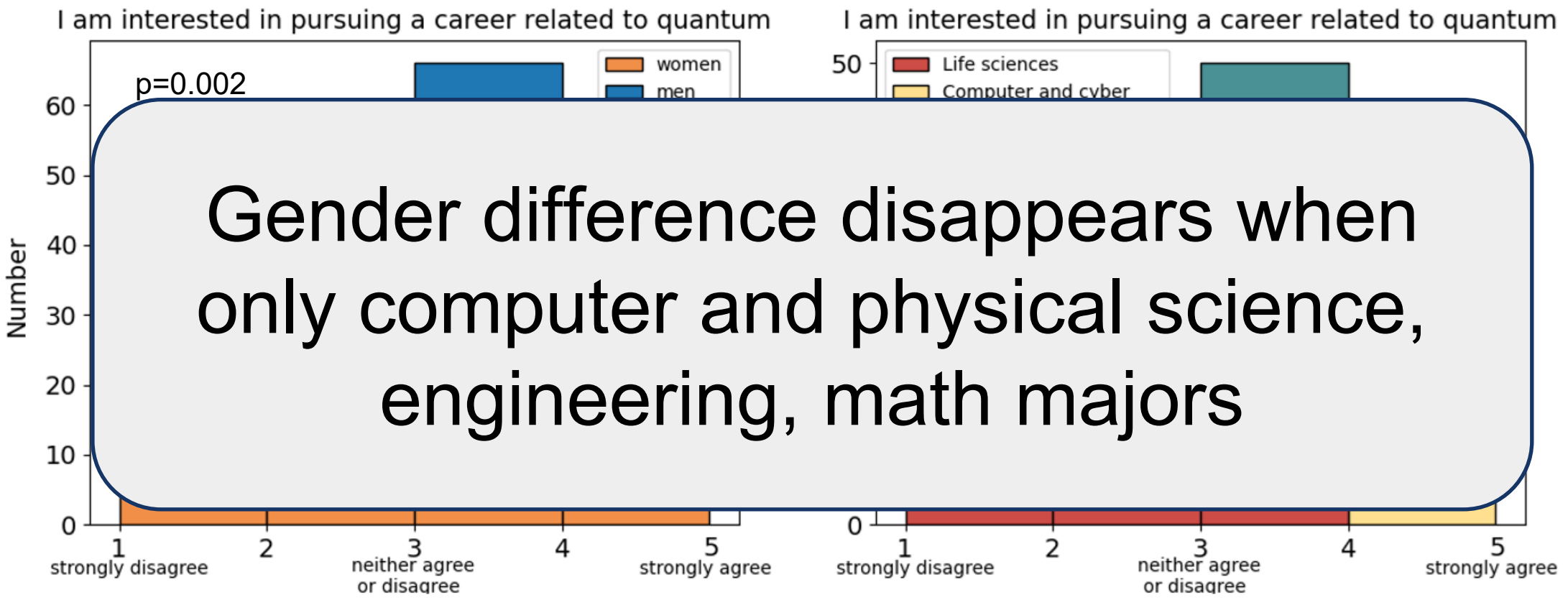
Interest Differs by Gender and Major



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

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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."

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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"

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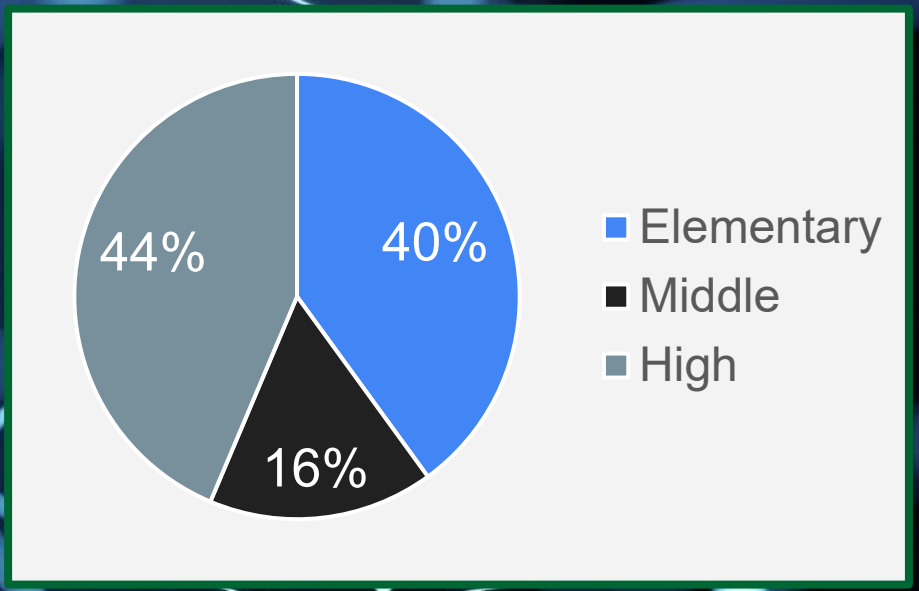
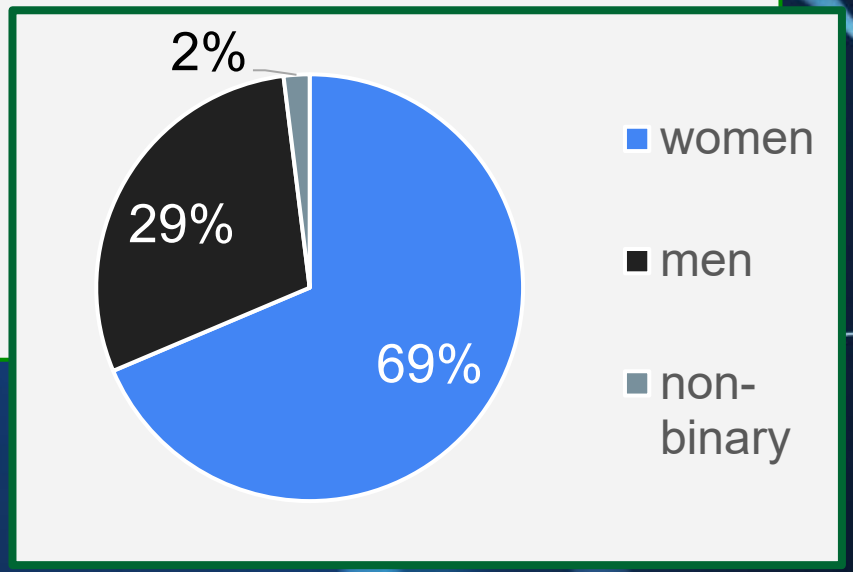
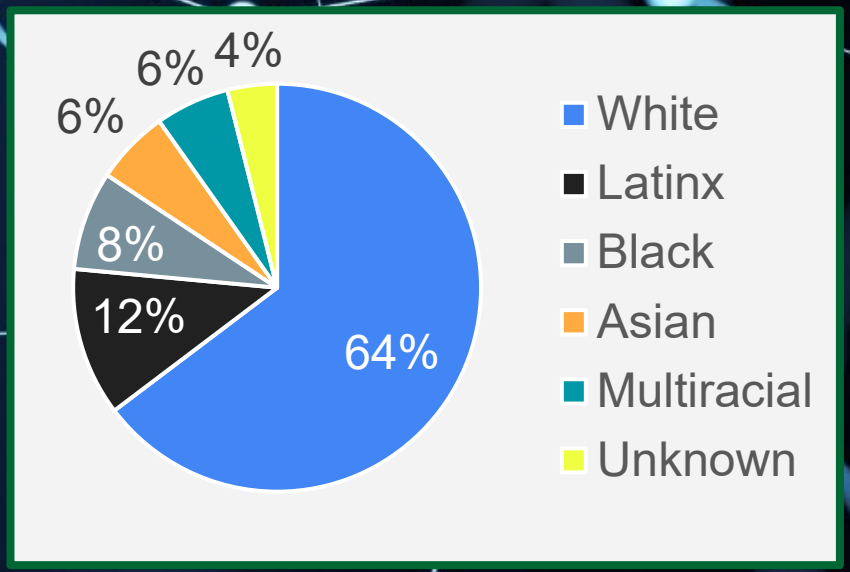
Quantum in Your Classroom

- 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







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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

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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"

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

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

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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"

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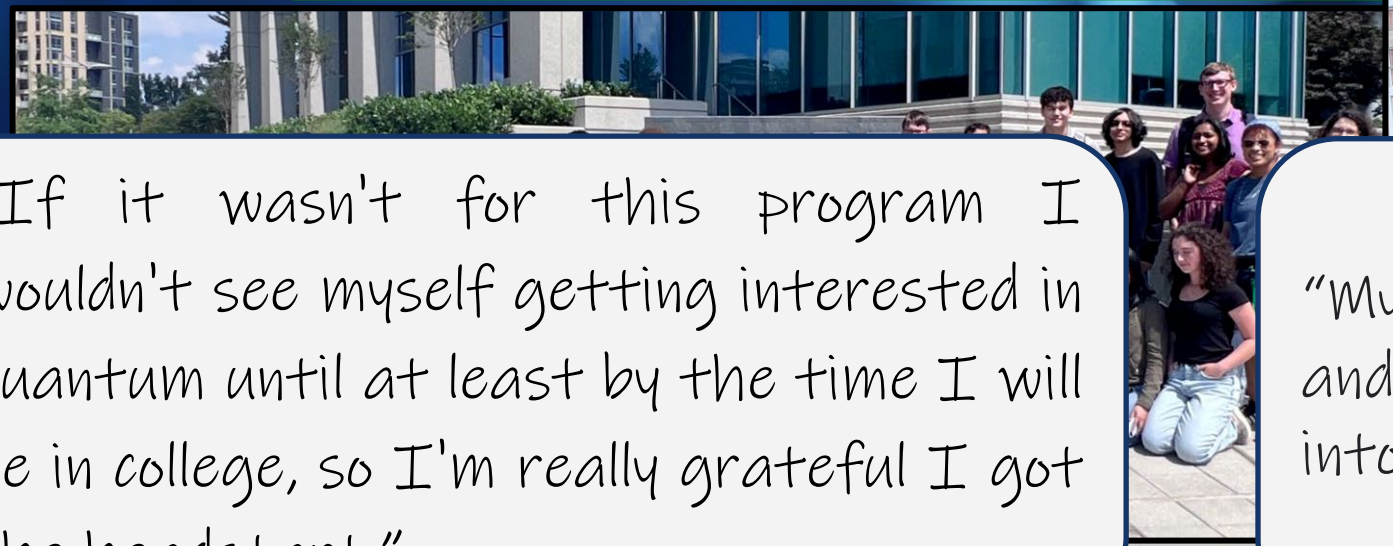
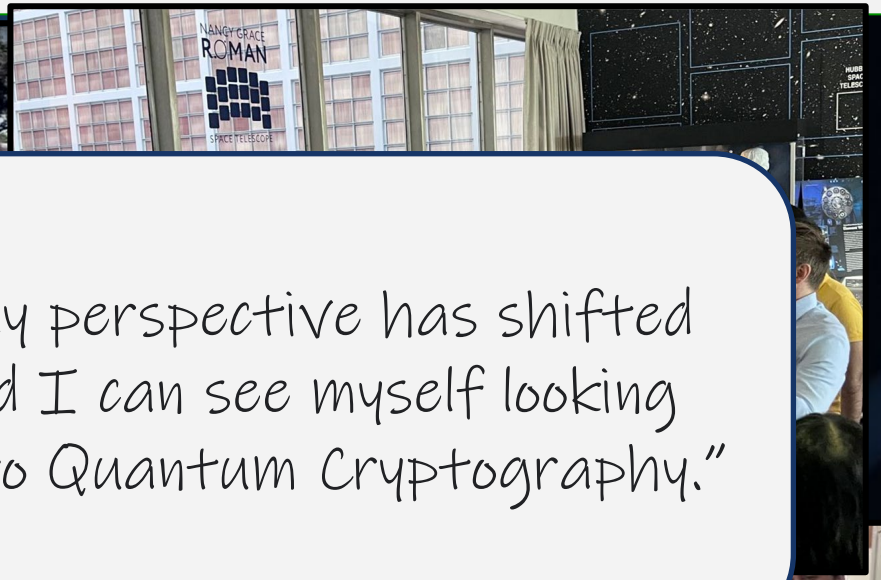
Quantum Immersion for High School Students

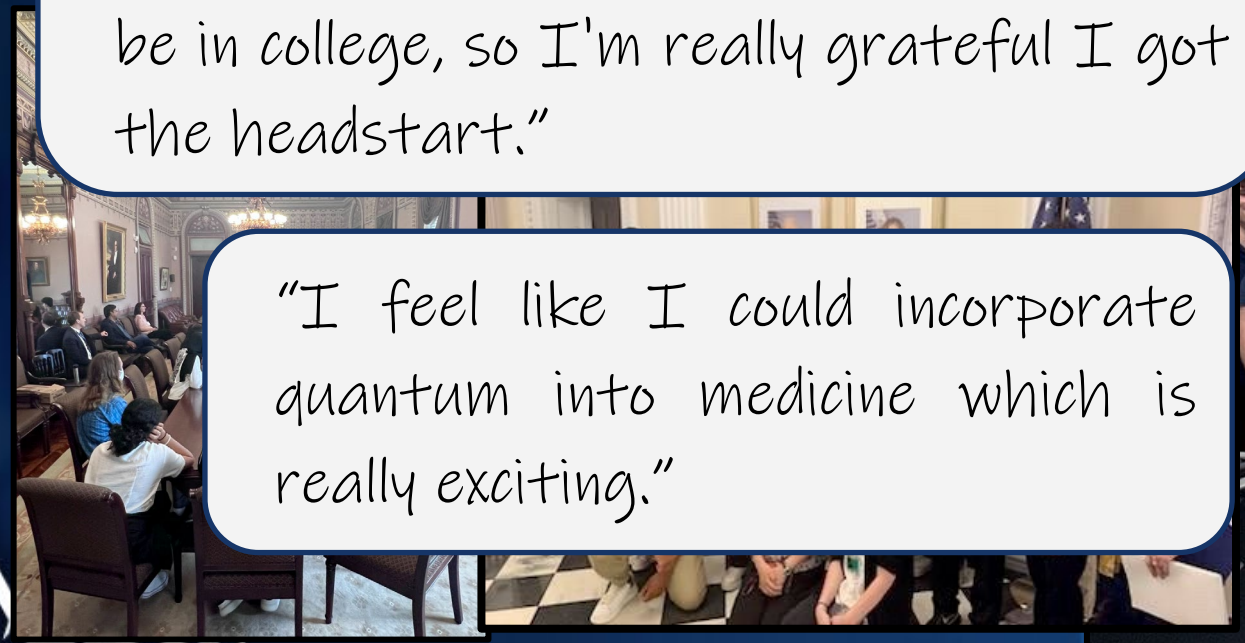
2 weeks online learning key concepts and about careers and applications
1 week immersive career-focused in-person

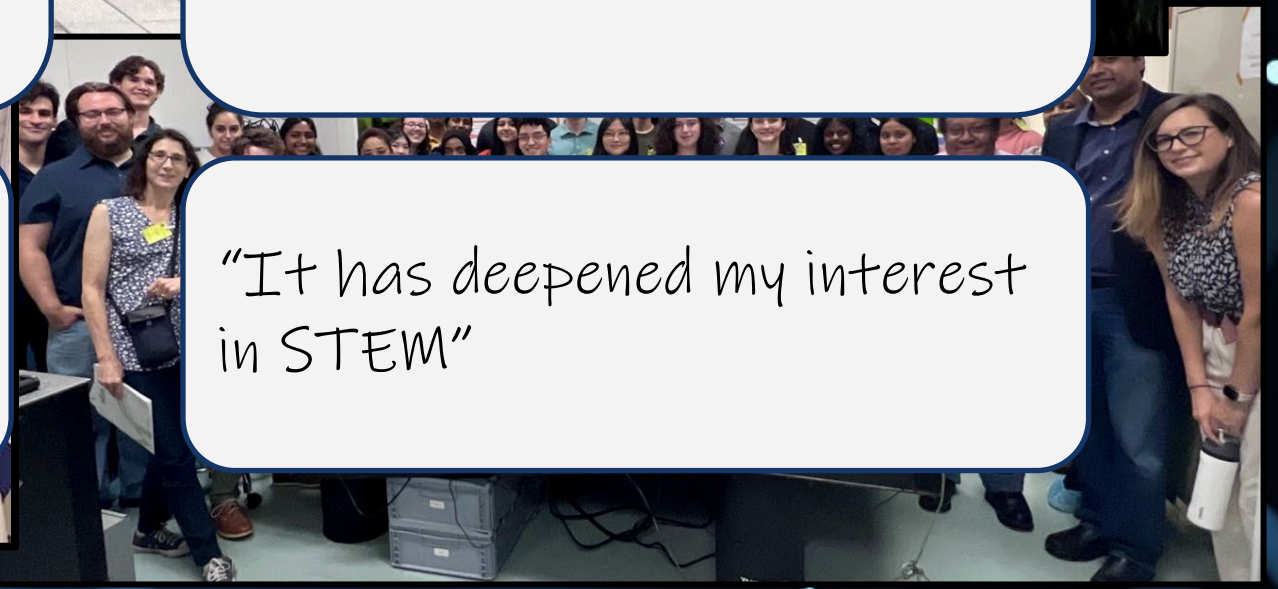




"If it wasn't for this program I wouldn't see myself getting interested in quantum until at least by the time I will be in college, so I'm really grateful I got the headstart."

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





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

"It has deepened my interest in STEM"

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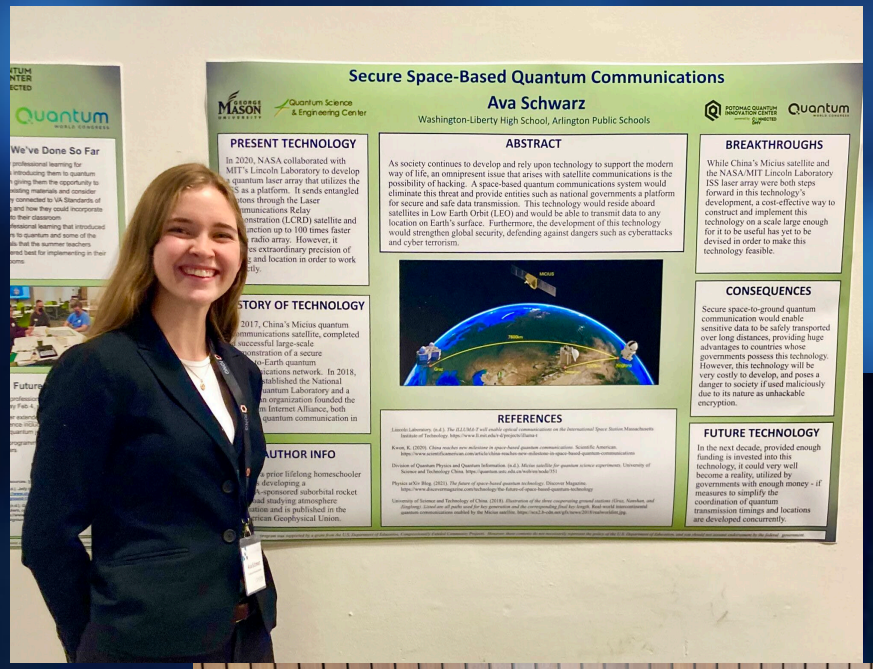
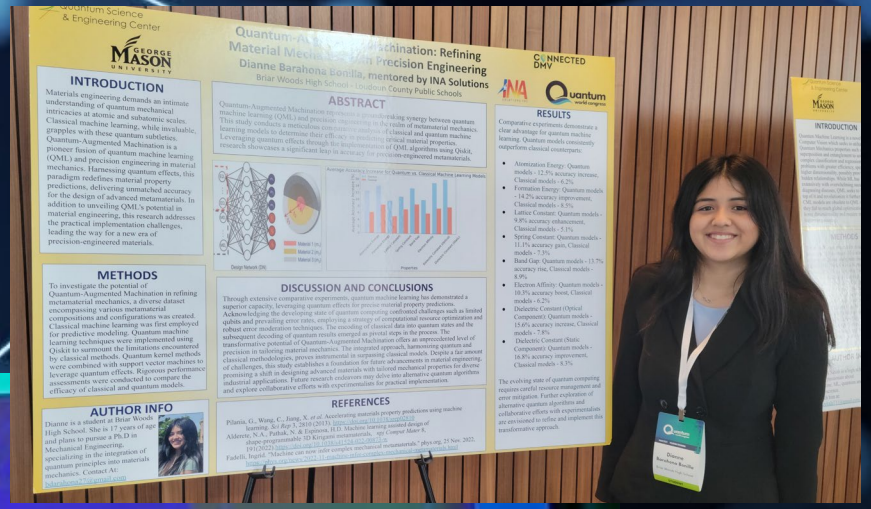
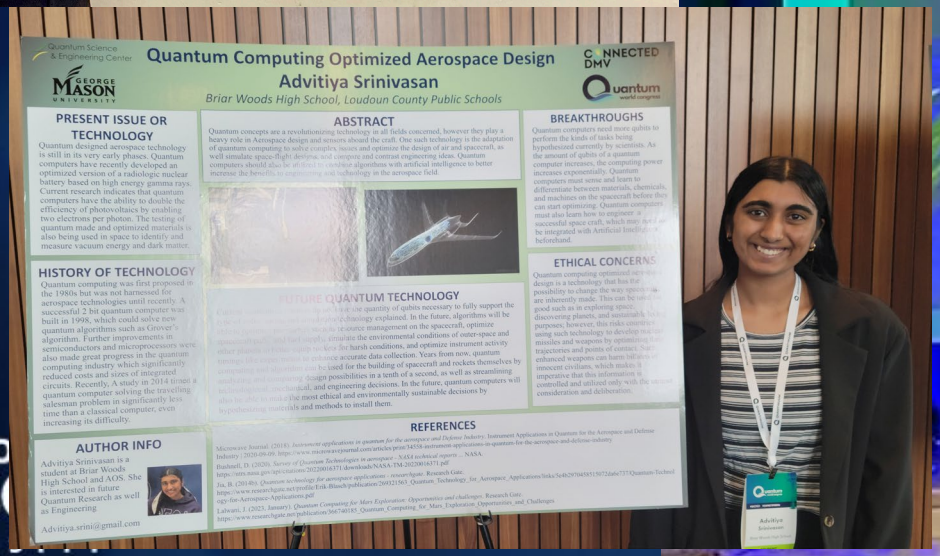
Optional internships and QWC Posters







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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."

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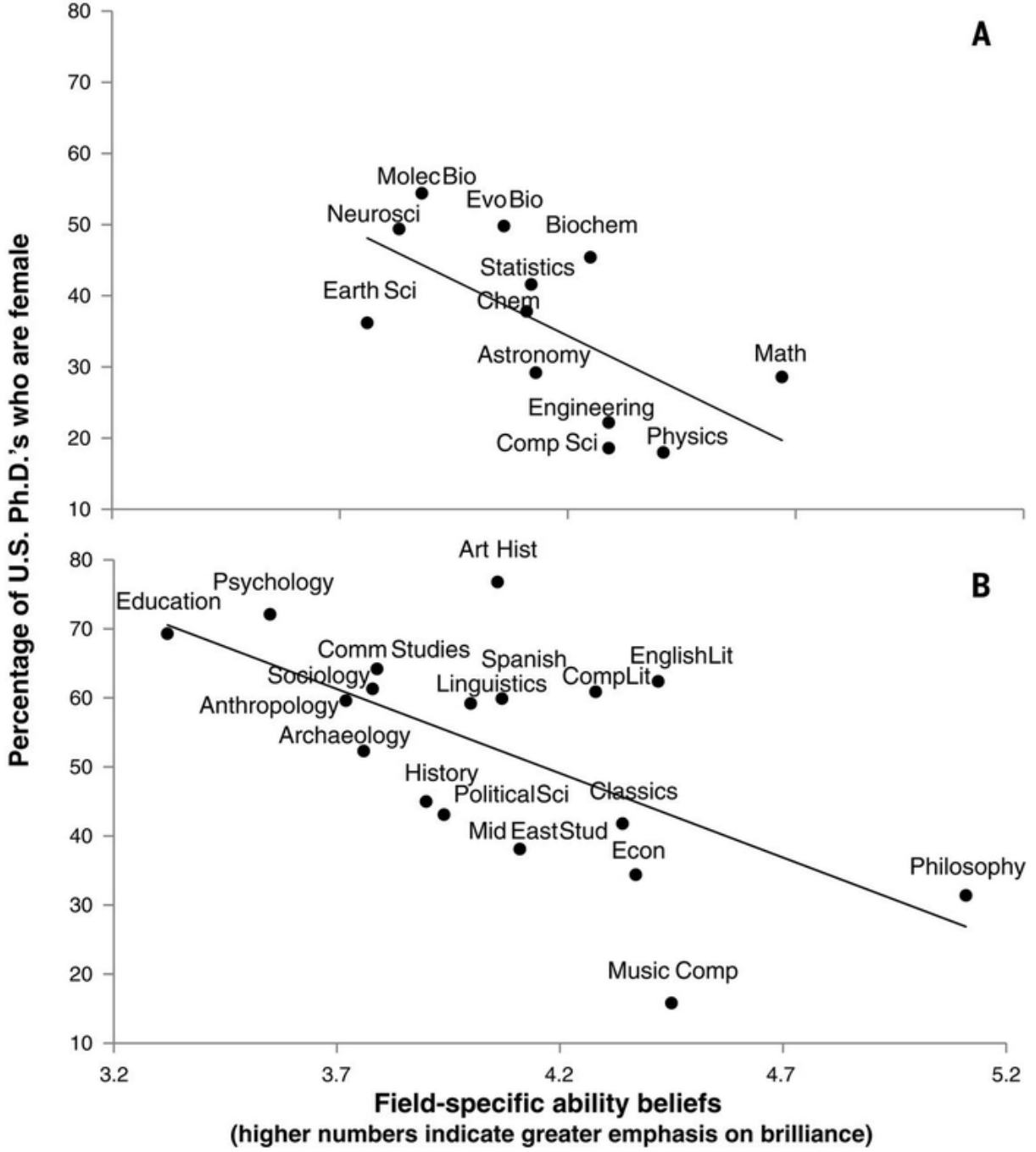

Fig. 1 **Field-specific ability beliefs and the percentage of female 2011 U.S. Ph.D.'s in (A) STEM and (B) Social Science and Humanities.**

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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

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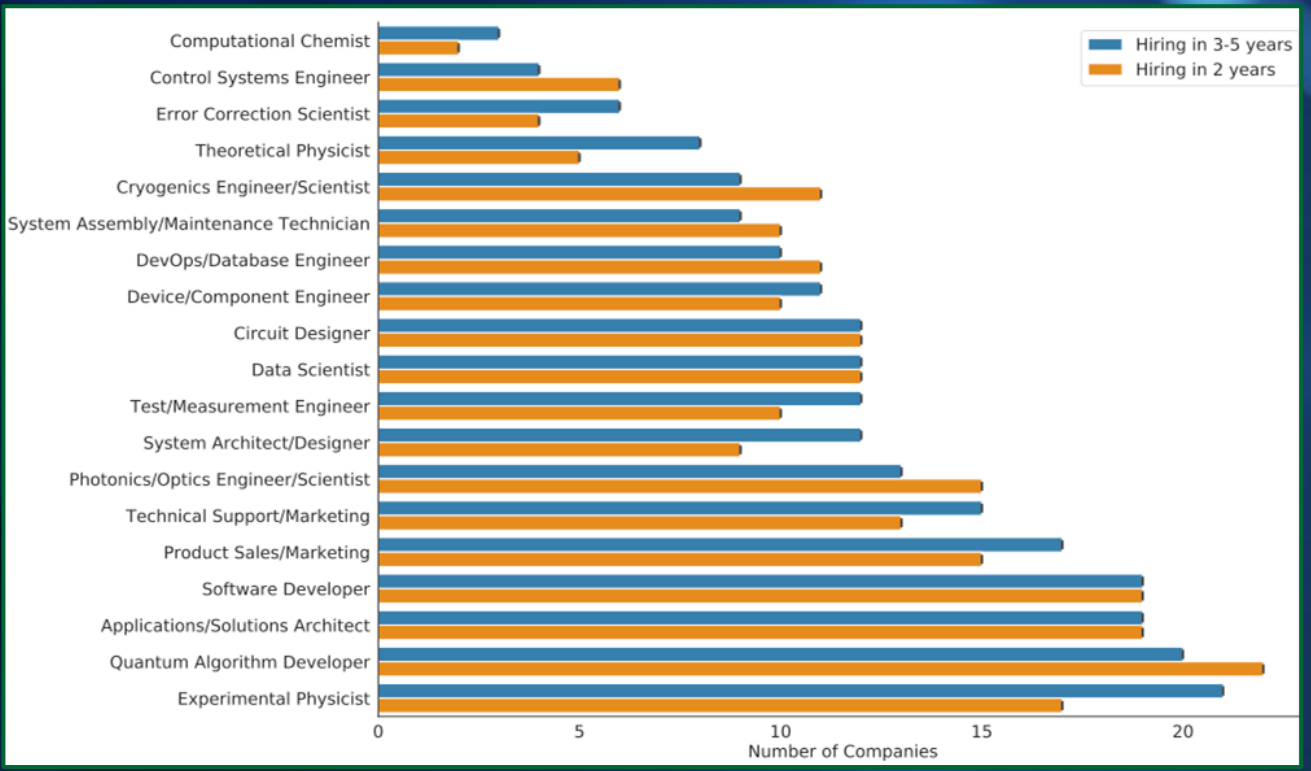
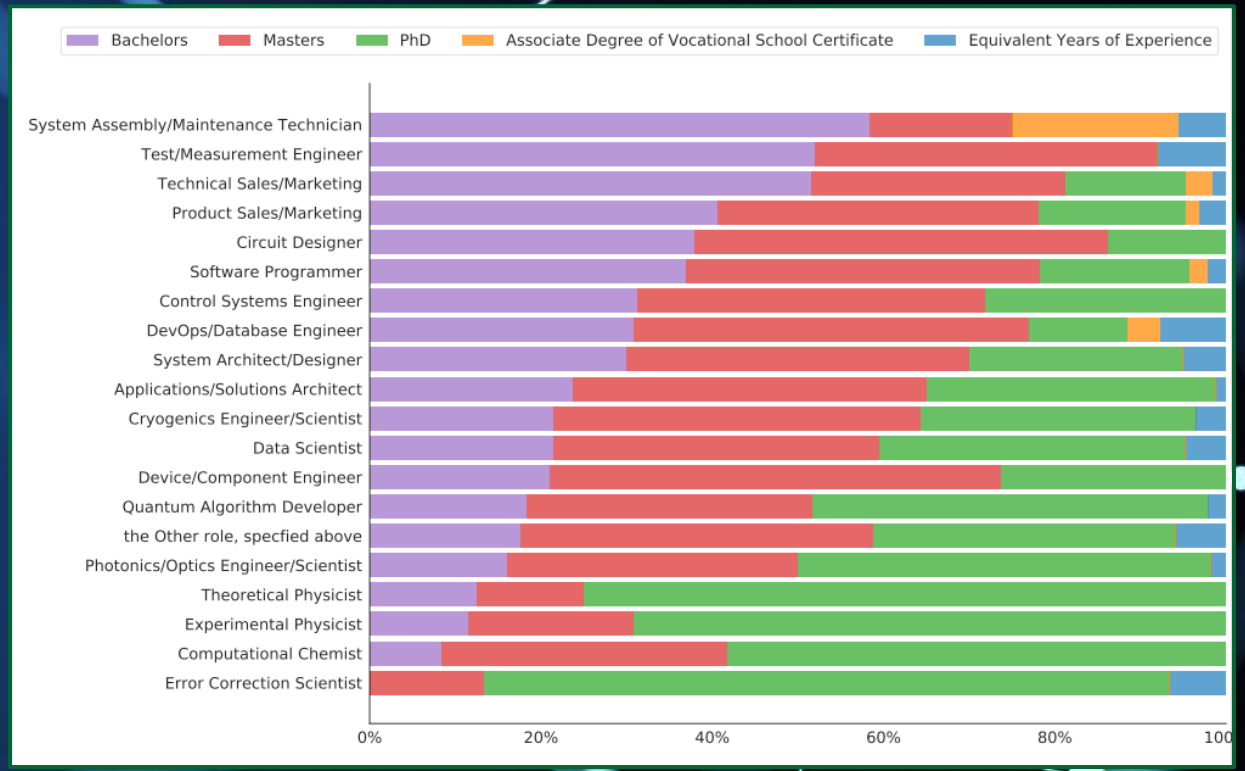
Who does Industry Expect to Hire?





Hughes et al 2021, http://arxiv.org/abs/2109.03601

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Excite ALL kids about quantum early!

"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."

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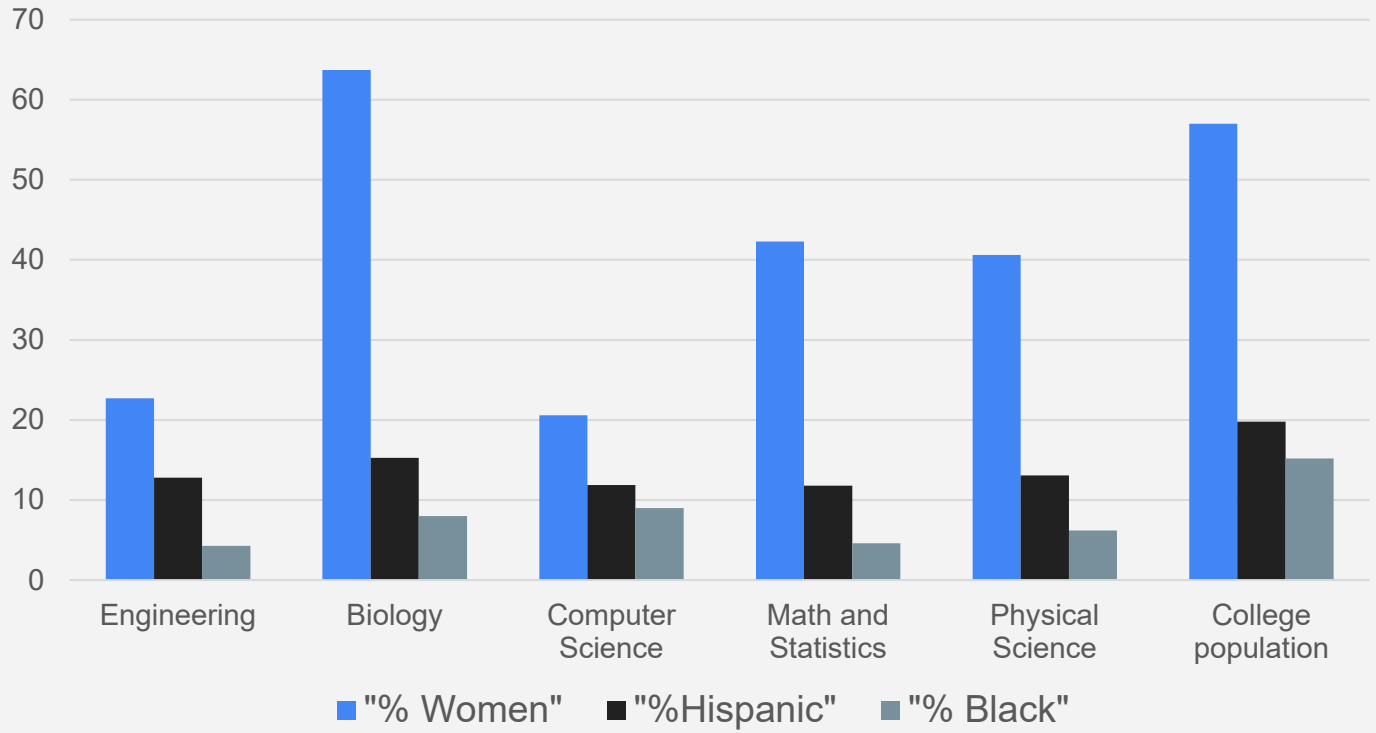
Challenge: Feeder Disciplines Struggle with Diversity

Without direct effort we risk reproducing these results in quantum



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