Teaching quantum at the high school level
Part 1. Identifying the problem space

November 25, 2020
IEEE Quantum Education
Quantum Universal Education
Challenge 1: learning curve

The challenge to teaching Quantum at the high school level is that most teachers need to become familiar with the material. — Erik DeBenedictis

Proposed solution 1a: Emerging technologies can debut in science fairs more easily than in a classroom setting.

So, could we use the IEEE WebEx meetings, at a different time of day, to have your associates, university faculty, and some people from industry discuss topics that a teacher would need to know to advise a quantum science fair project. WebEx has a substantial user capacity (1000?) and we could invite an audience of high-school teachers. The idea is that after supporting a quantum science fair project, a teacher would be better able to teach a class.

Spencer: quantum physics is one of those rare disciplines of physics where the best textbook on quantum, Shankar, does 100 pgs where it’s just learning the math, not thinking about physics. How do you make it fun without knowing what the physical interpretation is?

Erik: Daughter did a lot of stuff with science fairs. If a high school teacher wants to do classroom teaching in quantum, requires a lot of planning and a good bit of experience. Science fairs: teacher can support students, students are motivated, give teacher a way to get familiar with the material and subsequently teach a class.
Challenge 1: learning curve

The challenge to teaching Quantum at the high school level is that most teachers need to become familiar with the material. — Erik DeBenedictis

Cont. by Erik: there are networks of science fair organizers who provide materials for teachers and students who want to do science fairs. Some kids ex. in a desert want to do a science fair project on quantum, who do they talk to? Can reach out to here, Unitary Fund, etc. what other resources? Lia: online students’ communities of communities have lists of beginner-friendly projects, quantum game jams and articles Scott: Object to “teachers need to become familiar with the material”, yes if they need to teach but not if they are educating there’s other ways to get to learning without having the teacher learn first — other approaches ex. Creating a game, talk to other people and find resources online
Ideas from Erik DeBenedictis:

- "call for content" for these monthly meetings, for 20-minute pitches on something that would be useful to a teacher supporting a student, or a student. The content could range from lessons on quantum science and technology to overviews of resources available.

- Recordings would be saved on ed.quantum.ieee.org, but IEEE would not own the copyright so content can be given feedback and redistributed.

- Could invite teachers to these meetings, timed differently. Could be panel sessions where people who created content would present and discuss how to facilitate a quantum project.
5 Creating a quantum-smart workforce for tomorrow

Growing an American quantum-smart workforce with expertise in a broad range of physical, information, and engineering sciences is crucial for assuring sustained progress in QIS. However, America’s current educational system typically focuses on discrete disciplinary tracks, rarely emphasizing cross-disciplinary study that equips graduates for complex modern questions and challenges, prominently including QIS. While the responsibility of training students traditionally resides within the academic community, Government agencies and industry can partner with academia to meet the nation’s future needs.

Lia: universities are major-focused, students want to learn but face barriers to course registration, quantum computers would have applications in physics, CS, math, chemistry, pharmaceuticals, natural language processing, supply chain, finance, environmental science, ...

Erik: IEEE has courses / conferences that are cross-disciplinary

Lia: agree, but conferences are not super accessible to high schoolers and undergraduates

Erik: science fairs are accessible to bring a topic like quantum computing to a community and physically interact with it, made possible by the availability of the internet outside physical limitations
Challenge 2: QIS is interdisciplinary

National Strategic Overview for Quantum Information Science

5 Creating a quantum-smart workforce for tomorrow

Growing an American quantum-smart workforce with expertise in a broad range of physical, information, and engineering sciences is crucial for assuring sustained progress in QIS. However, America’s current educational system typically focuses on discrete disciplinary tracks, rarely emphasizing cross-disciplinary study that equips graduates for complex modern questions and challenges, prominently including QIS. While the responsibility of training students traditionally resides within the academic community, Government agencies and industry can partner with academia to meet the nation’s future needs.

Bruce: my kids have participated in science fairs as well. Most of them have become graders for the science fairs as they grow older. If there is a project in quantum computing or any other discipline, have to have people to grade the projects. If there was some way for us to identify qualified graders for science fairs, that would help as well. I agree that the student is fundamentally responsible for what goes on in the science fair and teacher is a facilitator but not expect teacher to be familiar with any/most of the projects students are undertaking. Am concerned we don’t have an inventory of people capable of understanding what the student did.
Challenge 2: QIS is interdisciplinary

Scott: challenge “finding a grader” for science fair: we’ve got actual computers that can run programs, simulators can function as graders

Erik: disagree, grading might not be the only aspect, students learn through this how to express themselves, identify rigor, be creative, be persuasive, understand what they can do. Requires 1-on-1 mentoring that’s extremely difficult to do with a computer program

Scott: accept that a mentor is really important, collaborators, etc. Those people’s function is different from a grader

5 Creating a quantum-smart workforce for tomorrow

Growing an American quantum-smart workforce with expertise in a broad range of physical, information, and engineering sciences is crucial for assuring sustained progress in QIS. However, America’s current educational system typically focuses on discrete disciplinary tracks, rarely emphasizing cross-disciplinary study that equips graduates for complex modern questions and challenges, prominently including QIS. While the responsibility of training students traditionally resides within the academic community, Government agencies and industry can partner with academia to meet the nation’s future needs.

Scott: challenge “finding a grader” for science fair: we’ve got actual computers that can run programs, simulators can function as graders

Erik: disagree, grading might not be the only aspect, students learn through this how to express themselves, identify rigor, be creative, be persuasive, understand what they can do. Requires 1-on-1 mentoring that’s extremely difficult to do with a computer program

Scott: accept that a mentor is really important, collaborators, etc. Those people’s function is different from a grader
Challenge 3: the learn, create, curate, share cycle of open-source resources

From silos to jungles

Today: open source vertical stacks

Tomorrow: a rich interlocking ecology in shared soil

This is not premature standardization
Below is from Will Zeng’s keynote at the quantum software workshop at the 2020 IEEE International Conference on Quantum Computing and Engineering

Proposed solution 3a, from Will Zeng’s keynote at QCE2020’s quantum software workshop:

Four strategies for the early quantum jungle
1. Healthy soil: build bottoms up community
2. Niches: target open niches
3. Specialization: choose modular design with small footprint
4. Symbiosis: choose reciprocal altruism

Erik: open-source didn't exist when I was a kid, but seems to be taking off exponentially due to the internet and so-forth. In the quantum area see a lot of open-source material, there is closed-source material as well. My view is if the people in charge of society recognize open-source as important then a percentage will be.

Lia: Mentioned in Rachel’s talk today about students being grateful for the scholarships/free access to learning
Challenge 4: students’ awareness of and exposure to QIS
This is fundamentally tied to diversity, equity, and inclusion.

Bavithra Govintharajah, a master’s student in quantum computing at RWTH Aachen, said:
Every new student who’s thinking about stepping into a specialized field is always hesitant about future job prospects and a doubt whether the field would thrive. On top of getting students hyped and interested it’s also important to boost their confidence about the future of this field when asking them to put in their future years of education in this field as the investment to make this field a reality.

Chandralekha: agree it’s a really important issue, think very carefully on how to provide access and opportunities to everybody. Starting early is very important, shouldn’t be focused on taking those courses that students aren’t able to join. In K-12 in the US, access and opportunities are really tied to what area you are in, the students who are the least privileged are the least likely to have AP and honors physics, CS, etc. as courses offered in their high school. Making sure that we actually center those kinds of students who never even find out that these kinds of exciting areas exist in which they could be the leaders and make a great contribution, providing them with meaningful opportunities, teaching about learning objectives so it’s meaningful, get students excited about the conceptual aspects of QIS where providing mentorship and support, they could make a difference, in the future you don’t necessarily need a PhD or undergrad degree to make an impact in this area — electronics / computer programming / statistics / vacuum / cryogenics technology, they might not even find out there’s this area where their expertise is needed. If we don’t connect K-12 we really will have missed those people. Our children will find out about it even if they didn’t learn in K-12 but that won’t be the case for many students. Happy to send papers on physics DE&I to anybody interested
Laur: spent last 3 yrs of life going full quantum, at Quarks Interactive made a video game for learning quantum without having to know math, have quantum education professors helping us improve it, making sure girls like the game. Tool to simulate absolutely any formal universal gate model. Have discussions with Claudia to bring it to US schools, if there are schools with no budget then we should give the game to free for those schools. Mission is to get people interested in quantum, get people to try what we made, contact if interested, gateway to math and Bloch sphere.
Thank you!