IEEE

The 2nd Quantum Science and Engineering Education Conference (QSEEC) 2023

Bellevue, WA, USA

September 17-18, 2023

Co-located with

IEEE QUANTUM WEEK

About QSEEC

Quantum Science and Engineering Education Conference (QSEEC) is an annual conference where education researchers and practitioners come together to discuss methodologies for curriculum and tool development for instruction and teaching. The emphasis is on addressing the need for quantum information science education, translating from teachable skills to real world applications, and sharing perspectives from educators and professionals in QSE alike. QSEEC is collocated with the IEEE International Conference on Quantum Computing & Engineering (QCE23, under a broader umbrella of IEEE Quantum Week).

IEEE Quantum Week — the IEEE International Conference on Quantum Computing and Engineering (QCE) — is bridging the gap between the science of quantum computing and the development of an industry surrounding it. As such, this event brings a perspective to the quantum industry different from academic or business conferences. IEEE Quantum Week is a multidisciplinary quantum computing and engineering venue that gives attendees the unique opportunity to discuss challenges and opportunities with quantum researchers, scientists, engineers, entrepreneurs, developers, students, practitioners, educators, programmers, and newcomers.

The 2nd IEEE Quantum Science and Engineering Education Conference 2023 (QSEEC23)

Sunday September 17 Venue: Hyatt Regency Bellevue				
Floor Room	2nd Floor Cedar A		2nd Floor Cedar B	
	Time	Session	Time	Session
	9:30-10:00	Break		
	10:00-11:30	QSEEC01: Welcome to QSEEC 2023 and Quantum in High Schools		
	11:30-13:00	Lunch	11:30-13:00	Lunch
	13:00-14:30	QSEEC02: Quantum in K-12	13:00-14:30	QSEEC05: Quantum Teaching
	14:30-15:00	Coffee Break	14:30-15:00	Coffee Break
	15:00-16:45	QSEEC03: Quantum Pedagogy	15:00-16:00	QSEEC06: Ethics and Society
	16:45-17:00	Break	16:00-17:00	Break
	17:00-18:00	QSEEC04: Posters	17:00-18:00	QSEEC07: Teaching Quantum in Pictures

Monday September 18 Venue: Hyatt Regency Bellevue		
Floor Room	2nd Floor Regency C	
	Time	Session
	9:30-10:00	Break
	10:00-11:30	QSEEC08: Quantum Outreach and Activities
	11:30-13:00	Lunch
	13:00-14:15	QSEEC09: Quantum Workforce Development
	14:30-15:00	Coffee Break
	15:00-16:15	QSEEC10: Quantum Education Tools

Schedule

Sun, Sept 17 Hyatt Regency Bellevue-2nd Floor Cedar A

BREAK
9:30 - 10:00

QSEEC01 : Welcome to QSEEC 2023 and Quantum in High Schools

Session Chair: Marek Osinski (University of New Mexico, USA)	
10:00 - 10:15	**Opening Remark: QSEEC23 Chair** *Marek Osinski (University of New Mexico, USA)*
10:15 - 11:00	**Keynote: Is teaching quantum in high school crazy?** *Karen Jo Matsler (The University of Texas at Arlington, USA)*
11:00 - 11:30	**Best Paper: QCaMP: Introducing quantum computing in high schools** *Megan Ivory (Sandia National Laboratories), Alisa Bettale (Lawrence Berkeley National Laboratory), Rachel Boren (New Mexico State University), Ashlyn Burch (Sandia National Laboratories), Jake Douglass (Sandia National Laboratories), Lisa Hackett (Sandia National Laboratories), Boris Kiefer (Sandia National Laboratories), Alina Kononov (Sandia National Laboratories, USA), Maryanne Long (New Mexico State University), Mekena Metcalf (HSBC International Banking, USA), Tzula Propp (New Mexico State University), Mohan Sarovar (Sandia National Laboratories)*

LUNCH
11:30 - 13:00

QSEEC02: Quantum in K-12

Session Chair: Brian La Cour (The University of Texas at Austin, USA)	
13:00 - 13:15	**Paper: Leveraging dual enrollment programs to expand secondary education in quantum computation** *Derrick Tucker (The University of Texas at Austin, USA)*
13:15 - 13:30	**Developing the quantum pipeline with K-12 teachers** *Nancy Holincheck (George Mason University, USA), Jessica Rosenberg (George Mason University, USA), Michele Colandene (George Mason University, USA), Ben Dreyfus (George Mason University, USA)*
13:30 - 13:45	**Teaching quantum computing in K-12 Career and Technical Education (CTE)** *Mark Newburn (Nevada K-12 Computer Science Advisory Committee, USA)*
13:45 - 14:00	**Qubit by Qubit: Can quantum computing be taught to middle school students?** *Gabbie Meis (The Coding School: Qubit by Qubit, USA), Kiera Peltz (The Coding School: Qubit by Qubit, USA)*
14:00 - 14:15	**Paper: Quantum Picturalism: Learning quantum theory in high school** *Selma Dündar-Coecke (Centre for Educational Neuroscience and Quantinuum, UK), Lia Yeh (University of Oxford and Quantinuum, UK), Caterina Puca (Quantinuum, UK), Sieglinde M.-L. Pfaendler (IBM Deutschland Research and Development GmbH, Germany), Muhammad Hamza Waseem (University of Oxford and Quantinuum, UK), Thomas Cervoni (Quantinuum, UK), Stefano Gogioso (University of Oxford, UK), Aleks Kissinger (University of Oxford, UK), Bob Coecke (Quantinuum, UK)*
14:15 - 14:30	**Educating to the "culture" of quantum technologies: Concepts for public awareness** *Zeki Can Seskir (Karlsruhe Institute of Technology, Germany)*

COFFEE BREAK
14:30 - 15:00

QSEEC03: Quantum Pedagogy

Session Chair: Lia Yeh (University of Oxford and Quantinuum, UK)	
15:00 - 15:30	**Poster Flash Talks**
15:30 - 15:45	**Paper: Investigating students' strength and difficulties in quantum computing** *Tunde Kushimo (Southern Methodist University, USA), Beth Thacker (Southern Methodist University, USA)*
15:45 - 16:00	**Undergraduate student knowledge and interest in quantum** *Jessica Rosenberg (George Mason University), Nancy Holincheck (George Mason University, USA), Michele Colandene (George Mason University, USA)*
16:00 - 16:15	**Quantum concepts teaching facilitated with a classical optics platform** *Xiaofeng Qian (Stevens Institute of Technology, USA)*
16:15 - 16:30	**Paper: QuCS: A lecture series on quantum computer software and system** *Zhiding Liang (University of Notre Dame, USA), Hanrui Wang (Massachusetts Institute of Technology, USA)*
16:30 - 16:45	**The Quantum Computing Conceptual Survey: Preliminary work and next steps** *Josephine Meyer (University of Colorado Boulder, USA), Gina Passante (California State University, Fullerton, USA), Steven J. Pollock (University of Colorado Boulder, USA), Bethany R. Wilcox (University of Colorado Boulder, USA)*

BREAK
16:45 - 17:00

QSEEC04: Posters

Session Chair: Kevin Joven (Universidad del Valle, Colombia) and Akshay Bansal (Virginia Tech, USA)	
17:00 - 18:00	**Interactive Poster Session**

Schedule

Sun, Sept 17 Hyatt Regency Bellevue-2nd Floor Cedar B

LUNCH
11:30 - 13:00

QSEEC05: Quantum Teaching

Session Chair: Marek Osinski (University of New Mexico, USA)	
13:00 - 13:15	**Paper: Taiwan Student Quantum Computer Society** *Ran-Yu Chang (National Yang Ming Chiao Tung University, Taiwan), Yu-Chao Hsu (National Cheng Kung University, Taiwan), Tsung-Wei Huang (Chung Yuan Christian University, Taiwan)*
13:15 - 13:30	**How to use chatbots for learning and teaching quantum programming** *Pablo Suárez Vieites (University of Galway, Ireland)*
13:30 - 14:30	**Tutorial 1: Quantum Abacus** *Dan-Adrian German, Alex Alani (Indiana University Bloomington, USA)*

COFFEE BREAK
14:30 - 15:00

QSEEC06: Ethics and Society

Session Chair: Brian La Cour (The University of Texas at Austin, USA)	
15:00 - 16:00	**Tutorial 2: Quantum Ethics** *Josephine Meyer (University of Colorado Boulder, USA)* **A holistic approach to quantum ethics education** *Joan Arrow (University of Waterloo, Canada), Rodrigo Araiza Bravo (Harvard University, USA), Sara Marsh (University of Waterloo, Canada), and Josephine Meyer (University of Colorado Boulder, USA)*

BREAK
16:00 - 17:00

QSEEC07: Teaching Quantum in Pictures

Session Chair: Marek Osinski (University of New Mexico, USA)	
17:00 - 18:00	**Tutorial 3: Quantum in Pictures** *Stefano Gogioso (University of Oxford, UK) and Lia Yeh (University of Oxford and Quantinuum, UK)*

Schedule

Sun, Sept 18 Hyatt Regency Bellevue-2nd Floor Regency C

BREAK
9:30 - 10:00

QSEEC08 : Quantum Outreach and Activities

Session Chair: Lia Yeh (University of Oxford and Quantinuum, UK)	
10:00 - 10:30	Invited Talk: **Paper: A physics lab inside your head: Quantum thought experiments as an educational** *Maria Violaris (University of Oxford, UK)*
10:30 - 10:45	**Paper: Teaching quantum computing using Microsoft Quantum Development Kit and Azure Quantum** *Mariia Mykhailova (Microsoft, USA)*
10:45 - 11:00	**Quantum computing educational tools based on the Quantum Enigmas video series** *Ghislain Lefebvre (Institut Quantique, Université Sherbrooke, Canada)*
11:00 - 11:15	**Paper: Design of quantum machine learning course for a computer science program** *Sathish Kumar (Cleveland State University, USA), Temitope Adeniyi (Cleveland State University, USA), Ahmad Alomari (Cleveland State University, USA), Santanu Ganguly (Northrup Grumman, UK)*
11:15 - 11:30	**Paper: A brief overview of programmed instructions for quantum software** *Richard Wolf (University of Galway, Ireland), Sho Araiba (University of Hawaii, USA)*

LUNCH
11:30 - 13:00

QSEEC09: Quantum Workforce Development

Session Chair: Brian La Cour (The University of Texas at Austin, USA)	
13:00 - 13:30	Invited Talk: **Designing and implementing a new Quantum Science and Engineering graduate degree program at the University of Delaware** *Matthew Doty (University of Delaware, USA)*
13:30 - 13:45	**Building capacity for regional quantum ecosystems: A look at Cleveland, Ohio** *Gabbie Meis (Coding School: Qubit by Qubit, USA)*
13:45 - 14:00	**Voluntary mentoring initiative aimed at enhancing quantum computing abilities** *Michał Stęchły (PsiQuantum, Canada), Alberto Maldonado-Romo (Instituto Politécnico Nacional, Mexico)*
14:00 - 14:15	**Concepts for upskilling the industry workforce in QT hardware** *Oliver Bodensiek (Physikalisch-Technische Bundesanstalt, Germany), Dion Timmermann (Physikalisch-Technische Bundesanstalt, Germany), Alexandros Metavitsiadis (Physikalisch-Technische Bundesanstalt, Germany), Larissa Braun (Physikalisch-Technische Bundesanstalt, Germany), Daniel Stuhlmacher (Physikalisch-Technische Bundesanstalt, Germany)*

COFFEE BREAK
14:30 - 15:00

QSEEC10: Quantum Education Tools

Session Chair: Marek Osinski (University of New Mexico, USA)	
15:00 - 15:15	**Paper: QWalkVis: Quantum Walks Visualization Application** *Addie Jordon (University of Victoria, Canada), Austin Hawkins-Seagram (University of Victoria, Canada), Samantha Norrie (University of Victoria, Canada), José Ossorio (University of Victoria, Canada), Ulrike Stege (University of Victoria, Canada)*
15:15 - 15:30	**Paper: Harnessing the VQE to simulate quantum chemistry in an undergraduate project: Properties of hydrogen, oxygen and water molecules** *Shah Ishmam Mohtashim (University of Dhaka, Bangladesh), Sheikh Mahatabuddin (Bangladesh Atomic Energy Regulatory Authority, Bangladesh), Md. Abdul Jabbar (University of Dhaka, Bangladesh)*
15:30 - 15:45	**Paper: QPCC: a quantum programming course for inhomogeneous cohorts of professional learners** *Emil Dimitrov (ICHEC, Ireland), Conor Dunne (Irish Centre for High-End Computing (ICHEC), Ireland), Venkatesh Kannan (ICHEC, Ireland), Karthik Krishnakumar (ICHEC, Ireland), Pablo Lauret Martínez de Rituerto (ICHEC, Ireland), Pablo Suárez Vieites (ICHEC, Ireland), Rajarshi Tiwari (ICHEC, Ireland), Richard Wolf (ICHEC, Ireland)*
15:45 - 16:00	**Paper: Exploring architecture of Qiskit Runtime for educational enablement** *Syed Farhan Ahmad (NC State University, USA), Nate Earnest-Noble (IBM Quantum, USA), Gregory Byrd (NC State University, USA), Hamed Mohammadbagherpoor (IBM Quantum, USA)*
16:00 - 16:15	**Utilizing automated quantum software management tools and a write-once-target-all quantum device python package to greatly reduce friction in education and coding environment setup** *Ricky Young (Qbraid, USA), Ryan Hill (Qbraid, USA), Alberto Maldonado-Romo (Instituto Politécnico Nacional, Mexico)*

The 2nd Quantum Science and Engineering Education Conference (QSEEC)

QSEEC01 : Welcome to QSEEC 2023 and Quantum in High Schools

Sunday, Sept 17, 2023 Hyatt Regency Bellevue-2nd Floor Cedar A (10:00 – 11:30)

Session Chair: Marek Osinski (University of New Mexico, USA)

Keynote Talk

Keynote speaker: Karen Jo Matsler (The University of Texas at Arlington, USA)

Dr. Karen Jo Matsler has been in STEM education for nearly 35 years and is the PI for the Quantum for All project. She currently supervises STEM Student teachers at UTeach Arlington, TX, but she has taught high school and university physics for over 30 years and served as a district K-12 Science Curriculum Coordinator. Her classroom experience, research in education, and long history of working with teachers have provided insights as to how to teach quantum in grades K-12.

Talk Title: Is Teaching Quantum Information Science in K-12 Crazy?

Karen Matsler (The University of Texas at Arlington, USA)

Abstract: In 2019 the National Quantum Initiative was signed into law with the intent of increasing quantum awareness at the K-12 level. Yet we are still behind other countries, especially China and Europe, in terms of our investment in our future quantum workforce. How do we catch up? Quantum centers, industrial partnerships with universities, and research are clearly important, but we must also consider the pipeline, which are precollege students. The Quantum for All project (funded by NSF) supports high school teachers who want to integrate quantum information science and engineering (QISE) into the high school STEM curriculum. Is this crazy? This talk will share insights, challenges, successes, and research related to these efforts.

Best Paper

QCaMP: Introducing quantum computing in high schools

Megan Ivory (Sandia National Laboratories), Alisa Bettale (Lawrence Berkeley National Laboratory), Rachel Boren (New Mexico State University), Ashlyn Burch (Sandia National Laboratories), Jake Douglass (Sandia National Laboratories), Lisa Hackett (Sandia National Laboratories), Boris Kiefer (Sandia National Laboratories), Alina Kononov (Sandia National Laboratories, USA), Maryanne Long (New Mexico State University), Mekena Metcalf (HSBC International Banking, USA), Tzula Propp (New Mexico State University), Mohan Sarovar (Sandia National Laboratories)

Abstract: The nascent but rapidly growing field of Quantum Information Science and Technology (QIST) has led to an increased demand for skilled quantum workers and an opportunity to build a diverse workforce at the outset. In order to meet this demand and encourage underrepresented groups in STEM to consider a career in QIST, we have developed an experiential curriculum for introducing quantum computing to teachers and students at the high school level with no prerequisites. In 2022, we launched the Quantum Computing, Math, and Physics summer camp "QCaMP" in which we delivered this curriculum over the course of two virtual one-week long summer camps, one targeting teachers and another targeting students. Here, we present an overview of the camp objectives, curriculum design, hands-on activities, as well as the results from the evaluation of both camps and the outlook for expanding QCaMP in future years to further attract underrepresented students into quantum career tracks.

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QSEEC02: Quantum in K-12

Sunday, Sept 17, 2023 Hyatt Regency Bellevue-2nd Floor Cedar A (13:00 – 14:30)

Session Chair: Brian La Cour (The University of Texas at Austin, USA)

Leveraging dual enrollment programs to expand secondary education in quantum computation

Derrick Tucker (The University of Texas at Austin, USA)

Abstract: As practical quantum computers near fruition and the market for quantum technology rapidly expands, there is a growing need for a quantum workforce prepared to carry quantum computation into the mainstream. Once primarily the domain of researchers and theoreticians, there has been a steady expansion of quantum information science into undergraduate programs to build the requisite expertise in optics, computer science, engineering, and materials science that will be needed in the quantum industries of the near future. To better prepare students for post-secondary quantum coursework, it is important to scale up quantum education at the secondary level. This article details the work being done at The University of Texas at Austin to pilot the first full-year high school course in optics-based quantum computing and to transition the course to a dual-enrollment model under the OnRamps distance education umbrella at The University of Texas at Austin in which college-aligned content is delivered to high schools across the state. Within this program, we are laying the groundwork for reaching a greater number of underrepresented students and improving participation in STEM fields through a unique combination of innovative pedagogy, technological-enhancement, and continuing professional development to deepen the expertise of high school teachers that deliver quantum computing classes.

Developing the Quantum Pipeline with K-12 Teachers

Nancy Holincheck (George Mason University, USA), Jessica Rosenberg (George Mason University, USA), Michele Colandene (George Mason University, USA), Ben Dreyfus (George Mason University, USA)

Abstract: Quantum technologies have the potential to transform industries within and beyond STEM, increasing the need to prepare students for jobs in quantum and quantum-adjacent fields. Historically, most quantum instruction occurred in undergraduate and graduate STEM programs, and more recent K-12 quantum education efforts have centered on students in advanced high school physics and computer science courses. This effectively reduces access to quantum, as most high school students do not take physics and even fewer have the option to take computer science. To diversify the future quantum workforce in this fast-changing field, we must introduce students to quantum concepts across the K-12 grade levels and disciplines. We will describe our work with K-12 teachers to develop their understanding of quantum concepts and their thinking about how it might be incorporated into their classroom. We will discuss lessons learned about how quantum can be introduced at a variety of grade levels and our ongoing work to develop curricular resources for K-12 classrooms.

Teaching Quantum Computing in K-12 Career and Technical Education (CTE)

Mark Newburn (Nevada K-12 Computer Science Advisory Committee, USA)

Abstract: Current efforts to introduce quantum computing into the formal K-12 education systems often focus on core academic subjects such as physics and chemistry. The interdisciplinary nature of quantum computing and the tight rules associated with K-12 core subjects can make adding significant quantum computing content difficult. In addition to traditional core academic courses, many K-12 education systems offer specialized Career and Technical Education (CTE) courses. Because CTE courses are designed to meet specific workforce needs, they can be more career-focused, project-oriented, interdisciplinary, and in-depth. CTE courses operate under different rules, such as teacher licensing and content expectations, and may come with additional funding. Some CTE course sequences even allow high school students to earn an industry-recognized credential. This talk will cover the differences between traditional K-12 core academic education courses and CTE courses, highlighting the advantages of CTE for subjects like quantum computing. Finally, this talk will propose specific CTE career clusters, course sequences, and individual CTE courses that could incorporate quantum computing.

Qubit by Qubit: Can quantum computing be taught to middle school students?

Gabbie Meis (The Coding School: Qubit by Qubit, USA), Kiera Peltz (The Coding School: Qubit by Qubit, USA)

Abstract: Studies show that middle school–grades 5-8–is one of the most critical times of development in a student's Science, Technology, Engineering, and Mathematics (STEM) identity. It is in this period that students, for a variety of reasons, 'self-select' out of topics such as physics, math, and engineering–the fundamental building blocks of quantum computing.

The world is facing a global shortage of trained, skilled workers needed for the second quantum revolution. In order to build an equitable and inclusive quantum workforce, we may need to look even beyond the high school level to begin training students in today's technology of tomorrow. In this presentation, Qubit by Qubit will share findings from their middle school quantum computing program, both virtual and in-person, and discuss the utility and benefit of introducing quantum to students in this key STEM-identity development period.

Quantum Picturalism: Learning quantum theory in high school

Selma Dündar-Coecke (Centre for Educational Neuroscience and Quantinuum, UK), Lia Yeh (University of Oxford and Quantinuum, UK), Caterina Puca (Quantinuum, UK), Sieglinde M.-L. Pfaendler (IBM Deutschland Research and Development GmbH, Germany), Muhammad Hamza Waseem (University of Oxford and Quantinuum, UK), Thomas Cervoni (Quantinuum, UK), Stefano Gogioso (University of Oxford, UK), Aleks Kissinger (University of Oxford, UK), Bob Coecke (Quantinuum, UK)

Abstract: Quantum theory is often regarded as challenging to learn and teach, with advanced mathematical prerequisites ranging from complex numbers and probability theory to matrix multiplication, vector space algebra and symbolic manipulation within the Hilbert space formalism. It is traditionally considered an advanced undergraduate or graduate-level subject.

In this work, we challenge the conventional view by proposing "Quantum Picturalism" as a new approach to teaching the

fundamental concepts of quantum theory and computation. We establish the foundations and methodology for an ongoing educational experiment to investigate the question "From what age can students learn quantum theory if taught using a diagrammatic approach?".

We anticipate that the primary benefit of leveraging such a diagrammatic approach, which is conceptually intuitive yet mathematically rigorous, will be eliminating some of the most daunting barriers to teaching and learning this subject while enabling young learners to reason proficiently about high-level problems.

We posit that transitioning from symbolic presentations to pictorial ones will increase the appeal of STEM education, attracting more diverse audience.

Educating to the "culture" of Quantum Technologies: Concepts for Public Awareness

Zeki Can Seskir (Karlsruhe Institute of Technology, Germany)

Abstract: In this study we offer a conceptual and practical contribution to the field of STEM education by investigating the concepts educators may include in Quantum Technologies (QT) outreach activities. We embed our approach in the discipline-culture (DC) framework, in which we consider the cultural nuances of QT as an important factor which must not be ignored in education efforts. To this end, a Delphi Study conducted by the pilot project Quantum Technologies Education For Everyone (QuTE4E), investigating key concepts for QT outreach, was conducted between December 2021 and June 2022. Here we present the results of the study, analysed through the DC framework, and consider the implications for designing QT outreach activities. The data hints at the perceived value of highlighting core concepts of Quantum Mechanics, while also raising the question of whether QT sits as a discipline of Physics, Computer Science, or elsewhere. The results of this study provide valuable insights and guidance for individuals and organisations engaged in quantum outreach efforts, as well as those interested in learning more about this rapidly-evolving field.

QSEEC03: Quantum Pedagogy

Sunday, Sept 17, 2023 Hyatt Regency Bellevue-2nd Floor Cedar A (15:00 – 16:45)

Session Chair: Lia Yeh (University of Oxford and Quantinuum, UK)

Investigating students' strength and difficulties in quantum computing

Tunde Kushimo (Southern Methodist University, USA), Beth Thacker (Southern Methodist University, USA)

Abstract: Quantum Computing is an exciting field that draws from information theory, computer science,mathematics, and quantum physics to process information in fundamentally new ways. There is an ongoing race to develop practical/reliable quantum computers and increase the quantum workforce. This needs to be accompanied by the development of quantum computing programs, courses and curricula coupled with the development and adoption of evidence-based materials and pedagogies to support the education of the next generation of quantum information scientists and workforce. At our university, we introduced an introductory course in Quantum Computing to undergraduate students and conducted a case study to investigate the strengths and difficulties of these students in quantum computing after taking the introductory course. Our goal is to contribute to the improvement of quantum computing education while understanding the topics that the students find easy to comprehend and topics that are difficult to comprehend. We conducted a series of interviews to identify these strengths and difficulties. This investigation is essential to help train the next generation of quantum scientists and researchers because it gives information and direction to quantum computing education, and it also helps us to develop research-based teaching and learning materials. We report on the results of these interviews and our initial work on the development of evidence-based materials for teaching an introductory course in Quantum Computing.

Undergraduate Student Knowledge and Interest In Quantum

Jessica Rosenberg (George Mason University), Nancy Holincheck (George Mason University, USA), Michele Colandene (George Mason University, USA)

Abstract: Historically quantum education has been focused within physics at the upper-level undergraduate and graduate level. As we move into the second quantum revolution and look to expand understanding of quantum and prepare today's students for the broad range of jobs in the field, we will need to educate students earlier and with a variety of STEM backgrounds. We have surveyed and interviewed undergraduate STEM students to understand what they know about quantum and the ways in which the subject interests them. We will discuss both the opportunities and barriers presented by students' interests and understanding. Only by addressing the cross-section between student perspectives and employer needs will we be able to create inclusive programs to build the quantum workforce of the future.

Quantum Concepts Teaching Facilitated with a Classical Optics Platform

Xiaofeng Qian (Stevens Institute of Technology, USA)

Abstract: Quantum wave equation and wave functions share many common properties with classical light wave equation and wave fields, e.g., vectors and vector spaces, ampli- tude superposition, matrix representation, interference, coherence, and even entanglement, etc. Based on these overlaps, we propose a new way of introducing quantum concepts and quantum information ideas through the analogous classical light context. An optics plat- form has the advantage of being visualizable, low-cost, robust and easy to control, thus accessible to college and pre-college students.

QuCS: A lecture series on quantum computer software and system

Zhiding Liang (University of Notre Dame, USA), Hanrui Wang (Massachusetts Institute of Technology, USA)

Abstract: In recent years, quantum computing has garnered a significant amount of attention as a burgeoning computing paradigm. With continuous advancements in quantum hardware and quantum computing theory, practical applications of quantum computing are now within reach. In order to expedite the journey towards quantum supremacy, a

growing number of researchers have shifted their focus to the software and system level (SSL) support for quantum computers. Recent SSL research breakthroughs indicate that it can significantly reduce the gap between the hardware requirements of quantum algorithms and the current devices, by orders of magnitude.

Regrettably, we have identified a shortfall in quantum SSL courses being offered in several universities. To address this issue, we propose the creation of the quantum computer systems lecture series, as detailed in this paper. The purpose of the lecture series is to increase the visibility of quantum computing SSL among the public and to promote the participation of people from different backgrounds at different universities in different countries in quantum computing research in order to increase the diversity of the field.

The lecture series commences with an introductory session designed to familiarize the audience with the fundamental concepts and basics of quantum computing. Following the introduction, research topics will be presented in a subsequent session, discussing cutting-edge research directions and the latest findings.

In this paper, we provide an outline of the lecture series format, a summary of the topics covered, and an explanation of their implications and importance.

The Quantum Computing Conceptual Survey: Preliminary work and next steps

Josephine Meyer (University of Colorado Boulder, USA), Gina Passante (California State University, Fullerton, USA), Steven J. Pollock (University of Colorado Boulder, USA), Bethany R. Wilcox (University of Colorado Boulder, USA)

Abstract: The Quantum Computing Conceptual Survey (QCCS) is a proposed research-based assessment intended to measure student understanding of the fundamental concepts and skills of quantum computing. We report on preliminary research establishing the need for and scope of the QCCS and initial stages of item development. We also present opportunities for educators to be involved in the piloting of the QCCS in the 2023-2024 academic year.

QSEEC04: Posters

Sunday, Sept 17, 2023 Hyatt Regency Bellevue-2nd Floor Cedar A (17:00 – 18:00)

Session Chair: Kevin Joven (Universidad del Valle, Colombia) and Akshay Bansal (Virginia Tech, USA)

Interactive Poster Session

Quantum Initiative in Undergraduate Education at Virginia Military Institute

Daniela Topasna, Gregory Topasna, George Brooke, and Manula Pathirana (Virginia Military Institute, USA)

Abstract: The National Quantum Initiative Act signed in 2018 promotes the advancement and development of quantum science in information and related technologies. National agencies, such as the National Science Foundation, Department of Energy, and the National Institute of Standard and Technologies are major contributors to the program. The efforts include university and industry researchers, educators, businesses, and other organizations. In all levels of education, there is an increased need for education, training, and research in the fields of quantum physics, materials science and engineering, quantum sensing, quantum computational science, applied mathematics and algorithm development, quantum information theory, and other related fields. We present our development of a focused, innovative program at an undergraduate institution that introduces and educates students in the field of quantum science and information. We introduce four technical elective courses related to quantum science and quantum information that are focused on experimental and computational activities in nanomaterials and thin films, superconductivity, astronomy, optics, and optical spectroscopy. Students learn key concepts such as quantum states, quantum information science, qubit, entanglement, coherence, quantum computing, quantum sensing, and quantum communication to name a few. They also participate in the interdisciplinary aspect of the field, they learn its basic requirements, advances, and projected developments. Based on interest and demand, we envision novel interdisciplinary courses to be further developed.

Quantum education for high school in Taiwan

Yi-Chuang Tsai (Department of Information and Computer Engineering, Chung Yuan Christian University, Taiwan) and Tsung-Wei Huang (Department of Intelligent Computing and Big Data, Chung Yuan Christian University, Quantum Information Center, Taiwan)

Abstract: Quantum science has been considered a revolution. It can change the behaviors of all life, including the communication method, the logic of simulation, sensing, and computation platform. Hence, it's an important to teach quantum knowledge to the next generation. In Taiwan, our proposal starts to touch the quantum knowledge and passing the basic math, physics, and quantum computation in high school level. Our past work had three main directions in quantum education including the training seed teachers, short and summer school for high school students and developing the suitable textbook. In this report, we only focus on the summer school for high school student part. We run more than six summer schools for passing three years, and each time has three days. We have two main purposes for each day. Both purpose of the first day are what quantum physics is and what the main math tool is. The second day is how to use quantum gate to build the classical logical computation and realizing the Deutsch and Deutsch-Jozsa algorithm. The third day is realizing the Grover's algorithm. In this report we focus on acceptability, understanding and feeling when students learn the Deutsch and Deutsch-Jozsa algorithm. According to our statistical result, about 80% students feel they understand Deutsch and Deutsch-Jozsa algorithm, although about 80% students feel it's not easy to learn. Hence, according to our result, we believe it's possible to make high school students accept, understand and establish interesting in quantum computation.

Educational initiatives at the Quantum Ethics Project

Joan Étude Arrow (University of Waterloo, Canada), Rodrigo Araiza Bravo (Harvard University, USA), Anna Knörr (Perimeter Institute, University of Waterloo, Canada), Sara E. Marsh (University of Waterloo, Canada), Josephine Meyer (University of Colorado Boulder), Zeki Seskir (Karlsruhe Institute of Technology, Germany), and David Sidi (Yale University, USA)

Abstract: The Quantum Ethics Project is a grassroots initiative to promote the study and teaching of quantum ethics, an academic discipline studying the ethical and social implications of quantum technologies with the goal of ensuring an equitable and socially just Second Quantum Revolution that maximizes public good. We introduce the educational and curriculum development initiatives of the Quantum Ethics Project as well as opportunities for broader growth and community involvement.

Investigating student interpretations of the difference between classical and quantum computers

Josephine Meyer (University of Colorado Boulder, USA), Gina Passante (California State University, Fullerton, USA), Steven J Pollock (University of Colorado Boulder, USA), Bethany R. Wilcox (University of Colorado Boulder, USA)

Abstract: Significant attention in the PER community has been paid to student cognition and reasoning processes in undergraduate quantum mechanics. Until recently, however, these same topics have remained largely unexplored in the context of emerging interdisciplinary quantum information science (QIS) courses. We conducted exploratory interviews with 22 students in an upper-division quantum computing course at a large R1 university crosslisted in physics and computer science, as well as 6 graduate students in a similar graduate-level QIS course offered in physics. We classify and analyze students' responses to a pair of questions regarding the fundamental differences between classical and quantum computers. We specifically note two key themes of importance to educators: (1) when reasoning about computational power, students often struggled to distinguish between the relative effects of exponential and linear scaling, resulting in students frequently focusing on distinctions that are arguably better understood as analog-digital than classical-quantum, and (2) introducing the thought experiment of analog classical computers was a powerful tool for helping students develop a more expertlike perspective on the differences between classical and quantum computers.

Breaking down barriers for entry to QIS

Emily Aragon and Jake Douglass (Sandia National Laboratories, USA)

Abstract: Within the quantum ecosystem, there are many opportunities to learn about quantum information science (QIS)that have been created over the past five years as a result of the National Quantum Initiative. Because it is such a nascent field, finding appropriate resources, opportunities, etc., can be very difficult, especially for underrepresented communities. In this poster, we will discuss efforts undertaken by Sandia Labs and the QED-C Workforce Technical Advisory Committee (TAC) to create a website that hosts available resources, opportunities, and general information in the field to help break down barriers to entry across the country. Through these efforts, we hope to increase diversity within the field by creating accessible, well organized, and descriptive resources that provide information about QIS and pathways into the field. We want to use this opportunity to connect with other experts in the field to highlight our efforts, network, identify gaps, and learn best practices.

Developing the UK quantum workforce and user community through quantum computing hackathons

Daisy Shearer and Chiara Decaroli (National Quantum Computing Centre, UK)

Abstract: Hackathons are collaborative events where researchers and practitioners in various fields come together to solve problems over a short period of time. The UK's National Quantum Computing Centre hosts an annual hackathon aimed at early-career quantum computing developers to give them the opportunity to work on real-world use cases provided by quantum computing end users across a variety of sectors. This event aims to investigate quantum solutions for industry-provided use-case problems across different sectors and application domains; help create an active quantum computing community spanning the full value chain from quantum compute providers, to quantum developers and end users; enhance connectivity between quantum computing providers and end-users, enabling discussions on both opportunities as well as limitations of current technology; and increase awareness of quantum computing and potential use-cases to research students and early-career scientists (Masters, PhD and Postdoc level). In this poster, we present our learnings and recommendations for hosting cross-sector quantum hackathons to get the most out of the event for each stakeholder group involved. We also consider a variety of considerations for best practices: 1) embedding responsible and ethical quantum computing practices, 2) ensuring quantum hackathons are accessible and equitable, and 3) defining measurable goals and outcomes for each stakeholder group.

Student-hosted Quantum Communication Workshop: Quantum Revolution Assembly Convention

Ran-Yu Chang (National Yang Ming Chiao Tung University, Taiwan), Tsung-Wei Huang (Chung Yuan Christian University, Taiwan) and Yu-Chao Hsu (Cross College Elite Program, National Cheng Kung University, Taiwan)

Abstract: QRACON (Quantum Revolution Assembly Convention) is an initiative driven by students

to facilitate the exchange and integration of the academic, industrial, and educational aspects of quantum technology. We believe that 'where there are three people, there must be my teacher. Through this annual conference, students are able to motivate each other, share knowledge, and interact with professionals from universities and industries. This not only provides students with opportunities to learn and grow, but also promotes cooperation and innovation between different fields. Join our annual conference and unleash the future of quantum computing together!

Q (Quality Speeches Given by Quantum Professionals in Taiwan)

R (Recreational Quantum Games to Inspire Students in Future Careers)

A (Advocating International Computing Competitions to Quantum Learners)

C (Competitions on Quantum Computing to Stimulate Academic Exchange)

O (Optimizing Quantum Educations with Posters, Fun Games, etc)

N (Narrowing Gaps Between High Schools - Universities - Enterprises)

Quantum LifeLong Learning - Developing a structured training and further education program in quantum technologies

Judith Gabel (Ludwig-Maximilians-Universität München, Germany), Björn Ladewig (Ludwig-Maximilians-Universität München, Germany), Lukas Sigl (Technische Universität München, Germany), Anna Donhauser (Ludwig-Maximilians-Universität München, Germany), Stefan Küchemann (Ludwig-Maximilians-Universität München, Germany), Bernhard Kraus (Technische Universität München), Jochen Kuhn (Ludwig-Maximilians-Universität München, Germany), Tatjana Wilk (Ludwig-Maximilians-Universität München, Germany), Alexander Holleitner (Technische Universität München), and Jan von Delft (Ludwig-Maximilians-Universität München, Germany)

Abstract: Quantum technologies are already an established and still rapidly growing scientific research field with great application potential for industry. The current challenge is to transfer the knowledge and technological expertise on quantum systems from the research laboratories to the industrial sector. A key role here is played by the experts and executives in the high-tech industry, who must recognize and implement the specific potential of quantum technologies for their respective companies. We present the project Quantum LifeLong Learning (QL3), a structured training and further education program of the Munich universities in the field of quantum technologies with the target group of specialists and executives in the high-tech industry.

We acknowledge financial support from the Bundesministerium für Bildung und Forschung (BMBF) of Germany.

Towards an Experiential Model of Learning for Quantum Researchers & Developers

Shwetha Jayaraj (New York Institute of Technology, USA)

Abstract: The proposed model serves as a roadmap to guide learners across a variety of demographics & disciplines to begin the pursuit of a comprehensive quantum technology education. Results from student findings are discussed in leading & teaching the NYIT Quantum Computing Club at the university level, further affirming the value learners can earn in an open & diverse environment. This methodology is validated by George Kuh's experiential teaching findings from the Association of American Colleges & Universities. In this research, methods to meet the bottleneck of the quantum ecosystem directly by connecting various quantum disciplines, outlining curriculum, and discussing potential approaches educators can take toward this experiential learning are reported.

Improving Quantum Computing Education Accessibility for High Schools

Shraddha Aangiras (RV PU College, India)

Abstract: The study discusses findings and insights at an offline introductory quantum computing workshop aimed at high school students in India. 236 students at RV PU College, a STEM- centric high school for 11th and 12th grade students, registered. The study helped gain better insight into the necessity for creating accessible educational resources to develop an improved incoming quantum workforce, and the required steps to create it. Despite the advancements in quantum technology and education, awareness of quantum computing in students interested in STEM degrees was observed to be low. 88.6% of students had no prior knowledge of quantum computing. The study reports the student demographics by their previous levels of quantum computing awareness, linear algebra and programming knowledge, topics of interest, future career choices, and interest in pursuing quantum computing further. This event was conducted under the IBM Qiskit Fall Fest 2022, a collection of global quantum computing events. Normally held at college campuses, RV PU College was the first high school to conduct it.

QSEEC05 : Quantum Teaching

Sunday, Sept 17, 2023 Hyatt Regency Bellevue-2nd Floor Cedar B (13:00 – 14:30)

Session Chair: Marek Osinski (University of New Mexico, USA)

Taiwan Student Quantum Computer Society

Ran-Yu Chang (National Yang Ming Chiao Tung University, Taiwan), Yu-Chao Hsu (National Cheng Kung University, Taiwan), Tsung-Wei Huang (Chung Yuan Christian University, Taiwan)

Abstract: In Taiwan, we founded a student-created and led community-Student Quantum Computer Society (SQCS) mainly for high school students. SQCS inspires people in quantum technology via the internet and self-learning, providing traditional Chinese learning opportunities. We provide three pathways including (1) Information and News, (2) Quantum Courses, and (3) Platforms to promote quantum technology in Taiwan. In Information and News, SQCS provides popular science reports and news for aspiring learners. In Quantum Courses, SQCS provides three different methods: Quantum workshops, Quantum micro-courses, and online courses. In online platforms, SQCS established a Discord server for aspiring learners and professionals to communicate, cooperate, and bond with each other. Until now, SQCS is the largest quantum online community in Taiwan. SQCS designs courses not only for high school level but also for college students majoring in science and technology. This provides more opportunities for self-learning and acquiring knowledge because of the Internet. We truly hope that more and more countries will establish their own community and stimulate academic exchange between communities, further establishing an international community with quantum lovers and advocates.

How to use chatbots for learning and teaching quantum programming

Pablo Suárez Vieites (University of Galway, Ireland)

Abstract: AI chatbots have recently attracted a great deal of interest from both the scientific community and the general public. While the potential and limitations of these technologies

are still uncertain, it is thought that they can be used as powerful tools in the field of education.

In this article we aim to analyse how we can use and AI chatbot as a tool to support the learning and teaching process of quantum programming. We will study its performance when it comes to generate and correct assignments, as well as its potential to explain new concepts or provide personalised learning.

Tutorial 1

Quantum Abacus

Dan-Adrian German, Alex Alani (Indiana University Bloomington, USA)

Abstract: At the time of this writing more than 60 (sixty) companies in the world are building quantum computers. These computers, based on quantum physics principles, are radically different from those that operate according to the more familiar principles of classical physics. The natural language of their quantum gates is that of linear algebra in a complex (Hilbert) vector space. Since 2017 it is known that it is possible to replace the linear algebra with some string-rewriting rules which are no more complicated than the basic rules of arithmetic. The original system was introduced by Terry Rudolph and has been promoted and disseminated in large-scale outreach projects (among others) by Diana Franklin (University of Chicago) and Sofia Economou and Ed Barnes (Virginia Tech) as well as several other educators at the high-school level. In this tutorial we show how a slightly modified (though still very elementary) system can be used to communicate a visual and entirely operational understanding of key quantum computation concepts such as: superposition, probability, entanglement, phase, interference and unitary state evolution, as they occur in well-known quantum algorithms. We give concrete examples of proving properties for quantum gates and quantum circuits without resorting at all to complex numbers or matrix multiplication. Only simple, abacus-like operations are used—hence the title of the tutorial.

QSEEC06 : Ethics and Society

Sunday, Sept 17, 2023 Hyatt Regency Bellevue-2nd Floor Cedar B (15:00 – 16:00)

Session Chair: Brian La Cour (The University of Texas at Austin, USA)

Tutorial 2

Quantum Ethics

Josephine Meyer (University of Colorado Boulder, USA)

Abstract: To date, quantum workforce development initiatives have focused primarily on technical skills. However, as quantum technologies move from an intellectual curiosity to a practical reality, it is more important than ever that our students also learn to reason through the ethical and societal implications of the technologies they will one day work to create. The Quantum Ethics Project is developing a series of modular, research-based curricular materials on quantum ethics appropriate for a variety of levels (from high school to grad school) designed to be easily slotted into existing quantum coursework. Come explore with us how you can integrate quantum ethics into your classroom, and get early access to our newest materials!

This tutorial session includes presentation of the following paper: A holistic approach to quantum ethics education

Joan Arrow (University of Waterloo, Canada), Rodrigo Araiza Bravo (Harvard University, USA), Sara Marsh (University of Waterloo, Canada), and Josephine Meyer (University of Colorado Boulder, USA)

This paper first provides an overview of the growing subfield of quantum ethics, including a working definition; research to date into social, economic, and political implications of various quantum technologies; and directions for future research. Second, it introduces the Quantum Ethics Project (QEP), its activities to date, and its organizing philosophy. The third section reports on QEP's ongoing curriculum development work, i.e. creating one of the first full-length courses on Ethics and Social Impacts of Quantum Technology. We outline the pedagogical approach being taken in the course design, including key learning outcomes, topic areas, teaching methods, and rationale. This is followed by a brief discussion of current limitations and future areas of attention, such as drawbacks to teaching ethical reasoning and ideas for assessment and implementation. Finally, the paper concludes with a call for collaborators and information on how people can join the QEP network.

QSEEC07 : Teaching Quantum in Pictures

Sunday, Sept 17, 2023 Hyatt Regency Bellevue-2nd Floor Cedar B (17:00 – 18:00)

Session Chair: Marek Osinski (University of New Mexico, USA)

Tutorial 3

Quantum in Pictures

Stefano Gogioso (University of Oxford, UK) and Lia Yeh (University of Oxford and Quantinuum, UK)

Abstract: The ZX calculus is a new graphical language that provides an intuitive and elegant way to reason about quantum computing. The ZX calculus is already taught at leading universities as part of quantum computing curricula, and it is used by researchers at quantum companies such as Quantinuum, IBM, Google and PsiQuantum.

In this tutorial, we will introduce the fundamental concepts and techniques of the calculus, without relying on the traditional mathematical prerequisites of complex vectors and matrices. This makes for an innovative way to learn quantum theory using pictures alone, accessible to a much wider demographic. This approach, known as Quantum Picturalism, has recently been taught for the first time to high-school students, as part of a collaboration between the University of Oxford, Quantinuum and IBM Quantum.

Having introduced the basics, we will immediately put our new language to work, picturing advanced quantum applications such as quantum teleportation, measurement-based quantum computing (MBQC), and the quantum approximate optimisation algorithm (QAOA). The presentation will be colourful, yet mathematically rigorous, and it will strengthen your intuition about the quantum phenomena powering these techniques.

QSEEC08 : Quantum Outreach and Activities

Sunday, Sept 18, 2023 Hyatt Regency Bellevue-2nd Floor Regency C (10:00 – 11:30)

Session Chair: Lia Yeh (University of Oxford and Quantinuum, UK)

Invited Talk

A physics lab inside your head: Quantum thought experiments as an educational

Maria Violaris (University of Oxford, UK)

Abstract: Thought experiments are where logical reasoning meets storytelling, catalysing progress in quantum science and technology. Schrödinger's famous cat brought quantum science to the public consciousness, while Deutsch's AI thought experiment was the first conception of a quantum computer. I will show how presenting thought experiments using quantum circuits can demystify apparent quantum paradoxes, and provide fun, conceptually important activities for learners to implement themselves on near-term quantum devices. Additionally, I will explain how thought experiments can be used as a first introduction to quantum, and outline a workshop based on the "quantum bomb tester" for school students as young as 11. This paper draws upon my experience in developing and delivering quantum computing workshops in Oxford, and in creating a quantum paradoxes content series with IBM Quantum of videos, blogs and code tutorials.

Teaching quantum computing using Microsoft Quantum Development Kit and Azure Quantum

Mariia Mykhailova (Microsoft, USA)

Abstract: This report describes my experience teaching a graduate-level quantum computing course at Northeastern University in the academic year 2022-23. The course takes a practical, software-driven approach to the course, teaching basic quantum concepts and algorithms through hands-on programming assignments and a software-focused final project. The course guides learners through all stages of the quantum software development process, from solving quantum computing problems and implementing solutions to debugging quantum programs, optimizing the code, and running the code on quantum hardware. This report offers instructors who want to adopt a similar practical approach to teaching quantum computing a comprehensive guide to getting started.

Quantum computing educational tools based on the Quantum Enigmas video series

Ghislain Lefebvre (Institut Quantique, Université Sherbrooke, Canada)

Abstract: Since the launch of the first video of the quantum computing educational tool, The Quantum Enigmas, in January 2022, several more videos have been produced and released in the series. In total, the series will consist of 12 videos that utilize classical enigmas and solve them on a quantum composer. This approach serves as an introduction to quantum computing, without the need for lengthy mathematical explanations or prior computer science knowledge.

To promote the widespread use of The Quantum Enigmas in training high school and college students in their initial foray into quantum computing, the team at Institut quantique has developed workshops based on each video. Additionally, intermediary level problem sets are now available on the Qiskit textbook, and introductory level modules will be hosted on IBM's Skillsbuild platform. These initiatives aim to expand the use of The Quantum Enigmas and provide educational resources for learners at different levels.

The global adoption of The Quantum Enigmas has surpassed all expectations, thanks in part to the exceptional production quality of the videos. Studio Nord-Est, the motion design firm responsible for creating The Quantum Enigmas, was recently awarded the 2023 Canadian Applied Art Award for best images. This recognition further solidifies the project's success.

The upcoming presentation will provide a comprehensive overview of the achieved results thus far, highlight related initiatives, and delve into future plans for The Quantum Enigmas project. For more detailed information, please visit quantumenigmas.com.

Design of quantum machine learning course for a computer science program

Sathish Kumar (Cleveland State University, USA), Temitope Adeniyi (Cleveland State University, USA), Ahmad Alomari (Cleveland State University, USA), Santanu Ganguly (Northrup Grumman, UK)

Abstract: In this work, we present the design and plan of Quantum machine learning (QML) course in a computer science (CS) University program at senior undergraduate level / first year graduate level. Based on our survey, there is a lack of detailed design and assessment plan for the delivery of QML course. In this paper we have presented the QML course design with week by week details of QML concepts and hands on activities that are covered in the course. We also present how this QML course can be assessed from CS program learning outcomes perspective.

A brief overview of programmed instructions for quantum software

Richard Wolf (University of Galway, Ireland), Sho Araiba (University of Hawaii, USA)

Abstract: In this paper we provide an overview of the programmed instructions approach for the purpose of quantum software education. The article presents the programmed instructions method and recent successes in STEM fields before describing its operating mode. Elements tackled include the core components of programmed instructions, its behavioural roots and early use as well as adaptation to complex STEM material. In addition, we offer recommendations for its use in the specific context of quantum software education and provide one example of PI-based instruction for the notion of entanglement. The aim of this work is to provide high-level guidelines for incorporating programmed instructions in quantum education with the goal of disseminating quantum skills and notions more efficiently to a wider audience.

QSEEC09 : Quantum Workforce Development

Sunday, Sept 18, 2023 Hyatt Regency Bellevue-2nd Floor Regency C (13:00 – 14:15)

Session Chair: Brian La Cour (The University of Texas at Austin, USA)

Invited Talk

Designing and implementing a new Quantum Science and Engineering graduate degree program at the University of Delaware

Matthew Doty (University of Delaware, USA)

Abstract: The numerous companies that have launched quantum computing and quantum information initiatives face a well-documented talent shortage. For example, a recent International Data Corporation analysis projected that the global quantum-computing industry will grow from $412 million in 2020 to $8.6 billion in 2027, which is approximately a 50% annual growth in the size of the industry and the required workforce. The skills and training required to meet this national need for a "Quantum workforce" have been nicely summarized by Fox et. al, who interviewed 21 'quantum technology' companies. However, there are substantial gaps between what industry needs and most available education and training programs.

In this talk I will report on the development and implementation of a new Quantum Science and Engineering (QSE) graduate degree program at the University of Delaware. Our program was developed in consultation with industrial partners, who described a need for employees with a wide range of technical skills and a shared understanding of quantum systems that allows their effective collaboration. To meet these needs, we developed a new curriculum that is designed to provide a shared vocabulary and common knowledge base to all QSE MS and PhD students before they begin to specialize in hardware, theory, or computational aspects of quantum technologies. The curriculum is designed to be accessible to those coming from a wide range of traditional STEM backgrounds, including those who have never previously been exposed to quantum mechanics or quantum information science. The program is also designed to provide elective opportunities for students earning graduate degrees in traditional disciplines. The first class of students matriculated in the QSE program at UD in the fall of 2022. I will review the program design, obstacles faced, lessons learned, preliminary feedback from students after their first year, and the challenges and opportunities we anticipate looking forward.

Building Capacity for Regional Quantum Ecosystems: A Look at Cleveland, Ohio

Gabbie Meis (Coding School: Qubit by Qubit, USA)

Abstract: The key to success in growing the world’s needed quantum workforce is collaboration. In this talk, Qubit by Qubit–the quantum education division of the nonprofit The Coding School–will discuss how they bridge the gap by connecting partners across K-12, university, industry, and beyond. In this talk, we will highlight three local case studies: Cleveland, Ohio, Tucson, Arizona, and College Park, Maryland. Partnerships are critical for prosperity, local economic innovation, and will assist in recruiting, supporting, and sustaining the future diverse quantum workforce.

In this session, Qubit by Qubit will expand on their activities with Cleveland State University to host a series of local workshops for middle school to undergraduate audiences via a Public Interest Technology-UN award.

Voluntary Mentoring Initiative Aimed at Enhancing Quantum Computing Abilities

Michał Stęchły (PsiQuantum, Canada), Alberto Maldonado-Romo (Instituto Politécnico Nacional, Mexico)

Abstract: The Quantum Open Source Foundation (QOSF) established a mentorship program in September 2020 to tackle the challenges of enhancing quantum computing skills and fostering knowledge-sharing between experts across academia and industry. Since its inception, the program has completed over one hundred projects, spanning from contributing to existing open-source projects to publishing new scientific papers. In this talk, we will delve into the program's framework, highlighting the key elements that have contributed to its success in its seventh edition, and address the challenges of managing a volunteer-based initiative.

Concepts for Upskilling the Industry Workforce in QT Hardware

Oliver Bodensiek (Physikalisch-Technische Bundesanstalt, Germany), Dion Timmermann (Physikalisch-Technische Bundesanstalt, Germany), Alexandros Metavitsiadis (Physikalisch-Technische Bundesanstalt, Germany), Larissa Braun (Physikalisch-Technische Bundesanstalt, Germany), Daniel Stuhlmacher (Physikalisch-Technische Bundesanstalt, Germany)

Abstract: Quantum Technology (QT) is currently shifting from scientific research to commercial application, leading to a high demand for scientists and engineers skilled in QT (Kaur and Venegas-Gomez 2022). This demand is expected to persist or even grow in the future (Hughes et al. 2022). In this talk, we discuss concepts we are developing at the German National Metrology Institute (Physikalisch-Technische Bundesanstalt / PTB) for upskilling professionals without experience in QT hardware. Such offerings are required for two reasons: Firstly, there currently exist only few QT study programs, resulting in fewer employees entering the job market than needed. Secondly, studies on industry needs have found that companies mostly value “traditional” science and engineering skills and only require few select QT related skills (Fox, Zwickl, and Lewandowski 2020). Hence, upskilling might be a valuable pathway, even in the long term, to provide future employees with the skill combinations necessary for their work.

In our talk we will discuss various training formats for this purpose and reason why national metrology institutes may play an important role in the QT education ecosystem: Employees working with and developing QT will often need to use or at least understand hardware that is specific to QT. The high costs of these devices restrict their availability to only a small number of companies, if any at all. National metrology institutes not only can provide the necessary QT infrastructure, but also excel in their design, construction and operation.

QSEEC10 : Quantum Education Tools

Sunday, Sept 18, 2023 Hyatt Regency Bellevue-2nd Floor Regency C (15:00 – 16:15)

Session Chair: Marek Osinski (University of New Mexico, USA)

QWalkVis: Quantum Walks Visualization Application

Addie Jordon (University of Victoria, Canada), Austin Hawkins-Seagram (University of Victoria, Canada), Samantha Norrie (University of Victoria, Canada), José Ossorio (University of Victoria, Canada), Ulrike Stege (University of Victoria, Canada)

Abstract: Quantum walks (QWs) are the quantum analogue to classical random walks. We present visualizations for quantum walks and show how they can be used to teach quantum concepts such as superposition and interference. Using our Quantum Walks Visualization Application (QWalkVis) for visualizing quantum walks lets the user select the dimensions, number of states, and number of steps in the walk and generates probabilistic plots on-the-fly. Users can view a plot for each step of the walk, allowing them to compare the probability distributions as time progresses. Visualizations share an important space in education; QWalkVis was created to aid students in learning about quantum walks and foundational quantum concepts through an interactive design. We highlight some potential use cases of QWalkVis for both self-directed student learning and the education in a classroom.

Harnessing the VQE to simulate quantum chemistry in an undergraduate project: Properties of hydrogen, oxygen and water molecules

Shah Ishmam Mohtashim (University of Dhaka, Bangladesh), Sheikh Mahatabuddin (Bangladesh Atomic Energy Regulatory Authority, Bangladesh), Md. Abdul Jabbar (University of Dhaka, Bangladesh)

Abstract: With the advent of convenient toolkits like Qiskit now allowing for the simulation of quantum information pro- cessing architectures from the ground up, it has now become likelier than ever to consider the possibility of widely adopting quantum computational methods towards research-led teaching of techniques in undergraduate-level quantum chemistry. To that end, we show how elementary formulations of the Variational Quantum Eigensolver (VQE) can be harnessed for computing key chemical properties of molecules, namely their ground states, excited states, dissociation energies, and the Potential Energy Surface. We conclude with a discussion of the potential for adopting our methods towards both the dissemination of wider applications of quantum mechanics and the teaching of quantum computational methods for scientific computing in undergraduate curricula for STEM, and beyond.

QPCC: a quantum programming course for inhomogeneous cohorts of professional learners

Emil Dimitrov (ICHEC, Ireland), Conor Dunne (Irish Centre for High-End Computing (ICHEC), Ireland), Venkatesh Kannan (ICHEC, Ireland), Karthik Krishnakumar (ICHEC, Ireland), Pablo Lauret Martínez de Rituerto (ICHEC, Ireland), Pablo Suárez Vieites (ICHEC, Ireland), Rajarshi Tiwari (ICHEC, Ireland), Richard Wolf (ICHEC, Ireland)

Abstract: The ongoing accelerated development and exploration of Quantum Computing (QC) -- systems, software, algorithms and applications -- has generated a huge amount of interest and need among a wide range of organisations and user communities to better understand the technology paradigm, its maturity, limitations and opportunities, and positioning alongside classical high-performance computing (HPC) methods and tools. This interest and need to learn about QC has been accentuated by the rapidness and breadth of developments in QC that is being disseminated in both mainstream and specialist scientific/technical media as well as the accessibility to early quantum computing systems and tools. It has become a challenge for the (potential) user community to sift through the material catering to developing

bottom-up fundamental scientific/mathematical skills as well as top-down exploitation oriented knowledge.

As the National and one among the European Competence Centres in HPC, the Irish Centre for High-End Computing (ICHEC) has worked with an international advisory board composed of quantum computing technology developers, the user community and the Irish State Agency's network that is responsible for national enterprise skills development in ICT to create and deliver a blended course which is customisable, modular and stackable, thereby offering different learning pathways to professional learners from the academic, enterprise and public sector communities with inhomogeneous backgrounds. Particular emphasis is laid on the stakes of engaging learners and organisations with different knowledge basis, skills and learning objectives, as well as making the content suitably-positioned and approachable to all (e.g. varied levels of mathematical knowledge required for basic understanding of quantum computing versus developing quantum algorithms).

In this paper, we discuss the Quantum Programming Certification Course (QPCC) by summarising the 4-year design process with the advisory board, drawing from ICHEC's experience in national and European HPC and QC R\&D projects as well as preparation of strategies and joint white papers, and methods to address gaps between mainstream academic programmes in quantum technologies and existing training courses (such as MOOCs, tutorials, workshops). We discuss the approaches in QPCC to target professional learners from inhomogeneous backgrounds, tools and pedagogical approaches in preparing and delivering the training material, opportunities and challenges in positioning QPCC within the academic framework, and summarise open opportunities for developing collaborative solutions.

Exploring architecture of Qiskit Runtime for educational enablement

Syed Farhan Ahmad (NC State University, USA), Nate Earnest-Noble (IBM Quantum, USA), Gregory Byrd (NC State University, USA), Hamed Mohammadbagherpoor (IBM Quantum, USA)

Abstract: A multitude of programming languages and frameworks exist for quantum computing today (Qiskit, Intel Quantum SDK, Pennylane, Cirq, Microsoft Quantum SDK, Yao.jl, etc.). Simultaneously, a given language or framework plays a vital role in a particular area of STEM education, and focuses on specialised features that can benefit specific domain(s) of computing & science. Accessing quantum computing backends from a software framework requires the development of integrations for every hardware platform, which becomes a challenge in the long run.

The Qiskit Runtime environment is composed of Primitives: Sampler/Estimator, Sessions, and a rich set of Error mitigation techniques and compiler optimization methods. In this paper, we show how the recent architecture of Qiskit Runtime environment, now accepting QASM strings into REST API calls, can bridge the gap between programming languages & quantum computing frameworks. More specifically, we highlight the students' needs of interfacing between languages & frameworks and the associated development to generate accepted inputs.

Utilizing automated quantum software management tools and a write-once-target-all quantum device python package to greatly reduce friction in education and coding environment setup

Ricky Young (Qbraid, USA), Ryan Hill (Qbraid, USA), Alberto Maldonado-Romo (Instituto Politécnico Nacional, Mexico)

Abstract: Our talk is motivated to investigate the benefits of browser based IDEs (integrated development environments) for educating individuals on coding with quantum devices at scale. In particular, we focus on qBraid, a quantum computing platform that provides automated python environments for quantum software. Our talk demonstrates how in less than three clicks users can run their first circuits on quantum computers provided by Amazon Braket and IBM Qiskit in educational settings with no dependency issues, package conflicts, or cloud compute setup with their favorite pythonic framework. With an imperative demand for a robust quantum workforce, qBraid is a resolute platform, providing students with an increasing worth that grows immensely as their utilization increases from undergraduate studies to the formidable realms of doctoral pursuits and professional endeavors. qBraid strives to elevate and demonstrate the extraordinary potential of pedagogy by utilizing the dynamic synergy of CPU, GPU, and QPU integration. This is done by demonstrating the profound efficacy that is accomplished through its cutting-edge, browser-based platform, which has been painstakingly tailored to the quantum computing industry.

We thank the IEEE Quantum Education Program Committee Members for their support.

Special thanks to Kathy Grise, Program Manager of the IEEE Quantum Initiative.

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